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# Modified Asphalt Using Buton Natural Rock Asphalt

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**Abstract:** The performance of asphalt pavements is mainly governed by the properties of the asphalt. Pavements made of asphalt can exhibit stresses when exposed to high temperatures. At high temperatures, permanent deformation or rutting occurs and leads to channels in the direction of travel. This is due to the viscous flow of the asphalt matrix in the pavement mixture, which resists the strain caused by traffic. This is due to the viscous flow of the asphalt matrix in the pavement mix, which resists traffic-induced strains. Therefore, pavement performance is strongly related to the rheological properties of asphalt, which can be improved by its modification. In this study, Pen. 60/70 asphalt was modified by using Buton Natural Rock Asphalt (BNRA). A total of 10 to 25% of fine BNRA passing sieve #200 was added to the asphalt. Four mixtures of asphalt and BNRA were then tested for penetration and softening point. From the Penetration and Softening Point test results, the Penetration Index (PI) was determined. The PI results obtained were 0; 0.2; 0.1; 0.1; and 0.4 for BNRA content of 0, 10, 15, 20, and 25%. The higher the PI value of asphalt, the lower its temperature susceptibility. It can be seen that with the addition of BNRA, the asphalt is more resistant to temperature changes. While it is evident that BNRA affects the resistance of asphalt to temperature changes, it is also evident that its strength.

**Keywords:** *asphalt pavements performance; high temperature deformation; viscous flow; rheological properties; buton natural rock asphalt*

## 1. Introduction

The only earth tar still in use today is Buton Natural Rock Asphalt. The last four natural tars have all been depleted, including Trinidad Lake Asphalt found in Trinidad Lake, three types of rock revealed in Gard, France, Neuchatel, Switzerland, and Ragusa, Italy, and a type of mud confirmed in Gard, France, Neuchatel, Switzerland, and Ragusa, Italy. Hetzel, a Dutch geologist, originally discovered Buton Natural Rock Asphalt in 1926. Asphalt content of 20% to 30% can be found in the rocks of Buton Island, an Indonesian island off the coast of Southeast Sulawesi. The island contains approximately six hundred and fifty tons of tar, hence the name Buton Natural Bitumen. When building pavements, these 650 million tons of BNRA are not used completely and effectively.

In an effort to use less crude oil base asphalt, this publication presents the findings of a study on the use of BNRA in HMA mixtures to find out if BNRA can make the asphalt stronger and use less crude oil-derived base asphalt. In this study, 60/70 penetration asphalt was mixed in amounts of ten, fifteen, twenty, and two-five percent with extra virgin Buton Natural Bitumen (with a particle size cross section of seventy-five millimeters). Bitumen and base asphalt mixtures were tested for entry at twenty-five centigrade as well as susceptibility to estimated entry list (PI), a criterion responsive to changes in binder temperature. Entrance and extra susceptibility testing of the base asphalt were also conducted to see how the asphalt properties.

The base will change if its hardness changes. To ascertain the impact on HMA, the BNRA-Bitumen Mixture binder was also examined. The results of all investigations showed that the PI weight, hot mix asphalt stability, and combined strength of HMA increased as the concentration of BNRA binder increased.

## 2. Material

### 2.1. Buton Natural Stone Asphalt

Buton Island in Southeast Sulawesi is the location of BNRA's natural asphalt discovery. Natural rock asphalt resources are estimated to be worth 650 million tons, according to research conducted by the archipelago's Department of Violence and Mineral natural assets. Rock asphalt reserves are only one to two meters deep, and contain 20 to 30 percent asphalt. There has been research on 3.4 million tons of rock asphalt since it was first discovered and utilized. For this research, BNRA is run by Buton Bitumen Nusantara Co, Ltd. When placed in a sack, [1] it contains 25 kg of large particles (Fig.1).


**Fig. 1.** Buton Bitumen Nusantara in sacks on the left side and BNRAin large particles on the right side

### 2.2. Bitumen

Bitumen use in this research was bitumen penetration grade 80/100 product by PERTAMINA Co. Ltd., the Indonesia State-Own Oil Company. Penetration at 25°C and Softening Point test conducted by the author shows that the bitumen has penetration 60, softening point 52°C, and specific gravity 1.041.

### 2.3. Aggregates

Bodri River, a river located 80 km west of Semarang, was used as the aggregate in this study. Basalt stone, the main raw material for boulders, has an abrasion resistance of 90% when used in conjunction with a Los Angeles Machine and small-sized coarse aggregate.

## 3. Research Methodology

Buton Natural Bitumen is broken down into extra fine particles with a grain size of zero point zero seventy-five millimeters or seventy-five meters between successfully sieved number two hundred in order to interact with asphalt easily, as shown in Fig. 2.


