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Laboratory Investigation on Skid Resistance Characterizations of Recycled Hot-Mix Modified Asphalt Nano Crumb Rubber

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Abstract

In developing countries such as Indonesia, the use of the road pavement recycling process has not been utilized continuously and maximally. The use of the Recycle Asphalt Pavement (RAP) technique has influenced the results for the fatigue test. Various ways to add other materials to the RAP have increased mixture rigidity, rutting resistance, but there are also impacts on crack resistance. Rejuvenation materials are often needed to be more flexible in how they are used. The rejuvenated properties of asphalt can be restored as required in the specifications. Ideally, rejuvenation should also have environmentally friendly properties, and it is better if the product is made from recycled materials.

This study aims to increase the use of RAP by taking into account the increase in the value of road surface slip resistance due to an increase in road surface temperature. This recycling process uses a layer of the old road surface that is rejuvenated by the asphalt content by adding used oil and used tire powder in Nano size. Skid Resistance Test using the British Pendulum Tester with changes in temperature from 27 ˚C to 45 ˚C at 5 ˚C intervals have shown an increase in the mixture to high temperatures on the road surface. The addition of 1.25% Nano Crumb Rubber (NCR) to the optimal bitumen content has shown better performance than recycling without NCR.

Keywords: Skid Resistance, Reclaimed Asphalt Pavement, Nano Crumb Rubber, Temperature

I. INTRODUCTION

Recycling technologie has been used extensively to use the remaining strength of a material. This method has several advantages in saving on the use of new materials, reducing reconstruction costs, maintaining road surface elevation, saving energy, and being environmentally friendly. The impact of the increasingly limited availability of construction materials, a thought of using asphalt scrap from road surface layers to be reused as a Reclaimed Asphalt Pavement. Limited availability of new aggregates, increased material prices and additional costs associated with waste disposal, have promoted the use of recycling technology for rehabilitation for the manufacture of road pavement [1]. The condition of aging asphalt in RAP has the potential to contribute to asphalt pavement thermal factors and fatigue cracking failures. This condition is caused by increased stiffness of the aging asphalt mixture in RAP [2]. Two main factors that influence the use of RAP in asphalt pavement are as economic savings and provide environmental benefits. The design of road pavement materials using asphalt mixture is expected to produce new road pavement materials by considering cost, material and energy savings. The aggregate and asphalt from the old asphalt mixture are redesigned so that it can still be used until the end of its service life. This material can still be used for several more years by adding new aggregates and asphalt to produce a new asphalt pavement mixture that is more economical and preserves the environment [3]. The long-term sustainability program of asphalt pavement requires that design techniques result in longer service of road material conditions and reduced maintenance costs over the service life. And also need to consider the use of local materials, reuse and recycling that can reduce road construction costs, save energy as a solution to the program to reduce emissions and waste [4]. The level of safety for road transportation users requires sufficient friction between the vehicle tire and the road surface. One of the main factors affecting friction between the tire and the road surface is the roughness of the surface texture of the road, and is called skid resistance. Friction on the surface of the pavement is the force caused by the interaction between the vehicle tire and the surface of the pavement. This can occur due to the contact area that causes tire friction when moving on the road surface. From this mechanism it can be defined that the existence of frictional force is a characterization of the sliding resistance of the vehicle wheels on the road surface [5]. Friction resistance is needed so that the vehicle can accelerate, slow down, or change the direction of driving in a safe manner. It is known that low skid resistance is directly related to an increased risk of accidents. There are several factors that can cause friction between the wheels and pavement, including pavement surface characteristics, tire conditions, vehicle movement conditions, and environmental factors. Provisions in the design of roads and speed limits can control the emergence of the properties of micro texture, macro texture, pavement material properties and slip speed [6].

Various characteristics of the pavement surface and tires affect the level of friction. The complexity of the tire-pavement interaction, it is very difficult to develop realistic models to predict in-situ pavement friction. Skid Resistance as a measure of pavement surface resistance for vehicle slip. This is the relationship between vertical and horizontal forces developed as a slip of the tire along the pavement surface. Skid resistance as an evaluation in the pavement parameters because if this value is inadequate will cause accidents related to vehicle slippage. Implementation of the pavement management systems program by monitoring pavement conditions with the aim of producing safe, efficient, comfortable road conditions and road surfaces can be used by vehicles in various weather conditions. The road maintenance program is intended to achieve a high level of security which is part of the pavement management system program. To achieve this goal by maintaining skid resistance at a high level of safety to reduce the risk of vehicle accidents due to skidding and hydroplaning [7]. Meanwhile, to increase the level of friction in the pavement many additional materials have been used, among which the addition of Crumb Rubber material, this material is the result of waste tire processing. The use of Crumb Rubber as a pavement material is carried out with two processes namely wet process and dry process. In dry process, crumb rubber is mixed with aggregate, whereas in wet process Crumb Rubber is mixed with asphalt. This mixing process is carried out before the binder is added to the aggregate [8] [9]. Some studies reveal that dry process has a slightly lower value than wet process crumb rubber. However, this is not a problem because the resistance to fatigue cracking and resistance to deformation from wet processes and dry processes are the same [10].

