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# Use of Latex as a Renewable and Sustainable Asphalt Mixture Material

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**Abstract:- Damage that occurs in asphalt pavement can result from traffic loads, weather conditions, and also the surrounding environmental factors. High rainfall and poor drainage systems often cause inundation of road pavement causing a decrease in the strength of the pavement itself.. Pavement with a mixture of rubber materials has been tested to have several advantages such as increasing viscosity and fatigue resistance, and reducing deformation. Therefore, it is necessary to conduct research on the continuous and periodical resistance of the rubber asphalt mixture to the inundation condition. This study tested the resistance of rubber asphalt mixture to rainwater immersion condition with varying times of immersion. The timing of the immersion was based on inundation condition in Indonesia, where in certain locations the inundation could take a short time and in others it took repeatedly. The rubber asphalt mixture without immersing treatment, three-day and seven-day immersion treatments had a dynamic stability value of 2.127, 2.278, and 2.460 passes/minute, whereas the normal asphalt mixture had dynamic stability values of 1,017, 1,189 and 1,311 passes/minute. It can be seen that the rubber asphalt mixture has a higher dynamic stability value than that of the normal asphalt mixture. The more immersed rubber asphalt mixture, the more increase its dynamic stability value will be. This is due to the asphalt mixture tending to harden and more frozen due to the immersion itself.**

***Keywords:-*** *Deformation Resistance, Dynamic Stability, Immersion, Natural Rubber, Rain Water, Rubber Asphalt, Wheel Tracking Machine.*

## I. INTRODUCTION

Damage occurs in the flexible pavement such as grooves, waves, and rising asphalt to the surface caused by traffic loads passing through it and weather or climate conditions. High rainfall can cause flooding and inundation on pavement roads. Duration of rainwater which is dirty and also contains acid affects the performance of road pavement. In addition to this rainwater immersion, the road pavement damage can also be triggered by inappropriate use of asphalt. Efforts are being made to overcome these problems by improving the quality of pavement mixture. One of the efforts is to modify the asphalt by adding an elastomer modifier. It has been studied and can improve the quality of road pavement mixtures. Relatively cheaper and widely available in Indonesia, the elastomer modifier material is rubber in the form of latex, or solid rubber and in the form of crumb rubber. Several studies show that asphalt composition already mixed with rubber can improve the performance of asphalt mixtures, among others, increasing viscosity, fatigue resistance, and reducing deformation. Natural rubber is very suitable as an asphalt modifier material for road construction in rubber producing countries because it can increase the flexibility and stability of asphalt to provide a longer service life (Tuntiworawit, 2005). In 2018 the Ministry of Public Works and Public Housing carried out asphalt pavement work using a rubber asphalt mixture. It was carried out on the Lahat - Tebing Tinggi road section of South Sumatra Province. In general, national roads still lack water channels. As a result, the rainwater inundated the pavement. The study of Henri Siswanto (2017) showed that inundation can cause road damage because water can reduce the bond strength between the aggregate and asphalt. The study was conducted using the method of water immersion at a temperature of $60^0$C. Therefore, it is necessary to do a study on the strength of the rubber asphalt mixture in the AC-Wearing mixture already submerged in water both continuously and periodically closer to the field conditions (without setting the immersion water temperature). The choice of immersion method was based on the inundation condition in Indonesia where in certain locations it took a short time and in others it took repeatedly. This study used a wheel tracking machine to be

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able to approach the conditions in the field and be more simulative than other laboratory methods to assess resistance to permanent deformation or groove damage.