**Fig. 2.** Granulated BNRA. Crushed BNRA with a diameter of 0.075 mm

On top of the base tar, 10, 15, 20, and 25% fine BNRA was added. At 120°C and a stirring speed of 2000 rpm, the BNRA was mixed with the base tar for 45 minutes in a vanemixer. To calculate the penetration index (PI), absorption test at twenty-five degrees Celsius, Attenberg Limits, and GS were conducted after the mixture was thoroughly mixed. The HMA binder will have a higher PI value.

The development of hot mix asphalt and HMA strength tests is shown below. The aggregate gradation used in the Bina Marga mix (Directorate General of Highways, Ministry of Public Works of the Archipelago) [2] for the final surface asphalt layer model is shown in Table 1.

**Table 1.** Aggregate specifications and tar content of HMA

| | Mix Designation | | | |
|---|---|---|---|---|
| Leve size (mm) | AC 10 | AC 14 | AC 20 | AC 28 |
| | percentage passing sieve size | | | |
| 37,5 | - | - | - | 100 |
| 26,5 | - | - | 100 | 90-100 |
| 19 | - | 100 | 90-100 | 73-88 |
| 13,2 | 100 | 90-100 | 71-86 | 58-76 |
| 9,5 | 90-100 | 72-83 | 58-75 | 47-67 |
| 6,7 | 68-82 | 54-71 | 46-64 | 37-58 |
| 4,8 | 50-70 | 43-61 | 37-55 | 30-50 |
| 2,4 | 32-51 | 28-45 | 24-42 | 20-37 |
| 1,2 | 22-40 | 19-35 | 15-32 | 13-28 |
| 0,6 | 15-30 | 13-27 | 10-24 | 09-22 |
| 0,3 | 10-22 | 09-20 | 07-17 | 06-16 |
| 0,015 | 07-14 | 06-13 | 04-12 | 04-10 |
| 0,075 | 04-07 | 04-07 | 03-06 | 03-06 |
| Minimum layer Thickness (mm) | 35 | 50 | 70 | 95 |
| Binder content (% by mass) | 4,5-6,5 | 4,0-6 | 3,8-5,8 | 3,5-5,5 |

In this study, a mix with AC 20 aggregate parameters and 5.50 percent asphalt component was used. There was no use of Marshaal's process to find the ideal binder content. Five different mixes of 10, 15, 20, and 25 percent BNRA asphalt mixture and three different samples each used base asphalt as the binder. The strength of the HMA mixes was evaluated using the Marshall Stability test. ASTM D1559-92 Marshall Stability test was performed [3].

## 4. Results and Discussion

### 4.1 Gs, Attenberg Limit, and Penetration testing

Table 2 contains the Penetration, Attenberg Limit, and Gs test findings as well as the PI values for the sub asphalt and each BNRA-tar mix.

**Table 2.** Penetration test results

| Sample | Penetration at $25^0$ C (dmm) | Softening Point (OC) | Specific Gravity | Penetration Index (PI) |
|---|---|---|---|---|
| Base bitumen | 60 | 50 | 1,041 | 0 |
| 0% BNRA | 41 | 57 | 1,091 | 0,2 |
| 10% BNRA | 39,2 | 58 | 1,115 | 0,02 |
| 15% BNRA | 38,6 | 58 | 1,123 | 0,1 |
| 20% BNRA | 35,2 | 60 | 1,145 | 0,4 |

The findings of the three tests were statistically analyzed using dispersion and regression modeling [4]. Table 3 presents the statistical analysis data for the tests related to the infiltration test, Attenberg Limit, and Gs, in contrast to sections 4.2, 4.3, and 4.4 which provide explanations and regression models.

**Table 3**. Findings of statistical analysis performed on penetration, softening and specificgravity tests.

| Test | Mean of test value | Standard Deviation ($\sigma$) | Coefficient of Confident (%) | Confidence Interval ($\mu$) | Coefficient of Correlation (R) | Coefficient of Determination ($R^2$) |
|---|---|---|---|---|---|---|
| Pen | 43 | 19,68 | 95 | $21 < \mu < 64$ | 0,9138 | 0,8351 |
| SP | 57 | 6 | 95 | $48 < \mu < 65$ | 0,9324 | 0,8694 |
| SG | 1,1 | 0,08 | 95 | $1 < \mu < 1$ | 0,9907 | 0,9814 |

Note: Pen = Penetration; SP = Softening Point; SG = Specific Gravity

### 4.2 $25^0$C penetration

As the concentration of Buton-NRA increases, the penetration test result of asphalt at 25°C decreases. Student's t distribution and an easy-to-understand regression model were used to test this hypothesis. Column 2 of table 2 contains the penetration test results. The penetration test results, which have a 95% confidence coefficient, a degree of relatedness R of 0.9138, and a determination rate R2 of 0.8351, make it clear that all penetration values are accurate and support the premise. The statistical analysis is depicted in Table 3, and the capable correlation model is shown in Fig. 3.

