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Enhancing flexural resistance in hot mix asphalt: a study of effects of wire mesh on load-bearing capacity

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ABSTRACT

In transportation engineering, road pavement is commonly categorized as either flexible pavement or rigid pavement. The pavement demonstrates a distinct capacity to endure a variety of loads, including compressive and tensile loads. The capacity to endure compressive and tensile forces is extremely important, especially in the field of pavement construction, as it ensures both the longevity and the safety of the pavement. The objective of this study was to evaluate the capacity of hot mix asphalt to endure compressive and tensile pressures. The experimental methodology employed four different wire mesh deployment configurations on hot asphalt mixtures, utilizing three-point flexural test equipment. The data indicates the most effective method for mimicking hot mix asphalt involves adding a wire mesh layer at a depth of 30 mm below the surface of the experimental specimen. The particular modeling method showed a measurement of flexural resistance up to 291.85 kN. The study's findings indicate that the hot asphalt mixture exhibits a state of balance in its capacity to endure both compressive and tensile pressures. Incorporating a wire mesh layer within the middle section of the hot asphalt mixture has been perceived to enhance its ability to withstand tensile loads, hence improving its overall performance.

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1. INTRODUCTION

Pavement in road construction is classified as either flexible or rigid. Due to both models of pavement having advantages and limitations, technical analysis is demanded to determine the type of pavement to utilize in a road construction project [1], [2]. The variety of pavement types is profoundly prompted by the specific attributes of the pavement. The primary determinant in the selection of pavement type is the capacity of the structure to endure compressive and tensile loads [3], [4].

The main element of rigid pavement, also known as reinforced concrete pavement, is cement. This mixture exhibits high resistance to compressive pressures while displaying somewhat lower resistance to tensile loads. The vulnerabilities identified in rigid pavement or reinforced concrete can be mitigated through the combination of strengthening inside the lower portion of the cement mixture. This reinforcement serves to enhance the overall strength and address the identified deficiencies [4], [5].

Hot mix asphalt is commonly employed in road construction projects in Indonesia as the topmost layer for road pavements. The utilization of asphalt as the main material is a classification of flexible pavement within the domain of road pavement construction [6], [7]. The flexible pavement is comprised of three distinct levels, namely the surface course, base course, and sub-base course. These layers are situated above the subgrade. The performance of flexible pavement is heavily reliant on the base course and subgrade as foundational elements. Consequently, defects may arise in the form of surface course degradation, leading to a potential reduction in the pavement's design [8].

The use of flexible pavement in unstable soil conditions is not advisable, as it heavily relies on the strength of the base course and subgrade. While flexible pavements offer numerous advantages in terms of strength and performance, their application is limited by several factors [9]. These limitations can hinder the effectiveness and durability in challenging soil environments, intensive study needs to be employed and it is essential before implementation [10].

In order to address this issue, it is imperative to implement a surface layer of flexible pavement that possesses the capability to endure the imposed load. This approach aims to minimize excessive reliance on the base course and subgrade [11]. The utilization of a wire mesh layer in the design of hot mix asphalt for the surface course is believed to offer a potential solution to this issue. This assertion is supported by an examination of the flexural resistance [11]–[13].

Additionally, flexural resistance is a treatment purposely designed for application on rigid pavement. The flexural resistance of concrete refers to its capacity to bear a perpendicular force given to a concrete block supported on two points until the block fractures. This resistance is quantified in pascals (MPa), which represents the force per unit area [14]–[16]. In rigid pavement the utilization of wire mesh serves the purpose of crack supervision and thrusting control due to its ability to regulate stress and deflection values, hence enhancing the service index, with the stiffness possessed by wire mesh, it is also considered to be able to increase the value of the modulus of elasticity [17]–[19].

Moreover, wire mesh is a commonly employed iron pattern reinforcement in rigid pavement. The utilization of reinforcement is regarded as a means to reduce the reliance of flexible pavement on the foundation layer and subgrade, therefore enabling its application in unstable soil conditions [20]. A pavement with a high modulus of elasticity will result in the structural strength being mostly inherent to the pavement [21], [22]. Numerous prior investigations have been conducted on the use of the checkerboard pattern inside pavement structures as a means to effectively manage fracture propagation and enhance resistance against tensile pressures [23]–[25].

The study seeks to analyze and evaluate the resistance of a hot mix test specimen to determine its ability to withstand compressive and tensile stresses. The experiment involved placing the wire mesh at distances of 20, 30, and 40 mm from the surface of the 60 mm high specimen. The objective was to determine the highest level of flexural resistance that can be achieved when a wire mesh layer is used as a foundation and to assess its capacity.