## II. LITERATURE REVIEW

### *A. Natural Rubber*

Natural rubber is a hydrocarbon compound produced through the clumping of sap from the tapping of the *havea brasiliensis* tree. The sap is then known as latex, which is a white liquid that comes out of the tapped plant stems (Le Brass 1968). According to Alfa (2005) natural rubber is one of the types of elastomer due to have elastic deformation properties. The elasticity of rubber is determined by the composition of the latex and the method of processing used to obtain raw natural rubber. To improve the quality of natural rubber to be more stable and more elastic, the vulcanization process is carried out. The vulcanization process itself is a chemical reaction that causes a linear rubber molecule to undergo a crosslinking reaction so that it becomes a polymer molecule that forms a three-dimensional series. The reaction changes rubber which is plastic (soft) and weak to be elastic, hard and strong rubber. Vulcanization is also known as the ripening process, and rubber molecules that have been cross-linked are referred to as rubber vulcanization. The conventional vulcanization process was first discovered by Charles Goodyear in 1839. This vulcanization uses sulphuric compounds as a binder of the rubber polymer. In this conventional vulcanization process it takes 3 to 4 kinds of chemicals, namely: sulphur, accelerator, activator and natural rubber mixture stabilizer. With these materials which are then heated at a temperature of 40-50$^0$C for 2 to 3 days, a second heating of 70$^0$C for 2 hours and a final heating of 100$^0$C for 1 hour. Vulcanization is one of the important stages in the formation of the desired physical and chemical properties of natural rubber. To produce the type and amount of crosslinking desired and produce the physical properties of the produced rubber, the regulation of the use of sulphur and accelerator in the vulcanization process must be compared.

Fig 1:-. Latex

### *B. Rubber Asphalt Mixture*

Rubber asphalt is the result of mixing oil asphalt and rubber with a certain ratio mixed with heat. Natural rubber mixed into hot asphalt will be dispersed; chemical reaction is formed with the liquid part of bitumen causing asphaltene levels to rise. In consequence, the asphalt becomes thicker and harder but still elastic. Generally the rubber material used to make asphalt rubber is synthetic rubber and natural rubber. Synthetic rubber or artificial rubber often used for asphalt rubber modification material called synthetic rubber is *styrine* polymerization combined with *butadiene* to produce *styrine butadiene rubber* (SBR) or *styrene butadiene styrene* (SBS), having properties such as natural rubber and has more advantages resistant to temperature and oxidation. Natural rubber that has been widely studied for its use as an asphalt modification material is liquid natural rubber in the form of latex. The use of natural rubber as an asphalt modification material is believed to increase the viscosity and elasticity of asphalt as a binding agent in asphalt mixtures. According to Road Note 36 quoted by Collin Huglles (2005), the use of natural rubber as an asphalt modification material in Britain initially used rubber as a powder, but from the subsequent experiments the use of natural rubber in the form of latex had a better effect on asphalt modification when rubber blended with asphalt in the form of jelly. In addition, the mixing time was shorter and the mixing temperature was lower. According to Kurniadji (1999), during the hot mixing process of oil asphalt and latex, the hydrogen atoms contained in rubber asphalt molecules can evaporate. In this condition, the rubber molecule is degraded to reduce the effectiveness of rubber asphalt. When latex is added to hot asphalt, the latex will spread in the form of fine particles due to the heat of rubber particles will absorb the oil content (maltene) asphalt and then expand and dissolve to get clay asphalt.

### *C. Effects of Rain Soaking on Asphalt*

Rain is a precipitation event (the fall of liquid from the atmosphere that is liquid or frozen to the surface of the earth) in the form of liquid. This rain requires the presence of a thick layer of atmosphere in order to meet temperatures above the melting point of ice near and on an Earth's surface. Tjasyono (2004) defines precipitation as a form of liquid and solid water (ice) that falls to the surface of the earth. The characteristics of the Indonesian region are the combination of land surface of 30% and the sea area of 70%. The Indonesian land has a lot of mountains and this surface condition causes very large variations in local climate. The pattern of daily rainfall is sometimes influenced by the maritime character, i.e. maximum rainfall occurs after midnight until early morning (Tjasyono, 2005). Rainwater contains several chemicals such as water vapor, nitric acid, carbon (silica and fly ash), sulphuric acid, and salt. The mixture of AC-WC using Buton asphalt which was already immersed with rainwater has decreased quality, as indicated by Marshall test results (Nanda, 2018). This quality decline continues along with the increasing immersion time.

### *D. Deformation Resistance*

Deformation resistance testing is the resistance of an object to moving loads. This test was carried out with a wheel tracking machine developed by the UK Transport Research Laboratory (TRL) which is used to simulate the rut tracks due to heavy vehicles at high temperatures on the road. This test was carried out to evaluate the resistance of asphalt mixture to deformation. The deformation resistance of a specimen that is asphalt mixture can be seen from the rut depth after being passed with a number of passes or rate of deformation in mm/min. In addition to the deformation rate, this test also got a dynamic stability value which was the number of passes needed to form a groove as deep as 1 mm. This test was carried out to measure the pavement performance and evaluate the resistance of asphalt mixture to permanent deformation. It was carried out at 600C, because the asphalt mixture was very sensitive to permanent deformation at high temperatures.

