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The Use of Reclaimed Asphalt Pavement as a Foundation for Pavements Based On the Indonesian National Standard

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ABSTRACT
This research aims to determine the use of materials from reclaimed asphalt pavement layers directly with the addition of virgin aggregates without the addition of other additives (filler) intended for quality improvement based on the 2010 general specifications of the Indonesian National Standard. Utilization of these materials was used for base courses (class A), sub-base courses (class B), and courses without asphalt coverings (class S). The method used was the laboratory-experiment method and the analysis of the relationship was made using the regression equation. Based on the analysis, by combining the mixture with the virgin aggregates, it was revealed that the materials from reclaimed asphalt pavement layers can be used for the base courses by no more than 3 percent, for the sub-base courses by no more than 9 percent, and for the courses without asphalt coverings or shoulders by no more than 10 percent.
***Keywords* -** Reclaimed asphalt pavement, Base courses, Sub-base courses, Courses without asphalt coverings

I. Introduction

The road conditions which have been partially damaged considerable repair costs, especially with the decreasing number of materials which meet the specified requirement. On the other hand, sustainable road maintenance is a major factor in maintaining the lifetime of a road. Improvements to road damage are generally carried out through a patchwork. If the damage is considered severe and is not strong enough to withstand the existing traffic load, then increases in the strength of the road can be done by providing an additional pavement layer. Repair through a patchwork to some degree is less effective because the materials used to repair the damage are not as good as the original pavement materials. Similarly, attachment of additional pavement layers sometimes does not last long. This is because the earlier pavement has been damaged and as a result the new pavement depends on the earlier pavement whose supportability has decreased. Besides, addition of an extra layer can also bring an less favorable effect such as the closing of the side drainage holes, the low road median, and the increasing amount of dead load of the bridge [1].

An example of the implementation of the eco-efficiency principles in sustainable development is the use of materials which can be recycled, recovered, and reused. Utilization of waste in construction is one of the real manifestations for the implementation of these eco-efficiency principles. However, the results of this utilization should meet the established standards. Recycling technology is one of the solutions to maintain the minimum level of road service standards since it will be more effective and efficient. Recycling asphalt and aggregates from the pavement which is often called Reclaimed Asphalt Pavement (RAP) materials, in addition to its economical value, also accommodate the need for conservation of natural resources. Moreover, the advantages given are an increase in the strength of the pavement structure without raising the elevation of the road surface, improvements in the quality of the course can be done quickly, in an environmentally-friendly manner and efficiently in terms of energy use.

In the United States of America, the use of RAP materials has been done by up to 50 percent of the Hot Mix Asphalt (HMA) [2]. The use of RAP by HMA producers is usually less than 15 percent since no necessary binder to grade changes or additional tests are required for this lower percentage [3]. In Indonesia, the use of this RAP have been initiated. In the research conducted by Suaryana (2009) on the case of the road segment of “Jalan Cirebon – Losari”, the use of RAP in hot mix asphalt by not more than 15 percent still can be performed well and meet the requirement [4]. This RAP percentage restriction is applied on a general basis. If connected to the Indonesian National Standard (SNI) – the 2010 General Specifications classify foundation materials for pavements into three classes which make it necessary to further describe the RAP percentage limits for each class.

In the present study, the RAP percentage which can be used as a mixture for each class pursuant to the requirements set by SNI was revealed. The courses consist of the base course (Class A), the sub-base course (Class B), and the course without asphalt coverings or shoulders (Class S).

II. LITERATURE REVIEW

2.1 Reclaimed Asphalt Pavement

According to Kearney (1997) [5], reclaimed asphalt pavement is the previous road pavement chunk materials which have been damaged. These materials are usually used as back-filling materials for road shoulders or simply become waste materials. One of the advantages of asphalt materials is that these materials can be recycled. Asphalt can be softened back and used a few times with any basic methods. Although RAP is only the remains of the road surface courses which is not used, the way to get it is to dredge the previous pavement layer using a tool called milling [6]. The main advantages of RAP among others are the savings of aggregates, asphalt, energy, its eco-friendly nature, and maintenance of the existing road geometry [7]. Meanwhile, the disadvantages of these RAP materials among others are their variability and their rich content of contaminants [8].

2.2 The use of RAP for aggregate base courses

RAP can be used as a granular base or sub-base materials for the pavement structure [9, 10]. Garg and Thompson (1996) conducted a study investigating the potential use of RAP as a base layer [9]. This study suggests that the performance of RAP as a base is comparable to the base made of crushed stones. A study by Taha et al. (1999) recommends mixing granular RAP with aggregates to produce sufficient strength because since the carrying capacity of RAP is usually lower than that of conventional granular aggregates. The percentage of conventional granular aggregates in the mix is increased so that the dry specific gravity and the CBR value will also increase [11]. There are at least 12 states in the United States which use RAP as road base course materials [12]. All the states in the USA which use RAP for road course requires that it should be mixed with aggregate materials.

