Analysis of Effect of Wire Mesh Layer in Hot Asphalt Mixtures on the Rutting Value

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Abstract. Rutting is a permanent deformation that occurs in a hot asphalt mixture of flexible pavement caused by cyclic loading at extreme temperatures in heavy traffic conditions. This study aimed to analyse the value of rutting on hot asphalt mixtures using wire mesh layers. The research employed an experimental method to test the hot asphalt mixtures with four types of wire mesh layer placement modelling using a Wheel Tracking Machine (WTM). The findings from the study revealed that the best dynamic stability according to the specifications ≥ 2,500 passes/mm was obtained in the asphalt mixture, laying a 20 mm wire mesh layer from the surface of the test object at 3,145.45 passes/mm with a deformation speed of 0.013 mm/minute which was smaller, around 52.6% of the speed of deformation of the asphalt mixture without using a wire mesh layer of 0.028 mm/minute. The amount of dynamic stability for the other three modelling types was below the specifications. Therefore, it was concluded that the hot asphalt mixture by laying a 20 mm wire mesh layer from the surface of the test specimen could overcome the rutting problem in hot asphalt mixture.

1. Introduction
A large traffic load with cyclic loading causes damage and fatigue to asphalt mixture whose effects are greatly increased which is influenced by temperature and humidity. Damage to the flexible pavement, such as asphalt pavement going down, fatigue cracking, and deformation of the surface of the fixed asphalt mixture (rutting) is a type of damage caused by repetitive traffic loads [1–5]. Load repetition that occurs in flexible pavement also effects permanent deformation (rutting) [6–9].

Rutting is permanent deformation that occurs when the asphalt mixture changes shape under heavy load conditions and fails to recover back to its original position (unrecoverable) [6–9]. Therefore, a good design for the thickness of road pavement is required to enable the road to function in serving traffic during its planned service life without incurring any substantial repairs to the road [10]. The application of Geogrid in previous studies by Walubita, L, F et al. (2018) explained that it can reduce the level of cracking, bonding between layers and reduce delamination and debonding of hot asphalt mixtures[11]. Referring to previous research on the application of geogrids, this study is uses Wire mesh as a substitute for Geogrid material. This study aims to, therefore, analyse the value of rutting on...
hot asphalt mixtures with the use of wire mesh layers. The wire mesh used is 2 mm in diameter with 20 mm hole dimensions as a miniature conversion of wire mesh M4.

The decision to use wire mesh is primarily because it is a type of reinforcement that is often used in reinforced concrete or rigid pavement. In rigid pavement, wire mesh is used to control cracking and as a pumping control due to controlled stress and deflection values, thereby increasing the service index.

This research is undertaken through employing an experimental method by modeling the location of the 20 mm wire mesh from the bottom of the test specimen, the middle or 30 mm from the top of the specimen and then 20 mm from the top of the specimen at the height of 60 mm in a hot asphalt mixture [12]. Marshall test equipment and Wheel Tracking Machine (WTM) is used to check the value of permanent deformation (rutting).

Several parameters are needed and considered in facilitating the process of analyzing data to obtain the expected results accurately and can be accounted for namely Marshall characteristics, dynamic stability, and deformation speed [10].

2. Literature Review and Theory

2.1. Hot Asphalt Concrete Mixture
Hot mix asphalt concrete (hot mix) as material, is used as a surface course in road and airport road pavement construction [13]. Hot mix asphalt in the context of Indonesia and in the Province of Aceh is used as a flexible pavement layer on the surface of road constructions having heavy, moderate, light traffic and other forms of pavement under all types of weather conditions [10].

Hot asphalt mixture is composed of material in the form of a mixture of aggregate and asphalt that is heated at a certain temperature [14]. In asphalt mixtures, asphalt acts as a binder or glue between the aggregate particles, in which the aggregates act as reinforcement.