An important characteristic of RAP that affects the nature and performance of recycled mixes is the aging conditions of the binding material. Compensation method to ensure asphalt pavement performance can be adequate by using additive material. The method of modifying asphalt using alternative materials or waste materials in an effort to improve the performance of asphalt is part of an environmentally friendly program [11] [12]. One of the impacts of the increase in the use of motor vehicles is used oil from motor vehicle engines. Waste Engine Oil (WEO) is a used motor lubricant material, and Engine Oil is produced from petroleum refining. This material has chemical and physical properties similar to the properties of asphalt so that it is widely used by researchers [13] [12]. Various types of rejuvenation have been introduced to the asphalt recycling industry, some products are commercialized and still remain in the scientific literature. Therefore, the intuitive idea arises that without rejuvenation, recycling of RAP mixtures will result in brittle, rigid and lower flexibility of pavement.

In this research, RAP material with WEO rejuvenation material and NCR added material has been used. Some tests are carried out using the Marshall test (standard and immersion) and the skid resistance test. These tests are intended to determine the characteristics of NCR modified RAP asphalt mixture, especially the value of skid resistance using a modified British Pendulum Tester in the laboratory.

II. MATERIALS AND METHODES

II.I. Determining aggregates of Reclaimed Asphalt Pavement (RAP)

RAP material as a material that has become an aging process, to be reused requires an investigative process to determine the physical characteristics of asphalt and aggregate by physically separating between asphalt and aggregate. There are several ways to separate asphalt from aggregate in a concrete asphalt mixture, including the solvent extraction method, the ignition oven method and the ignition oven with solvent combination. To get aging asphalt from RAP, this material is placed in the reservoir extractor. The extraction process starts by turning the reservoir extraction for a specific time [14]. In this study, Reclaimed Asphalt Pavement material was obtained from dredged surface layer of pavement at Jakarta Outer Ring Road (JORR) Toll Road, and used Centrifuge Extractor to separate asphalt and aggregate.

The results of extraction of RAP asphalt mixture have known the composition of the aggregate as shown in Figure-1, where the specification of the asphalt mixture before the aging process of the Asphalt Concrete Wearing Coarse (ACWC) aggregate specifications. From this figure it is seen that there is a decrease in the number of medium-sized aggregates and a slight increase in fine aggregates. Changes in the composition of this aggregate as a result of traffic loads, especially from heavy vehicles.

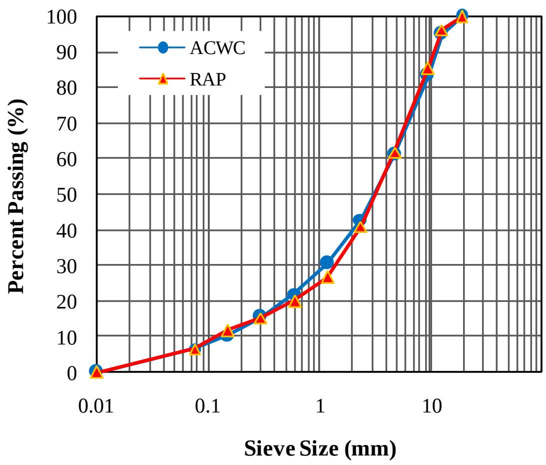

Fig. 1. Gradation curve of Aggregate (AC-WC and RAP)

II.II. Determination Asphalt Content

The results of physical tests of aging asphalt and virgin asphalt can be seen in table-1, from this data it can be seen that there have been many changes in the nature of asphalt compared to virgin asphalt. The low penetration value and ductility value and the high soft point value are common characteristics of asphalt that are already in aging condition.

Table 1. Specification of binders.