## 4.3 Change Point

The temperature at which the binder softens and penetration have an opposite relationship. As the softening point temperature rises, the penetration value of the binder decreases or its hardness increases. row 3 in Table 2 displays the test results for softening point temperature. Based on the numerical data processing shown in note 3 as well as the regression model shown in Fig. 3, the test result data has a confidence value of Ninety-five percent, a degree of relatedness R of 0.9324, and a determination level R2 of 0.8694, showing the conclusion that the attenberg limit value is correct and matches the theory.

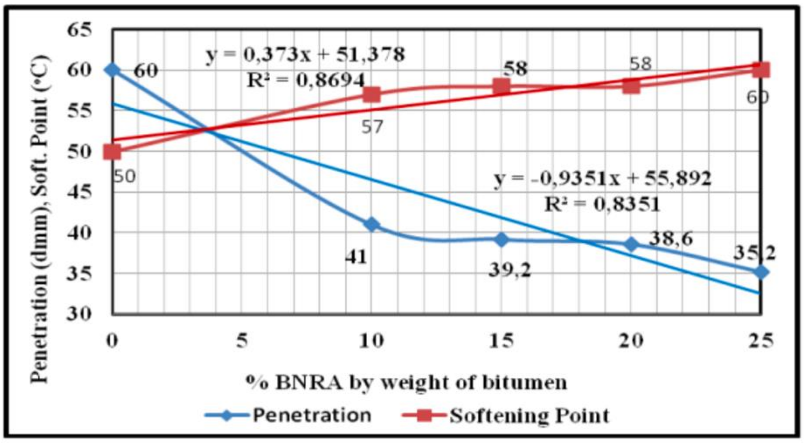


**Fig. 3.** Combination test data of base asphalt and Buton Natural Bitumen forpenetration and softening point regression

## 4.4 Special gravity

To further assess the findings of each gravity test and compare them with the penetration and softening point test results, simple regression and dispersion models were used. The findings showed that the test data had a 95% confidence level, a degree of relatedness R of 0.9907, as well as a degree of determination R2 of 0.9814, all of which contributed to the very high specific gravity values for BNRA.

## 4.5 Penetration Index (PI)

In the database of two rows of five, the permeability list output is presented. The permeability list figure displays the sensitivity of the coalescer to temperature. The justification offered by Pfeiffer and Van Doormaal, mentioned by Robert et al. [Fig. 5] states that as the PI value of asphalt decreases, the more susceptible it is to temperature variations. The PI number varies as far as min. three for tar which is highly susceptible from ambient temperatures plus seven for tar which is easily affected by low heat, following Read, J. and Whiteoak, D. Based on the pi data, the most susceptible binder to temperature changes is 25% BNRA [6].

## 4.6 Marshall Test Findings

Table 4 displays the Marshall Stability, Flow, and Marshall Quotions, or stiffness. It is clear that the Buton Bitumen Nusantara asphalt content significantly affects the stability and stiffness of the mix; in other words, the combination being the highest percent Buton Bitumen Nusantara has high hot asphalt strength stability and stiffness. This finding is confirmed on the part of the regression models for hot asphalt strength stiffness and Marshall Stiffness, respectively, and the numerical investigation of the distribution in Table 5. The statistical results show that Marshall Stability has a 95% determination coefficient R-square coefficient value of 0.9908, Marshall

Stiffness only has a value of 0.9954, and Marshall Stability has a 95% determination coefficient R-square coefficient value of 0.9612. These statistical calculations show that the BNRA-Bitumen modified HMA combination has a very, very large level of stability and stiffness.