2.2. Flexible Pavement
Flexible pavement is made of asphalt and granular material [14,15]. The pavement is a layer consisting of surface, base course, sub-base course and subgrade [10,14] material comprising of the following criteria:
- Uses asphalt as a binder.
- The nature of this pavement is to carry and spread the burden of traffic to the subgrade.
- The effect on load repetition is the emergence of rutting (deflection in the wheel lane).
- The effect on the subsidence of the subgrade in the form of a bumpy road (following the subgrade).

![Figure 1. Composition of flexible pavement components [10]](image-url)
2.3. Wire Mesh

Wire mesh used as reinforcement in this study consisted of reinforcement patterns in rigid pavement [16] shaped in the form of woven wire or iron boxes, where each contact point is welded together.

Two types of wire mesh are available in the market. A standard size with dimensions of 2.1 m x 5.4 m and a roll type having a width of 2.1 m and length up to 54 m. The mesh has a tensile strength of 490 N/mm with different diameters of iron [17].

![Figure 2. Wire Mesh.](image)

2.4. Marshall Test

In Indonesia, the most widely used mixed method is the mixed design method based on empirical testing, using Marshall tools [10]. The Marshall test is an essential step in determining the characteristics of an asphalt mixture.

The Marshall parameters used to evaluate the characteristics of asphalt mixtures include: Voids in Mix (VIM), Voids Filled Bitumen (VFB), Voids Mix Aggregate (VMA), Stability, Melting and Marshal Questions.

![Figure 3. Marshall Test Equipment](image)
2.5. Wheel Tracking Machine

For testing hot mix asphalt (AC-WC) due to load repetition in order to overcome the fatigue caused by prolonged crack use, a WTM is used. This test aims to obtain data on deformation depth due to repetitive loads, analyze the deformation velocity and the dynamic stability value of asphalt, which is the mixture's ability to withstand deformation or deformation due to dynamic loads at high temperatures. The dynamic stability test parameter is the rutting depth, expressed in trajectories/mm [9].

The mould used for the wheel tracking specimen was a plane consisting of a square, 400 mm (L) x 300 mm (W) x 900 mm (H). The surface temperature of the specimen and the chamber in the test equipment was maintained at 60°C to assess the dynamic stability of the asphalt concrete at elevated temperatures when the concrete loses its adhesion and is resistant to external forces [6].

The test wheel, having a diameter of 200 mm x 50 mm, and a rubber layer with a thickness of 15 mm, was moved forward and backward on the surface of the specimen at 42 cycles per min. The perpendicular load exerted by the specimen was maintained at 686 N in the test wheel.

Dynamic stability was determined by the number of horizontal shuttle test wheels needed to cause 1 mm of rutted depth in the specimen, and was calculated using the following equation [6]:

\[
DS = 42 \times \frac{t_2 - t_1}{d_2 - d_1}
\]

\[(1)\]

\[DS = \text{Dynamic Stability (number of cycles/mm)}\]
\[d_1 \text{ and } d_2 = \text{Specimen displacement measured at } t_1 \text{ and } t_2\]
\[t_1 \text{ and } t_2 = 45 \text{ and } 60 \text{ min}\]
\[C = \text{Correction Factor}\]

\[RD = d_{60} - \frac{d_{45}}{15}\]

\[(2)\]

\[RD = \text{The rate of deformation (mm/min)}\]
\[d_{45} \text{ and } d_{60} = \text{Represent the amount of deformation measured respectively at } 45 \text{ and } 60 \text{ min}\]
3. Result and Discussion

3.1. Optimum Asphalt Levels
The initial stage of the research on the hot asphalt mixtures was first to determine the Optimum Asphalt Level. In this study Optimum Asphalt Levels were obtained by testing with the Marshall Tools to analyse the characteristics of Marshall, including the Voids in Mix (VIM), Voids Filled Bitumen (VFB), Voids Mix Aggregate (VMA), stability, melting and Marshal Questions.

The results of the Marshall characteristics evaluation based on the testing using the Marshall tools were obtained for an Optimum Asphalt Level value of 5.75%.