Asphalt Characteristics			
No.	Type of Testing	Virgin Asphlat	Aged Asphalt
1	Penetration (25 C, 5 s, 100 g)/0.1 mm	62.5	8
2	Loss on heating (TFOT)	0.108	0.35
3	Penetration after TFOT	61	5.8
4	Softening Point (° C)	45	65.3
5	Flash Point (° C)	306	322.6
6	Solubility in Trichloroethylene (%)	99	89.8
7	Ductility (cm)	107	12.3
8	Specific Gravity	1.048	1.07

In this research, virgin asphalt and new aggregate have been used to determine the optimum asphalt content of ACWC asphalt mixture as a guideline for determining RAP asphalt content.

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Calculation of optimum asphalt content using Marshall test refers to the SNI standard (Indonesian National Standard) 06-2489-1991. Marshall standard testing uses samples with levels of 5%, 5.5%, 6%, 6.5%, and 7%. The results of this test have obtained the optimum asphalt content at 6% of the total weight of the asphalt and aggregate mixture. And to find out the susceptibility of asphalt mixes to the effect of water, the Marshall Immersion test was carried out referring to (ASTM D1075, 2007) by immersing the test sample for 24 hours at 60 ° C.

II.III. Material Additive

Crumb Rubber material is obtained from the processed waste of used tires produced by PT Daurindo Indonesia in Bogor. This material has been grinded to Nano size and processed by ball mild for 10 hours. The purpose of smoothing crumb rubber into Nano size is to facilitate the mixing process of crumb rubber with asphalt. Nano-sized particles are expected to produce a homogeneous mixture. Asphalt mixture process with Nano Crumb Rubber (NCR) is done by dry process. NCR percentage of asphalt content with variations of 1.25%, 2.5%, 3.75%, 5% and variations of RAP mixture without added NCR material as a reference.

II. IV. Waste Engine Oil

Used oil from motor vehicle engine lubricant has physical and chemical similarities with asphalt so that in this study it is used as an aging asphalt softener material in RAP. The need for the amount of Waste Engine Oil (WEO) is measured by the amount to increase the penetration value of aging asphalt reaching 60/70 penetrates as the target specification for the ACWC asphalt mixture for this RAP asphalt mixture.

II.V. Modified Skid Resistance Test

The equipment to measure the value of pavement surface roughness which is used based on the guidelines of SNI (Indonesian National Standard) 4427: 2008 British Pendulum Tester (BPT). BPT is a dynamic pendulum type test, by measuring the energy lost when the rubber at the bottom of the pendulum rubs the surface being tested. This tool can be used for testing on a flat surface in the field or laboratory (figure-2),

This research has completed the BPT used in the field by adding a water ponds as shown in figure-3, and to make some testing in the laboratory requires a 75 mm x 150 mm x 45 mm sample (figure-2). The contact area of sample must be reached between the rubber pendulum and the surface of the sample between 124 mm and 127 mm for flat surface testing. The sample is compacted like the density of the sample in the Marshal test. Temperature variations in this Skid Resistance test are at temperatures of 27 ° C, 30 ° C, 35 ° C, 40 ° C, and 45 ° C. Each test object is carried out at least 5 times the measurement.

Water ponds are used to regulate the surface temperature of the test sample by heating the water. Water is always set at the same height as the surface of the test object, so that the test object is in a wet surface. Before testing, the surface to be tested is cleaned and moistened with sufficient water. The base of the pendulum is mounted with rubber launcher and its height is adjusted so that its position touches the contact surface area of the sample between 124 mm - 127 mm.

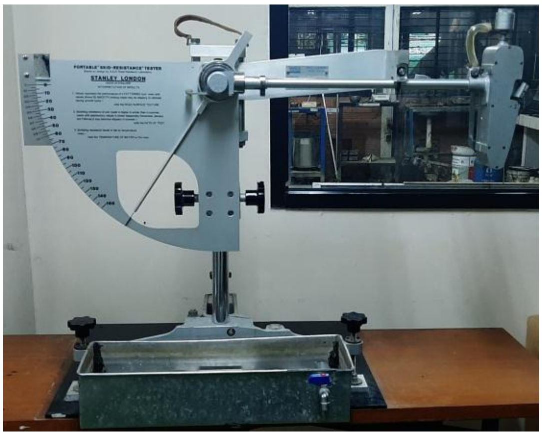

Fig. 2. Modified British Pendulum Number

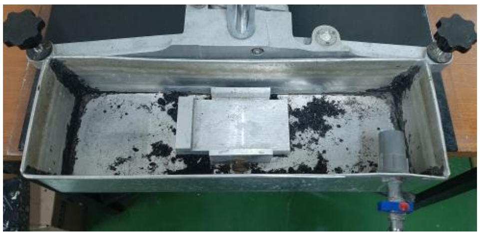

Fig.3. Water ponds of Sample

To refer to the value of road surface resistance using the Skid Number (SN) value. The higher SN value shows that the road surface has more resistance. SN Value is calculated from the conversion of BPN values resulting from the BPT test. The BPN value is calculated by correcting the standard diviation value and the effect of temperature. The SN value is calculated using the formula (1) below.

$$SN = 0.862 (BPN) - 9.69 \qquad (1)$$

Where, SN : skid number and BPN : British Pendulum Number.