2. METHOD

This study employs an experimental technique, utilizing a wire mesh as a reinforcing material. Wire mesh is utilized due to its capability to enhance the tensile strength of asphalt mixtures. The experimental specimen employed consists of a blend of hot mix asphalt with a mixture of aggregate and asphalt. Additionally, it incorporates a wire mesh with wire mesh M4 standards, characterized by a 4 mm diameter and a hole size of 150 mm. The overall quantity of test specimens is 32, comprising 24 specimens utilized for the determination of optimum asphalt content by Marshall characteristic analysis, and an additional 8 specimens employed for the evaluation of the flexural resistance value of hot asphalt mixture, wherein a wire mesh layer is utilized as reinforcement. The dimensions of the test object fabricated are 300 mm in length, 400 mm in width, and 60 mm in height. During the examination, the objective was to assess the flexural resistance of hot asphalt mixtures using three-point flexural test equipment. Four different configurations of wire mesh layer placement, as presented in the table, were implemented.

In this study, we examine the effects of wire mesh layer placement within hot mix asphalt on performance characteristics. The aim is to understand how varying depths of wire mesh influence the overall stability and durability of the asphalt. Table 1 summarizes the different test specimens utilized in the experiment, each representing a distinct configuration of wire mesh placement.

As outlined in Table 1, the first specimen serves as a control, consisting of hot mix asphalt without any wire mesh, allowing for a baseline comparison. The subsequent specimens incorporate wire mesh at varying depths of 20, 30, and 40 mm from the surface. This variation enables an analysis of how different placements impact the mechanical properties and longevity of the asphalt, which could inform future engineering practices in pavement design.

Several parameters are taken to analyze the data in obtaining the results in the form of Marshall characteristics and flexural performance in the form of maximum load values and deflection or deformation. Determination of the ability of the hot mix asphalt to withstand compressive and tensile loads is taken based on the analysis of the maximum flexural resistance obtained in the flexural test using three-point flexural test equipment. A three-point flexural test was performed according to the standard to measure the flexural performance of asphalt concrete at 10 °C, the temperature at which the asphalt mixture becomes susceptible to cracking. The loading rate was controlled at 50 mm/min. The specimen and test setup as well as the three-point flexure test are shown in Figure 1.

Table 1. Types of wire mesh layer placement

Test Specimens	Types of wire mesh layer placement
1	hot mix asphalt without wire mesh as a comparison
2	hot mix asphalt with wire mesh placement 20 mm from the surface of the test object
3	hot mix asphalt with wire mesh placement 30 mm from the surface of the test object
4	hot mix asphalt with wire mesh placement 40 mm from the surface of the test object

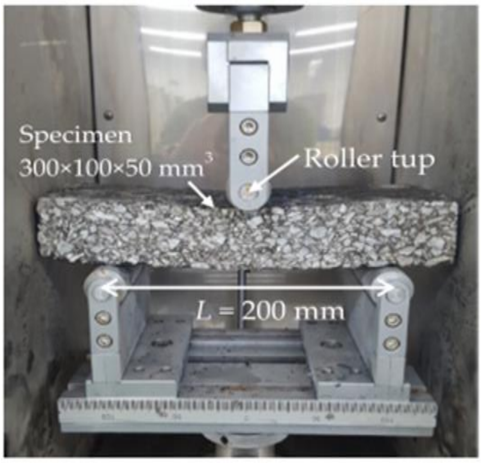

Figure 1. Three points flexure test

3. RESULTS AND DISCUSSION

3.1. Optimum asphalt content

The initial step in performing a study on hot mix asphalt is to estimate the optimum asphalt content. After performing a comprehensive examination of the aggregate and asphalt materials, the next step involves creating a test sample to analyze the properties of the Marshall. The Marshall characteristics play a vital role in the analysis process for finding the optimal asphalt content value. These traits encompass the ability to close gaps within the composite, the integration of asphalt and aggregate to occupy empty spaces, stability, melting characteristics, and the Marshall test. The analysis performed on the test specimen utilizing the Marshall tool yielded an optimum asphalt content value of 5.75%.

3.2. Correlation between load and test object

The correlation between the load and the arrangement of wire mesh in hot mix asphalt is being examined. The analysis was conducted with a three-point flexural test apparatus. The experimental specimen used is asphalt at the optimum content, obtained by analyzing the marshall characteristics, resulting in a value of 5.75%. The specimens were constructed using four different arrangements of M4 wire mesh layer placement. The results of the analysis are presented in Table 2, which demonstrates the load correlation analysis and its following outcomes.

In this section, we present a correlation analysis that examines the relationship between the applied loading and the resulting deflection of the test objects. This analysis is crucial for understanding how different loading conditions affect the structural integrity of the pavement materials being tested. Table 2 provides a summary of the test data collected during this analysis.