3.2. Relationship between Deformation and Trajectory
Based on the Optimum Asphalt Level value of 5.75% from the Marshall characteristics evaluation, it was planned that the mixture would be used for creating test specimens for testing using the Wheel Tracking Machine test equipment.

The relationship between deformation and trajectory and the analysis from the research results can be seen in the following table.

| # | Number of Traffic | Deformation of Test Object | Information |
|---|------------------|----------------------------|-------------|
|   |                  | 1 (mm)                    | 2 (mm)      | 3 (mm) | 4 (mm) |           |
| 1 | 0                | -                          | -            | -      | -      |           |
| 2 | 200              | 0,532                      | 0,495        | 1,242  | 0,857  |
| 3 | 300              | 0,795                      | 1,147        | 1,715  | 1,133  |
| 4 | 600              | 1,008                      | 1,257        | 2,312  | 1,441  |
| 5 | 800              | 1,270                      | 1,323        | 2,536  | 1,759  |
| 6 | 946              | 1,451                      | 1,380        | 2,896  | 1,981  |
| 7 | 1000             | 1,530                      | 1,427        | 2,985  | 2,054  |
| 8 | 1261             | 1,874                      | 1,580        | 3,509  | 2,384  |
| 9 | 1915             | 2,867                      | 1,988        | 5,237  | 3,394  |
| 10| 2500             | 3,627                      | 2,194        | 6,507  | 4,159  |

Note:
Type of test object:
1. Hot asphalt mixture without wire mesh layer (as comparison standard);
2. Hot asphalt mixture by laying 20 mm wire mesh layer from the surface of the test object;
3. Hot asphalt mixture by laying 30 mm wire mesh layer from the surface of the test object;
4. Hot asphalt mixture by laying 40 mm wire mesh layer from the surface of the test object;

Based on the graph from Figure 6 and table 1, it can be seen that the deepest deformation on the 2,500th path of 6.507 mm was found in type 3 modelling, namely hot asphalt mixture with wire mesh placed 30 mm from the surface of the test object. The best model on the hot asphalt mixture with wire mesh was placed 20 mm from the surface of the test object, which was 2.194 mm.
3.3. Analysis of Dynamic Stability and Deformation Speed

The Optimum Asphalt Concentration value of 5.75%, was planned as the mixture for creating the test specimens for testing using the Wheel Tracking Machine test equipment. The table below depicts the relationship between the value of dynamic stability and deformation speed with the four types of wire mesh placement models.

Table 2. Analysis of Dynamic Stability and Deformation Speed.

| #  | Number of Test Object | DS Traffic/mm | RD mm/minute | Information                  |
|----|-----------------------|---------------|--------------|------------------------------|
| 1  | 1                     | 1.489,370     | 0.028        |                              |
| 2  | 2                     | 3.145,450     | 0.013        | DS= Dynamic Stability        |
| 3  | 3                     | 1.050,891     | 0.041        | RD= Deformation Speed        |
| 4  | 4                     | 1.573,104     | 0.027        |                              |

Note:

Type of test object:
1. Hot asphalt mixture without wire mesh layer (as comparison standard);
2. Hot asphalt mixture by laying 20 mm wire mesh layer from the surface of the test object;
3. Hot asphalt mixture by laying 30 mm wire mesh layer from the surface of the test object;
4. Hot asphalt mixture by laying 40 mm wire mesh layer from the surface of the test object;

Based on the graphs as illustrated below, the dynamic stability meeting the specification requirements ≥ 2,500 trajectories/mm was for type 2 modelling which was 3,145.45 trajectories/mm. The best deformation velocity was obtained in type 2 modelling at 0.013 mm/min,
which was smaller than the other modelling types and 52.6% smaller than the deformation speed of hot asphalt mixture without using a wire mesh layer.

![Figure 7](image7.png)  
**Figure 7.** Relationship between Dynamic Stability and Wire mesh placement model

![Figure 8](image8.png)  
**Figure 8.** Relationship between Deformation Speed and the Wire mesh placement model.