## III. MATERIALS AND METHODS

The procedure of this study is given in the following Figure 2.

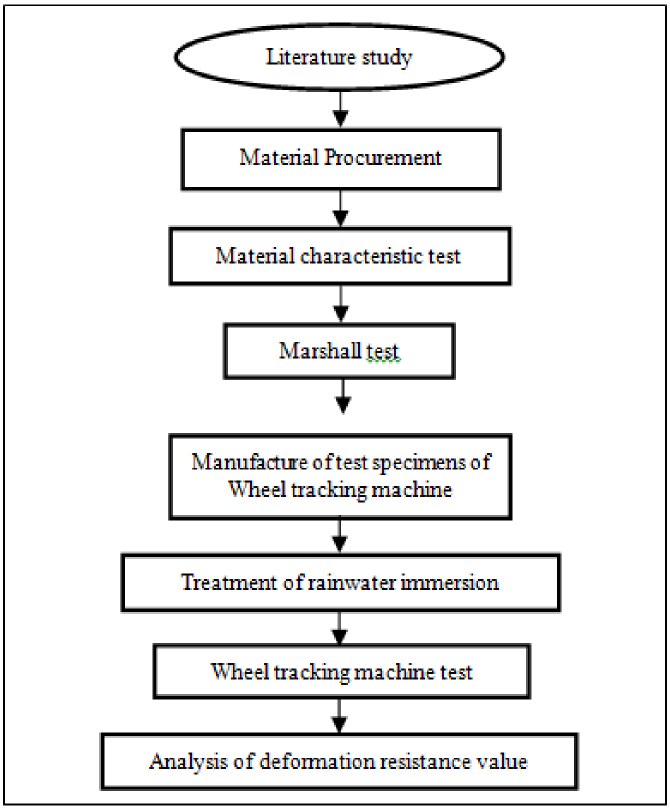


Fig 2:- Flow Chart of Research Procedure

### *A. Material Procurement*

➢ *Aggregate*

Coarse and fine aggregates were obtained from PT. Rotari Persada (Lingut/OKU Timur). The used coarse aggregates were crushed stone of 1-2 and 1-1fractions, while the fine aggregates were stone ash.

➢ *Asphalt*

There were two types of asphalt used in this study. Normal asphalt mixture used Pertamina Pen 60/70 asphalt and rubber asphalt mixture used natural rubber asphalt obtained from PT. Sarana Lampung Utama, which at present is only this company producing the rubber asphalt. The used rubber asphalt was the result of mixture of asphalt pen 60/70 with latex having a vulcanization process of 7%.

➢ *Rain Water*

Rainwater was used as an immersion treatment of the test specimen. The natural rainwater was immediately collected when it rained.

### *B. Material Characteristic Test*

➢ *Test of Aggregate Material*

Coarse and fine aggregates must meet the general specifications of Bina Marga of 2018 using the Indonesian National Standard testing method. The test results of the physical properties of coarse and fine aggregate material are given in Table 1.

| Test Types | Test Result | Specification |
|---|---|---|
| - Abrasion of 100 revolution (%)<br>- Abrasion of 500 revolution (%) | 5.85<br>22.16 | Max 8%<br>Max 40% |
| Sand equivalent (%) | 61.74 | Min 0% |
| Specific Gravity and Absorption<br>a. Broken Stone of Fraction 1-1<br>- BJ Bulk<br>- BJ SSD<br>- BJ Apparent | 2,636<br>2,668<br>2,273 | Differences between BJ coarse and fine agg. ≤ 0.2 |
| - Absorption | 1,217 | Max 3% |
| b. Broken Stone of Fraction 1-2<br>- BJ Bulk<br>- BJ SSD<br>- BJ Apparent | 2,662<br>2,690<br>2,741 | Differences between BJ coarse and fine agg. ≤ 0.2 |
| - Absorption | 1,087 | Max 3% |
| c. Fine Aggregate<br>- BJ Bulk<br>- BJ SSD<br>- BJ Apparent | 2,562<br>2,595<br>2,650 | Differences between BJ coarse and fine agg. ≤ 0.2 |
| - Absorption | 1,297 | Max 3% |
| Fine Aggregate Angularity (%) | 45.50% | Min 45% |
| Broken grains of coarse aggregate<br>a. One or more fields are broken<br>b. Two or more fields are broken | 99.86%<br>98.95% | Min 95%<br>Min 90% |
| Viscosity (%) | 96%+ | Min 95% |
| Flat and oval particles, (%) | 3.79% | Max 10% |