2.3 The General specifications for aggregate base courses in Indonesia

In the 2010 General Specifications, the Department of Public Works of the Republic of Indonesia classifies the foundation materials into the aggregate base course materials Class A, Class B, and Class S. Generally, the aggregate base course Class A is the quality of the base course under the asphalted layer while the aggregate base course Class B is intended for the sub-base course. The aggregate base course Class S is used for the shoulder of the road without asphalt coverings [13]. Foundations in principle should be made of crushed stones in varying sizes which form closed gradation. The whole aggregate base course should be free from organic materials and clay clumps or any other unnecessary materials and after compacted this course must meet the gradation requirement (using wet enrichment) presented in Table 1 and the physical properties given in Table 2.

Table 1. The Gradation Requirements for Granular Aggregates as Foundation Materials [13]

Sieve Size		Percentage by Weight Passing Square-Mesh Sieves		
ASTM	(mm)	Class A	Class B	Class S
2”	50	-	100	-
1 ½”	37.5	100	88 - 95	-
1“	25.0	79 - 85	70 - 85	89 - 100
3/8”	9.5	44 - 58	30 - 65	55 - 90
No.4	4.75	29 - 44	25 - 55	40 - 75
No.10	2.0	17 - 30	15 - 40	26 - 59
No.40	0.425	7 - 17	8 - 20	12 - 33
No.200	0.075	2 - 8	2 - 8	4 - 22

Table 2. The Physical Properties of Granular Aggregates as Foundation Materials

Physical Properties	Class A	Class B	Class S
Abrasion of the coarse aggregates (SNI 2417: 2008) [14]	0 - 40%	0 - 40%	≤ 40%
Plasticity Index (SNI 1966: 2008) [15]	0 - 6	0 - 10	4 – 15
Results of the multiplication between the Plasticity Index and the percentage of the total passing the square-mesh sieve No. 200	≤ 25	N/A	N/A
Liquid Limits (SNI 1967: 2008) [16]	0 - 25	0 - 35	0 – 35
Clay lumps and friable particles in aggregates (SNI 03-4141-1996) [17]	0 - 5%	0 - 5%	0 - 5%
CBR (SNI 1744:2012) [18]	≥ 90%	≥ 60%	≥ 50%

III. RESEARCH METHODS

This research examines the resulted RAP located on the road segment of “Jalan Trans Kalimantan Poros Selatan, Palangkaraya – Banjarmasin”. The method employed was the experimental method, i.e. the method done by holding a trial to obtained necessary data. The data were then analyzed to generate a comparison under the terms and conditions specified by the SNI (the 2010 General Specifications). The composition of RAP and the virgin aggregates (aggregate quarry ex. “Batulicin”) was made in seven different combinations in which the percentages of the RAP were 0%, 3%, 6%, 9%, 12%, 15%, and 100%. All these combinations were analyzed in terms of the characteristics of the aggregates in each combination, and then a correlation to the percentage of the RAP was made until the permitted limit of the RAP use for all classes under study (Classes A, B, and S) was revealed. In this study, the correlation was carried out only on the values of abrasion, specific gravity, and CBR.

IV. DATA ANALYSIS AND RESULT

The results of the laboratory examination on aggregate characteristics, both the RAP aggregates (residual asphalt content of 3.98 percent) and the virgin aggregates as well as a mix between RAP and the virgin aggregates re shown in Table 3.

Table 3. Characteristics of the Aggregates in Each Combination

No.	Combined Mixture (Percentage of the RAP)	Characteristics of the Aggregates		
		Abrasion (%)	Specific gravity (kg/ cm^3)	CBR (%)
1	0% (only the virgin aggregates)	24.35	2.962	92.2
2	3%	26.85	2.551	90.0
3	6%	30.67	2.507	80.0
4	9%	32.86	2.484	60.0
5	12%	34.22	2.460	37.0
6	15%	34.34	2.386	22.0
7	100% (only RAP)	35.93	2.319	16.6

Based on Table 3, it is shown that the virgin aggregates used as foundation materials for all classes meet the requirements. The RAP materials studied generate a CBR value which is less than the minimum value required both for Class A, Class B, and Class S. Generally, it can be seen that the greater the percentage of RAP used in the mixture, the poorer the quality of the resulting course materials since the abrasion value increases while the specific gravity value and the CBR value decrease. If connected to the requirements on the physical properties of aggregates as foundation materials both for Class A, Class B, and Class S as described in Table 2, the relationships between the percentage of RAP used and the characteristics of aggregates in each combination are shown in Fig. 1 to 3.

Based on Fig. 1, it can be seen that all the mixture compositions under study meet the required abrasion value with the technical specifications of a maximum of 40 percent both for Aggregate base courses Class A, Class B, and Class S. In general, the greater the percentage of RAP used, the greater the resulting abrasion value.