As indicated in Table 2, the average loads applied to the test objects range from 188.50 to 291.85 kN. Interestingly, the corresponding deflection measurements show a trend where higher loads tend to correlate with lower deflection values, particularly in tests 3 and 4. This observation suggests that the test objects may exhibit increased stiffness or resistance to deformation under greater loading conditions, which can provide valuable insights for optimizing material design and pavement performance. The correlation between loading and deflection is an essential aspect of evaluating the mechanical behavior of asphalt mixtures reinforced with wire mesh.

Table 2. Correlation analysis between loading and test object

Number of Tests Object	Average kN	Load (P) N	Deflection mm
1	188.50	188.500	9.5
2	197.70	197.700	9.0
3	291.85	291.850	8.0
4	251.30	251.300	8.0

The load correlation and the model of wire mesh placement, as reflected in the test results from Table 2, are illustrated in Figure 2. Figure 2 visually represents the relationship between the applied loads and the corresponding deflection measurements for each test specimen, allowing for a clearer understanding of how different wire mesh placements affect performance. By examining these correlations, we can better assess the efficacy of wire mesh reinforcement in enhancing the structural integrity of hot mix asphalt under varying loading conditions. This analysis not only highlights the mechanical behavior of the materials but also informs future design considerations for pavement engineering.

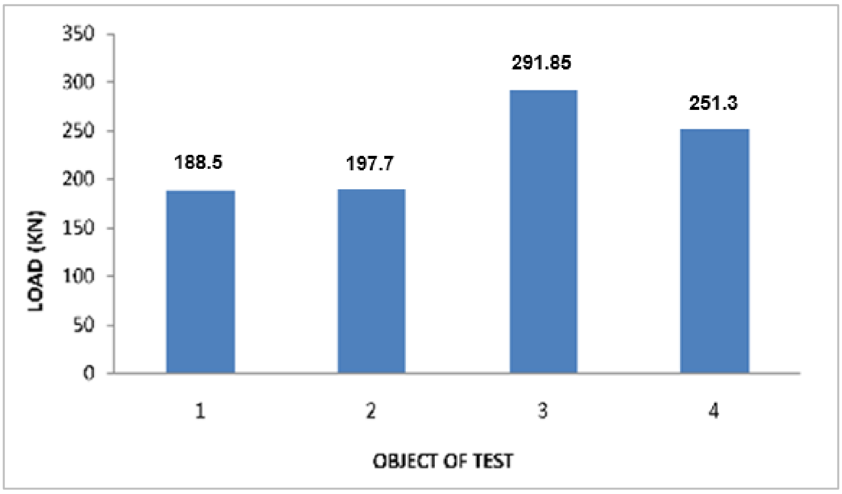

Figure 2. Correlation between wire mesh loading and placement model

The results of this study indicate that the asphalt demonstrated its reliable load-bearing capacity on the type 3 test specimen. Specifically, this test specimen consisted of a hot mix asphalt with a 30 mm wire mesh positioned 291.85 kN below the surface. The magnitude of deflection ranges from 8 to 9.5 mm.

3.3. Percentage analysis of maximum loading comparison

The three-point flexural test apparatus is utilized to gather data on the ultimate load capacity of different wire mesh layers subjected to bending forces. This method allows for a precise measurement of how each configuration responds to applied loads, which is crucial for assessing their performance in real-world applications. The results of this examination, particularly the highest loading percentages correlated with the specific configurations of the wire mesh layers, are presented in both Table 3 and Figure 3, providing a comprehensive view of the data collected. By analyzing these results, we can gain insights into the effectiveness of various wire mesh placements and their potential impact on the overall structural integrity of hot mix asphalt.

As shown in Table 3, the maximum loads recorded for each specimen varied significantly, with specimen 3 exhibiting the highest maximum load of 291.85 kN, serving as the baseline for the percentage analysis. The other specimens showed varying levels of performance, with specimen 1 achieving a maximum load of 188.5 kN, which corresponds to 35.41% of the maximum load of specimen 3. Specimen 2 reached a maximum load of 197.7 kN, representing 32.26% of the baseline, while specimen 4 recorded a maximum load of 251.3 kN, amounting to 13.89% of the maximum load in comparison to specimen 3. These findings highlight the variability in performance among the specimens, which is essential for evaluating their suitability for specific applications. Figure 3. illustrates the association between the percentage of wire mesh and the test object.