Table 1:- Results of Aggregate Material Test

➢ *Normal Asphalt Test*

The asphalt material had to be in accordance with the General Specifications of Bina Marga of 2018. The standards of testing carried out to obtain good asphalt had to be in accordance with the Indonesian National Standards. The test results showed that the 60/70 Pen asphalt tests met the General specifications of Bina Marga of 2018, as a result the asphalt could be used as an ingredient in a normal

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AC-WC mixture for further research. The test results of Pen 60/70 asphalt physical properties are given in Table 2.

| Test Types | Test Result | Specification |
|---|---|---|
| Penetration at 25 °C | 63,6 | 60 – 70 |
| Softening Point (°C) | 48,9 | $\geq$ 48 |
| Ductility at 25 °C (cm) | $\geq$140 | $\geq$ 100 |
| Flash Point (°C) | 304 | $\geq$ 232 |
| Specific Gravity | 1.015 | $\geq$ 1.0 |

Table 2:- Results of Normal Asphalt Material Test

➢ *Rubber Asphalt Test*

The rubber asphalt material used had to be in accordance with the applicable specifications in Indonesia. The specifications used the 2010 Revised-3 General Bina Marga Specifications on the Draft special specifications for concrete asphalt layer of natural rubber. The results of this rubber asphalt test are given in Table 3.

| Test Types | Test Result | Specification |
|---|---|---|
| Penetration at 25 °C | 57 | Min 50 |
| Softening Point (°C) | 56 | $\geq$ 52 |
| Ductility at 25 °C (cm) | $\geq$ 120 | $\geq$ 100 |
| Flash Point (°C) | 328 | $\geq$ 232 |
| Specific Gravity | 1.035 | $\geq$ 1.0 |

Table 3:- Results of Rubber Asphalt Material Test

### C. *Marshall Test*

To get optimum asphalt content (KAO), a mixture planning used the AASHTO T245-97 (2004) method. The asphalt mixture planned in this activity was normal asphalt mixture and rubber asphalt mixture, with AC-wearing course. Both mixtures were distinguished from the types of asphalt used. The normal asphalt mixture used 60/70 Pertamina pen asphalt and rubber asphalt mixture used natural rubber asphalt.

### D. *Manufacture of Wheel Tracking Machine Test Object*

Optimum asphalt content obtained from the Marshall test stage would be used as asphalt content in the manufacture of test specimens for testing the wheel tracking machine. The asphalt mixture planned in this activity was a hot asphalt mixture AC Wearing Course with a size of 30 x 30 x 5 cm for 3 samples for each variation.

### E. *Rain Water Immersion Treatment*

After the optimum asphalt content value was obtained from the marshall test, then the test specimen could be made for the wheel tracking test. Before testing the wheel tracking, the specimens were treated with immersion first. There were three variations of immersion in this study as follows:

➢ Not immersed
➢ 3 day immersion
➢ 7 day immersion

### F. *Wheel Tracking Machine Test*

The relationship between the nature of asphalt and the permanent deformation response in the asphalt-aggregate mixture was evaluated using the Wheel Tracking tool. Before testing the Wheel Tracking Machine, the asphalt mixture already compacted in a 30 x 30 x 5 cm mold was pre-conditioned in a conditioning chamber for 6 hours at $60^0$C. At the time of the test, the wheel speed was 42 passes/minute with a tire pressure of 6.5 ± 0.115 kg/cm2.