**Table 4**. Marshall test results

| BNRA content (%) | Marshall Stability (kg) | Marshall Flow (mm) | Stiffness (kg/mm) |
|---|---|---|---|
| 0 | 528,75 | 3,12 | 169,65 |
| 10 | 722,50 | 3,72 | 194,22 |
| 15 | 791,00 | 3,97 | 199,08 |
| 20 | 902,50 | 4,00 | 225,44 |
| 25 | 950,00 | 4,11 | 230,96 |

**Table 5.** Statistical study findings of Marshall Stiffness and Marshall Stability

| | Mean | Standard Deviation (σ) | Coefficient of Confident (%) | Confident Interval (μ) | Coefficient of Correlation (R) | Coefficient of Determination (R2) |
|---|---|---|---|---|---|---|
| Stability | 778,95 | 332,35 | 95 | 415< μ <1143 | 0,9954 | 0,9908 |
| Stiffness | 203,87 | 49,86 | 95 | 149< μ <258 | 0,9804 | 0,9612 |

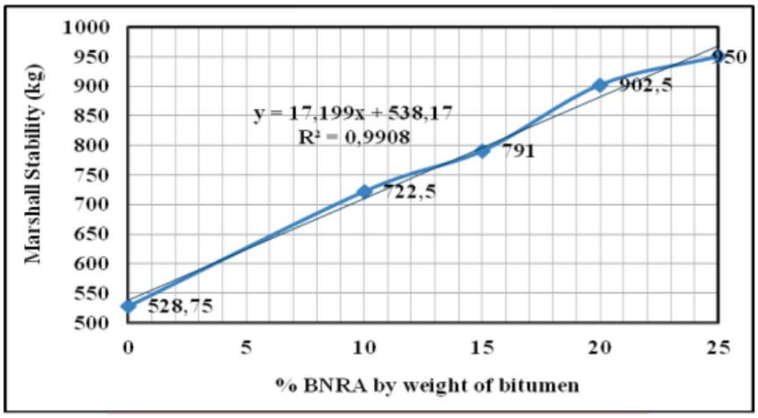


**Fig. 4.** Using the Marshall Stability regression model

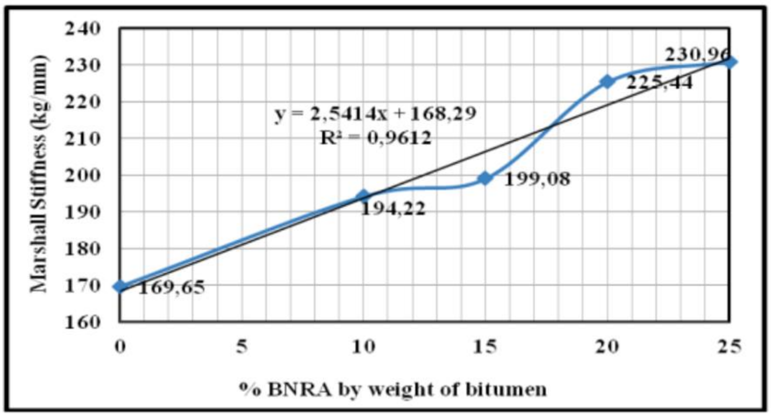


**Fig. 5.** Model for Marshall stiffness regression

## 5. Conclusion

The findings of this research and study can lead to the following conclusions.

1. Buton Bitumen Nusantara will strengthen the insulation's resistance to reactive temperatures.
2. The binder contains Buton Bitumen Nusantara, which means it is strong and has high Marshall Stability.
3. The binder has a high Marshall Flow and BNRA content, which means it is flexible.
4. The binder has a higher Marshall Stability because it contains 25% Buton-NRA.

The fourth finding shows that the amount of petroleum-based tar used in hot mix asphalt and pavement projects can be reduced by using BNRA.

## Recommendation

Rheological testing as well as other tests, including Wheel Tracking test and Indirect Tensile Resilient Modulus test for HMA mixes, should be conducted to learn more about the use of BNRA as an asphalt additive.

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## Reference

[1] Buton Asphalt Indonesia Company Limited (2008). Retrieved from www.alibab.com/member /butonaspaltindonesia.html

[2] Directorate General of Highways (Roads), Ministry of Public Works, Republic of Indonesia. (1995). *International Competitive Bidding, Second Highway Sector Investment Project. Volume Three - General Specifications*. pp. 6.55 - 6.63.

[3] American Society for Testing and Materials. (1992). *ASTM D1559 - 92: Standard Test Method for Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Equipment*. Philadelphia: ASTM International.

[4] Scheaffer, R. L., and McClave, J. T. (1990). *Probability and Statistics for Engineers*. Boston, MA: PWS-KENT Publishing Company.

[5] Robert, F. L., Kandhal, P. S., Brown, E. R., Dah, Y. L., and Kennedy, T. W. (1996). *Hot Mix Asphalt - Materials, Mix Design and Construction (2nd edition)*. NAPA Education Foundation, Lanham, Maryland. pp 448-463.

[6] Read, J., & Whiteoak, D. (2003). *The shell bitumen handbook* (5th ed., pp. 136-139). London, UK: Thomas Telford Publishing.