Table 3. Percentage analysis of maximum loading

No	Number of the Specimen	Maximum Load kN	Maximum Load Comparison (%)
1	1	188.5	35.41
2	2	197.7	32.26
3	3	291.85	0
4	4	251.3	13.89

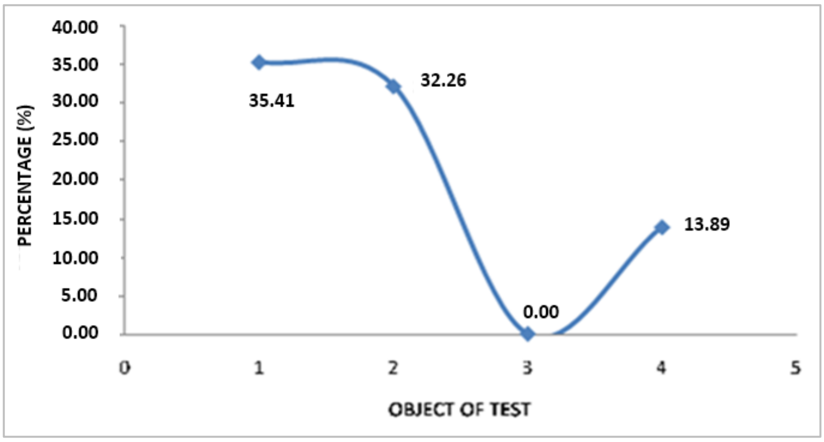

Figure 3. Correlation between wire mesh placement models and percentage analysis

By applying a hot mix of asphalt to a maximum load of 291.85 kN and placing a wire mesh layer 30 mm below the surface of the test specimen, the percentage ratio of the maximum load to various types of bearings can be established based on the presented Table 3 and Figure 3. When comparing percentages to three other types of test objects, it is evident that: applying a 30 mm wire mesh layer onto the surface of the test object (type 3) leads to a 35.41% increase in the volume of the hot mix asphalt compared to the absence of a wire mesh layer (type 1), which had a load capacity of 188.5 kN.

Furthermore, when wire mesh is placed in hot mix asphalt, with a distance of 30 mm from the surface of the test item (type 3), there is a 32.26% increase compared to the hot mix asphalt with wire mesh placed at a distance of 20 mm from the surface of the test object (type 2). This leads to a difference of 197.7 kN. Moreover, the placement of wire mesh into hot mix asphalt with wire mesh at a distance of 30 mm from the surface of the test item (type 3) shows a 13.89% increase compared to the placement at a distance of 20 mm from the bottom of the test object (type 4). This difference amounts to 251.3 kN.

3.4. Analysis of capability to withstand compressive load and tensile load

The fundamental factor in establishing the strength calculation of a construction pavement is its capacity to endure both compressive and tensile stresses. Understanding how these stresses affect the pavement is essential for ensuring long-term durability and performance. By examining the maximum load capacity of the construction pavement material, we can assess the dimensions and properties necessary for it to withstand these forces effectively. This evaluation not only informs design decisions but also helps in predicting the pavement's behavior under varying load conditions, ultimately enhancing its reliability and longevity.

The wire mesh layer is a substance employed in analyzing the tensile load and is commonly employed in rigid pavement for multiple purposes, including crack management and pumping control. Additionally, it plays a crucial role in enhancing the pavement's ability to withstand tensile loads, thereby reinforcing the pavement area. The augmentation of flexural resistance can be attributed to the treatment of stress and deflection levels, thereby leading to an elevation in the service index.

The data in Table 4 presents the maximum load analysis values obtained from different wire mesh layer locations, measured using a three-point flexural test apparatus. The results indicate that the flexural resistance of specimen 1 was 188.5 kN. This sample was used without a wire mesh layer and exhibited a reduced load-bearing capacity. Specimen 2 has a compressive load area that is 20 mm smaller than the tensile load area. The object's flexural resistance value is determined to be 197.7 kN. Specimen 3 exhibits superior flexural resistance in comparison to other placement variations, as evidenced by a value of 291.85 kN. The specimen 4 exhibited a force of 251.3 kN with a wire mesh placement of 40 mm.

Table 4. Maximum loading analysis

Number of Tests Specimen	Average kN	Load (P) N
1	188.50	188.500
2	197.70	197.700
3	291.85	291.850
4	251.30	251.300

4. CONCLUSION

The study's findings revealed that the hot mix asphalt exhibits a state of balance in its capacity to endure both compressive and tensile pressures. Incorporating a wire mesh layer within the central area of the asphalt has been discovered to augment its ability to withstand tensile loads, hence improving its overall performance. In addition, the inclusion of a wire mesh layer in the middle section of the hot mix asphalt improves its ability to withstand tension, thereby maximizing its total effectiveness. The highest flexural resistance value demonstrates that hot mix asphalt has the ability to endure equal levels of compressive and tensile strain.

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