## IV. RESULT AND DISCUSSION

### A. *Results of Marshall Test*

Based on the results of Marshall tests, the optimum asphalt content of normal asphalt mixture was 6.1%. In the Marshall asphalt rubber testing, the percentage of asphalt content of 6.1% and 6.6% already met the required specifications. Then 6.6% asphalt content was used as the optimum asphalt content for the rubber asphalt mixture. This optimum asphalt content value was used as asphalt content in the manufacture of test specimens in testing the wheel tracking machine. The Marshall test results for normal asphalt mixture and rubber asphalt mixture are given in Tables 4 and 5.

| Asphalt content (%) | Stability (Kg) | Flow (mm) | VIM (%) | VMA (%) | VFA (%) |
|---|---|---|---|---|---|
| Specification | min 800 | 2 - 4 (mm) | 3% - 5% | min 15 % | `min 65 % |
| 4.6 | 1660 | 3.10 | 8.93 | 16.76 | 46.69 |
| 5.1 | 1535 | 2.80 | 7.82 | 16.83 | 53.50 |
| 5.6 | 1340 | 2.55 | 5.90 | 16.17 | 63.55 |
| 6.1 | 1202.5 | 2.90 | 3.51 | 15.14 | 76.85 |
| 6.6 | 930 | 3.05 | 2.67 | 15.50 | 82.77 |

Table 4:- Marshall Test Results of Normal Asphalt Mixture

| Asphalt content (%) | Stability (Kg) | Flow (mm) | VIM (%) | VMA (%) | VFA (%) |
|---|---|---|---|---|---|
| Specification | Min 800 | 2 - 4 (mm) | 3% - 5% | min 15 % | min 65 % |
| 4.6 | 1790 | 2.45 | 7.78 | 15.55 | 49.94 |
| 5.1 | 1725 | 2.75 | 6.36 | 15.33 | 58.51 |
| 5.6 | 1500 | 3.30 | 6.09 | 16.16 | 62.30 |
| 6.1 | 1388 | 3.90 | 4.66 | 15.96 | 70.77 |
| 6.6 | 1460 | 3.40 | 3.79 | 16.26 | 76.66 |

Tabel 5:- Marshall Test Results of Rubber Asphalt Mixture

*B. Test Results of Wheel Tracking Machine*

Based on the graph of the wheel tracking machine test results of the two asphalt mixtures, the asphalt mixture already immersed in rainwater for 3 days had a higher value of deformation depth than the not-submerged asphalt mixture. This can happen because when immersion occurred, the water made the bond between asphalt and aggregate more loose so as to make the asphalt mixture more deformable during testing. However, the different results were shown in 7 days of rainwater immersion, in which the value of the deformation depth was lower than the asphalt mixture immersed for 3 days. The graphical model of the test results fluctuated among the asphalt mixtures of not submerged, 3 day submerged, and 7 day submerged. The graphs of the wheel tracking machine test results for the two asphalt mixtures are given in Figures 3 and 4.