II.VI. Sample Preparation

New RAP material has been added new aggregate to return the aggregate composition to specifications. WEO is added to the aggregate, then stored in a closed container for 24 hours. Figure 4 shows a change in color to darker, RAP before and after the WEO addition process.

Fig. 4. RAP+WEO before and after

RAP + WEO is heated to 150 ° C and added NCR + virgin asphalt, then compacted at 145 ° C. Compaction is carried out on molds dimension of 300 mm x 300 mm x 45 mm using a Wheel Tracking Machine (WTM) compactor until it reaches the same density as the Marshall Stability test sample. Compaction results in the form of plates, then cut into sample sizes as needed for BPT test samples (figure-5).

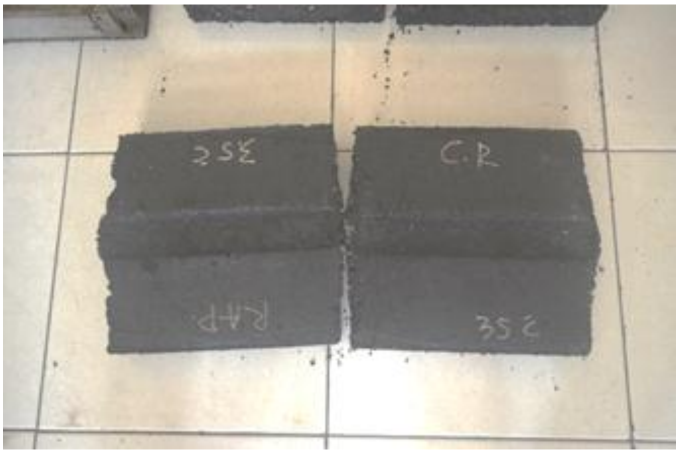

Fig. 5. BPN sample from flat sample compaction

III. RESULT AND DISCUSSION

III.I. Marshall Standard and Immersion

Samples for the BPN test were made from ACWC specifications without added material as a basis for comparison. Figure 6 shows the change in Marshall Stability (MS) value by adding NCR. In this study, the addition of NCR to the RAP asphalt mixture did not increase MS values, even decreased MS values. In contrast, the addition of NCR has resulted in a higher Residual Immersion Stability (RIS) value compared to the RAP asphalt mixture without NCR added material (figure-7).

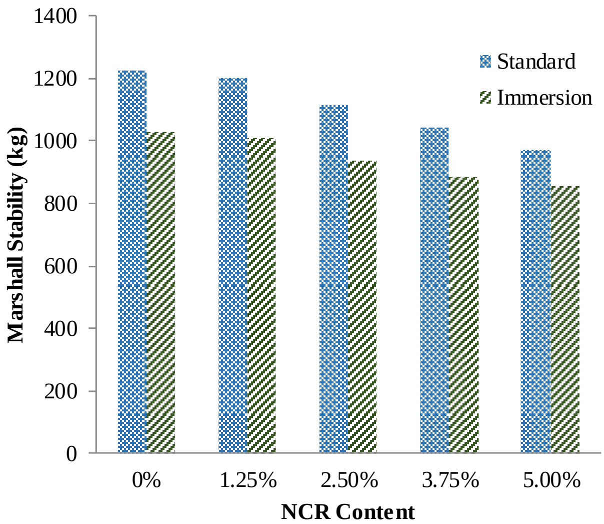

Fig. 6. Marshal Standard and Immersion

The addition of NCR 1.25% has decreased the value of MS 1.91% and increased the value of RIS 0.30%, compared to the addition of NCR 5% has decreased the value of MS 20.73% increased the value of RIS 5.13%. From this data it can be concluded that although the addition of NCR 5% increases the value of higher suscebtibility but on the contrary causes a decrease in the value of MS is very high. The use of NCR to increase the susceptibility value of asphalt mixture to the effect of temperature at 1.25% NCR shows the best results.