### 4. Conclusion

Based on the results of this research using the Marshall test equipment and Wheel Tracking Machine, the following conclusions are presented:

a) The Optimum Asphalt Levels obtained were 5.75%;

b) The best deformation on the 2500th passage was obtained on the hot asphalt mixture with wire mesh layer placed 20 mm from the surface of the object test of 2.194 mm;

c) Dynamic stability that met the specification requirements ≥ 2500 passes/min was found in the mixture of hot asphalt with wire mesh layer placed 20 mm from the surface of the object test of 3,145.45 passes/min;

d) The best deformation rate was obtained on the hot asphalt mixture with wire mesh layer placed 20 mm from the surface of the object test of 0.013 mm/min; and

e) From the three types of modelling that was planned, the hot asphalt mixture with wire mesh placed 20 mm from the surface of the object test was the best when compared to the hot asphalt mixture without using a wire mesh layer.

### References

[1] A. Maaty, 2012. Fatigue and rutting lives in flexible pavement, Vol. 3.

[2] Q. Xu, H. Chen, dan J. A. Prozzi, 2010. Performance of fiber reinforced asphalt concrete under environmental temperature and water effects. *Constr. Build. Mater.*, Vol. 24, no. 10, 2003–2010.

[3] M. J. Kim, S. Kim, D. Y. Yoo, dan H.O. Shin, 2018. Enhancing mechanical properties of asphalt concrete using synthetic fibers. *Constr. Build. Mater.*, Vol. 178, 233–243.

[4] G. D. Airey, A. C. Collop, S. E. Zoorob, dan R. C. Elliott, 2008. The influence of aggregate, filler and bitumen on asphalt mixture moisture damage, *Constr. Build. Mater.* Vol. 22, no. 9, 2015–2024.

[5] T. W. Kennedy, FL. Roberts and KW. Lee, 1983. Evaluation of moisture effects on asphalt concrete mixtures No. 911.

[6] S. Wu, Q. Ye, dan N. Li, 2008. Investigation of rheological and fatigue properties of asphalt mixtures containing polyester fibers, *Constr. Build. Mater.*, vol. 22, no. 10, 2111-2115
[7] C. Gorkem dan B. Sengoz, 2009. Predicting stripping and moisture induced damage of asphalt concrete prepared with polymer modified bitumen and hydrated lime, *Constr. Build. Mater.*, vol. 23, no. 6, 2227-2236.

[8] Sesaria, D A. 2018. Effect of Crumb Rubber Gradation on Asphalt Mixture Characteristics. *Repositori Institusi USU*, (Universitas Sumatera Utara)

[9] I Gusti Ngurah Widyantara, Latif Budi Suparma, Imam Muthohar, 2018. Marshall Stability and Warm Mix Asphalt Deformation Resistance Using Zycotherm. *Masters in Transportation Systems and Engineering*. Department of Civil and Environmental Engineering. UGM.

[10] Sukirman, S., 2003, Hot Mixed Asphalt Concrete, *1st Edition*, Granit, Jakarta.

[11] L. F. Walubita, T. P. Nyamuhokya, J. J. Komba, H. Ahmed Tanvir, M. I. Souliman, dan B. Naik, 2018. Comparative assessment of the interlayer shear-bond strength of geogrid reinforcements in hot-mix asphalt, *Constr. Build. Mater.*, Vol. 191, 726–735.

[12] National Center for Road Works Laboratory, 2019, Medan.

[13] Tm. Suprapto, 2006, Highway Materials and Structures, *3rd Edition*, (KMTS FT UGM, Yogyakarta).

[14] SNI 03-1732-1989. Procedure for Planning Flexible Pavement Pavement Thickness Using Component Analysis Method. National Standardization Agency (BSN).

[15] Bukhari D K K, 2007, Engineering Material and Pavement Thickness, Engineering Faculty, Universitas Syiah Kuala.

[16] Suryawan. A, 2005. Pavement Concrete Pavement Road (Rigid Pavement). Beta Offset. Jakarta

[17] Size of iron wire mesh PT. Batraja, October 2011, http://www.ilmusipil.com/ukuran-besi-wiremesh-m