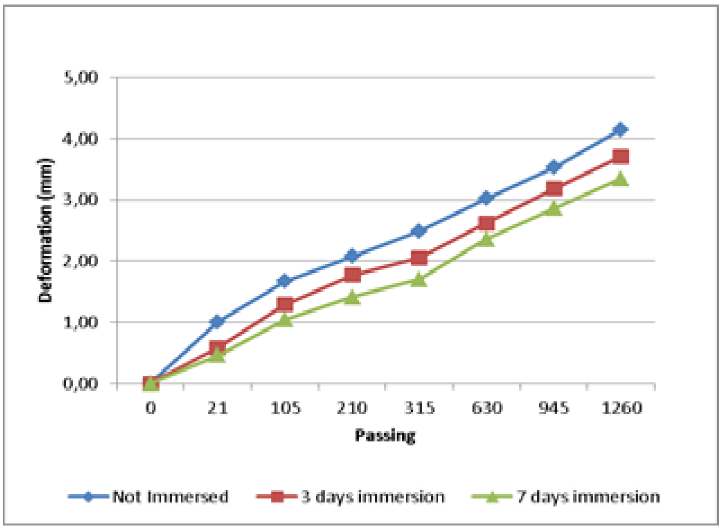


Fig 3:- Graph of Wheel Tracking Machine Test Results of Normal Asphalt Mixture

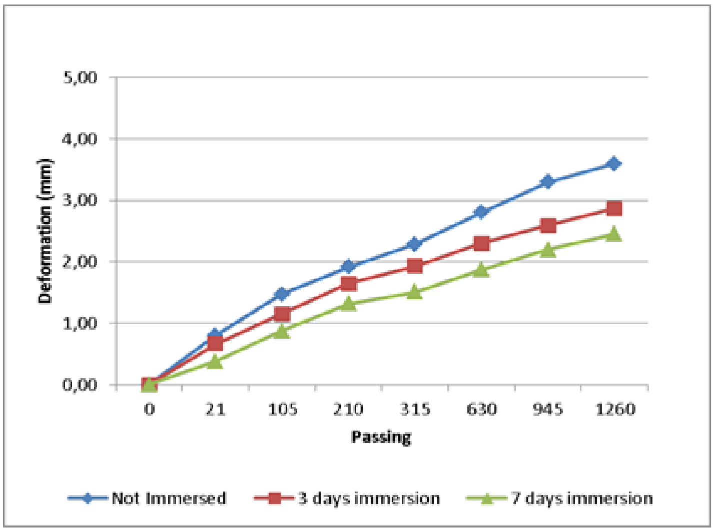


Fig 4:- Graph of Wheel Tracking Machine Test Results of Rubber Asphalt Mixture

Based on the deformation value of the results of the two asphalt mixture tests, the deformation resistance values for each parameter can be calculated as shown in Tables 6 and 7.

| Parameter | Normal Asphalt Mixture | | |
|---|---|---|---|
| | Not immersed | Immersed | |
| | | 3 day | 7 day |
| Permanent deformation (mm) | 0.54 | 1.04 | 1.18 |
| Deformation rate (mm/minute) | 0.0327 | 0.0413 | 0.0287 |
| Dynamic Stability (pass/mm) | 1286 | 1017 | 1467 |

Table 6:- Deformation Resistance Value of Normal Asphalt Mixture

| Parameter | Rubber Asphalt Mixture | | |
|---|---|---|---|
| | Not immersed | Immersed | |
| | | 3 day | 7 day |
| Permanent deformation (mm) | 0.43 | 0.83 | 1.02 |
| Deformation rate (mm/minute) | 0.0171 | 0.0269 | 0.0180 |
| Dynamic Stability (pass/mm) | 2460 | 1573 | 2335 |

Table 7:- Deformation Resistance Value of Rubber Asphalt Mixture

➢ *Permanent Deformation*

From the deformation values shown in Figure 3 and 4, a permanent deformation value for each variation and type of asphalt mixture could be determined. The comparison of the permanent deformation value is shown in Figure 5. Figure 5 shows that the duration of immersion in rainwater caused the permanent deformation value of asphalt mixture to be higher. The permanent deformation value in the rubber asphalt mixture looked better than the normal asphalt mixture, with a comparative value of permanent deformation relatively the same in each variation of the immersion. The permanent deformation values increased significantly from asphalt mixture that was not immersed to asphalt mixture immersed for 3 days. The permanent deformation value continued to increase in the asphalt mixture that was immersed for 7 days, but it was not too large.

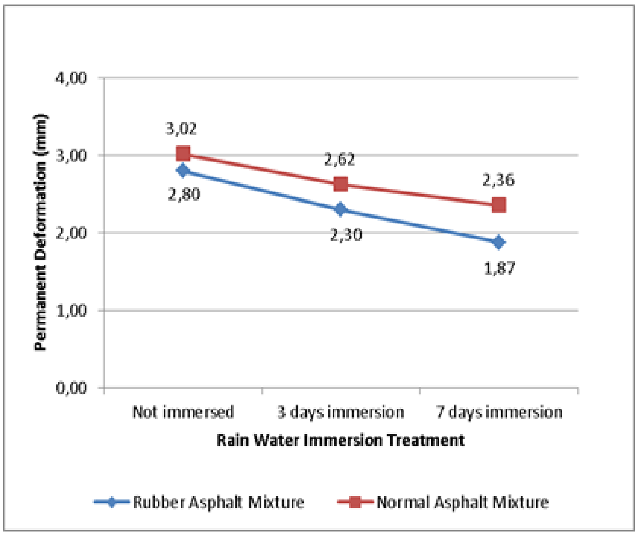


Fig 5:- Comparison of Permanent Deformation Values Between Rubber Asphalt Mixture and Normal Asphalt Mixture

➢ *Deformation Rate*

The comparison of the dynamic stability values between the rubber asphalt mixture and the normal asphalt mixture showed that the rubber asphalt mixture was still superior to the normal asphalt mixture in each variation of the immersion. However, the value of the deformation rate did not appear to be directly proportional to the duration of the immersion duration. After being immersed for 3 days, the asphalt mixture had an increase in the value of the deformation rate. It means that the asphalt mixture after being immersed for 3 days decreased its strength causing the asphalt mixture to deform more quickly. This is not directly proportional to the results shown on the 7 day immersion in which the deformation rate dropped to a lower value. It indicates that the asphalt mixture after being immersed for 7 days increased its strength resulting in the slower value of the deformation rate. The comparison of the deformation rate values for these two asphalt mixtures is given in Figure.6.