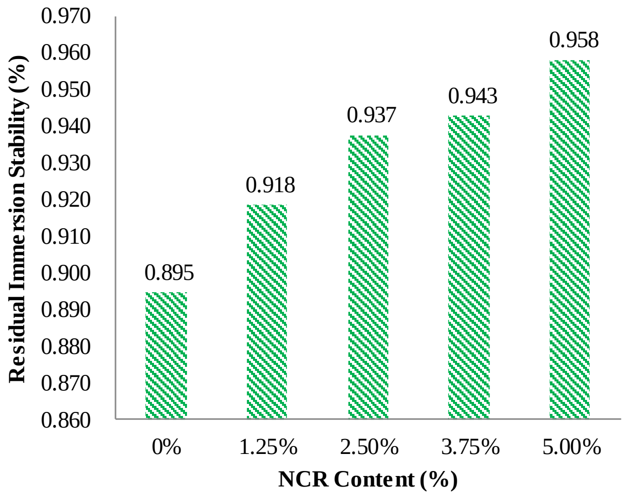

Fig.7. Residual Immersion Stability

III.II. Influence Material Additive on Skid Number

Test results using the BPN test of RAP asphalt mixture with the addition of NCR showed a similar increase in BPN curve, an increase in temperature of 30 ˚C and 35 ˚C then decreased based on increasing temperature. From figure-8 it can be seen that the addition of NCR 1.25% has produced the highest BPN value and is more stable with increasing temperatures.

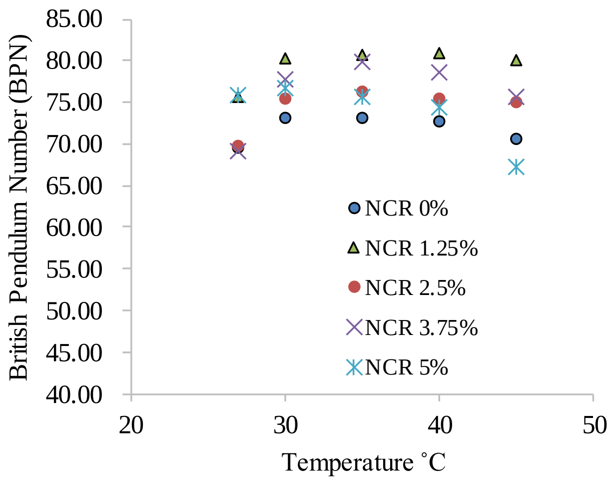

Fig.8. The BPN value of the NCR Modified RAP

III.III. Influence Temperature on Skid Number

Figure-9 shows the change in SN values in the NCR modified RAP mixture. SN value of RAP asphalt mixture without added material has produced the lowest SN value compared to NCR modified RAP asphalt mixture. This shows that the addition of NCR to the RAP asphalt mixture increases the SN value.

The addition of NCR 1.25% in the RAP asphalt mixture showed the highest value and was more stable against the effect of increasing temperature. NCR addition of 1.25% has shown an increase in SN value of 12.54% compared to RAP asphalt mixture without NCR added material.

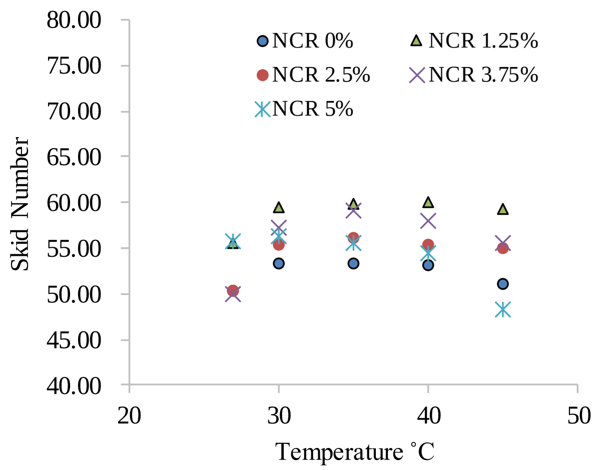

Fig.9. SN value of RAP Modified NCR with changes in temperature

VI. CONCLUSION

Several previous studies on the use of CR as an added material in tightly graded hot-mix asphalt have shown an increase in the performance of asphalt mixes. In this study CR material has been processed into smaller sizes, the results of testing in the laboratory several conclusions can be written as follows:

1. The use of WEO as a rejuvenator on RAP material as a modified RAP has increased the penetration value.
2. Addition of NCR by dry mixing method to RAP + WEO asphalt mixture did not show an increase in Marshall Stability value but an increase in Residual Immersion Stability value.
3. The addition of NCR 1.25% added material shows the most optimum results in terms of Marshall Stability and Residual Immersion Stability.
4. BPN and SN values have shown that the addition of NCR 1.25% is the highest value compared to the modified RAP mixture without NCR added material or other NCR content compositions.

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