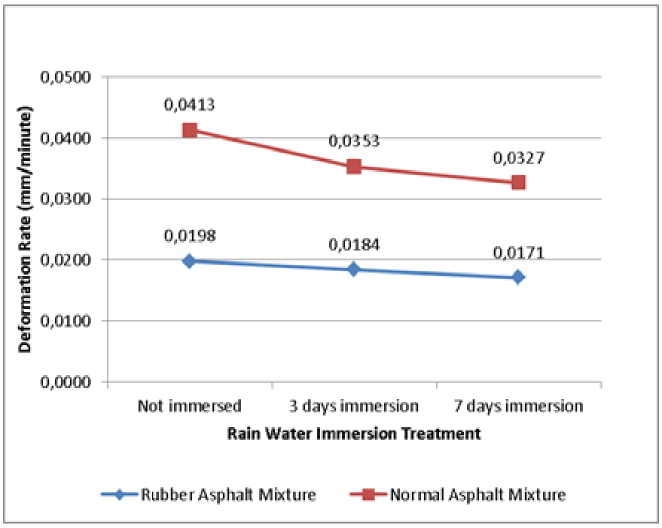


Fig 6:- Comparison of Deformation Rate Values between Rubber Asphalt Mixture and Normal Asphalt Mixture

➢ *Dynamic Stability Value*

The comparison of the dynamic stability values between the rubber asphalt mixture and the normal asphalt mixture showed that the rubber asphalt mixture had a much higher dynamic stability value than the normal asphalt mixture in each variation of immersion. The dynamic stability value decreased when the asphalt mixture was immersed for 3 days, but the dynamic stability value increased when the immersion duration was 7 days, both in the rubber asphalt mixture and normal asphalt mixture. The comparison of the dynamic stability values of the two asphalt mixtures is shown in the following Figure 7.

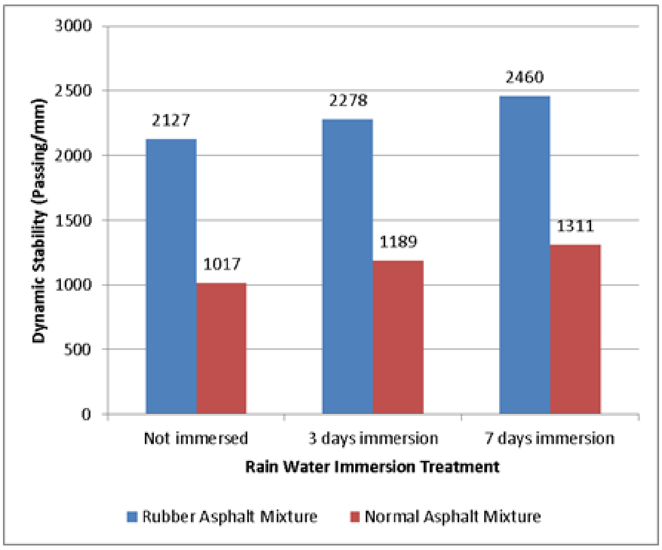


Fig 7:- Comparison of Dynamic Stability Values between Rubber Asphalt Mixture and Normal Asphalt Mixture

## V. CONCLUSION AND RECOMMENDATION

The results of the deformation resistance tests showed that the rubber asphalt mixture had a superior deformation resistance value compared to the normal asphalt mixture in each variation of its immersion. The longer it was immersed the dynamic stability value of asphalt mixture tended to increase. The increase in dynamic stability values for the two asphalt mixtures was also relatively stable. The rubber asphalt mixtures with the treatments of not being immersed, 3 day immersion, and 7 day treatments had a dynamic stability value of 2.127, 2.278, and 2.460 passes/minute, whereas the normal asphalt mixture had the dynamic stability values of 1.017, 1.189, and 1.311 passes/minute. But there was a concern that the longer immersion, the elasticity value of the asphalt mixture also decreased to cause the asphalt mixture to be more susceptible to cracking. For further research, the decrease in elasticity values of asphalt mixture with this immersion treatment has to be considered.

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