As can be seen from Fig. 2, the specific gravity values of each combination meet the technical specifications since the resulting values are higher than the minimum value by 2 percent for the aggregate base course Class A, Class B, and Class S. In general, it can also be seen that increases in the RAP percentage will result in decreases in the specific gravity value.

Based on Fig. 3, it can be seen that not all the obtained CBR values of each combination meet the technical specifications, namely the aggregates Class A by at least 90 percent, the aggregates Class B by at least 60 percent and the aggregates Class S by at least 50 percent. In general, it can also be seen that increases in the RAP percentage will result in decreases in the obtained CBR value. The composition of the aggregate Class A which meets the requirements is a maximum RAP percentage by 3 percent, while for the aggregate Class B, the composition which meets the requirements is a maximum RAP percentage by 9 percent.

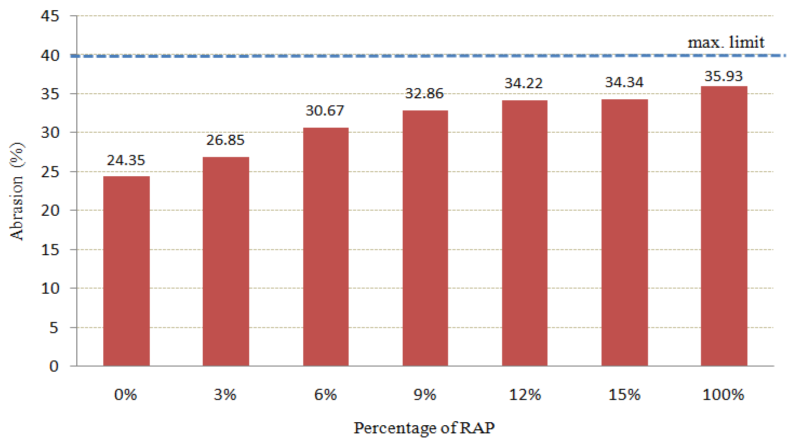

Figure 1. The Diagram of the Abrasion Values based on the RAP Percentage in Each Combination

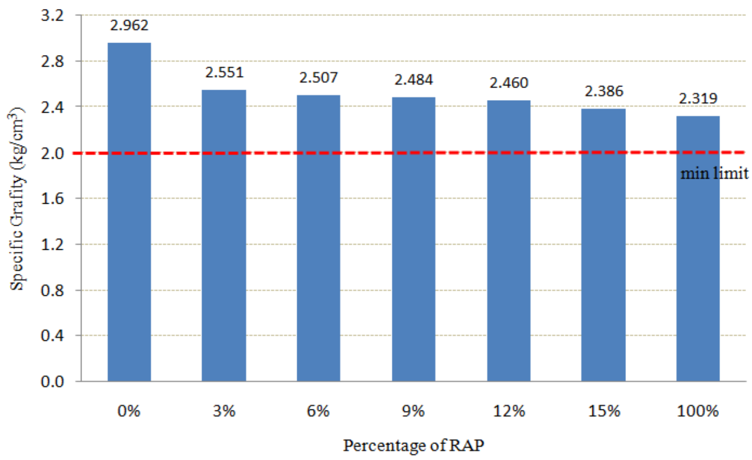

Figure 2. The Diagram of the Specific Gravity Values based on the RAP Percentage in Each Combination

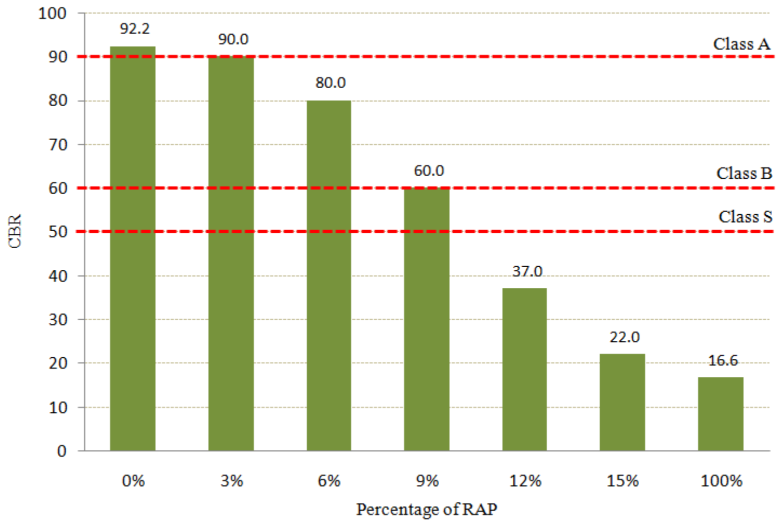

Figure 3. The Diagram of the CBR Values based on the RAP Percentage in Each Combination

To determine the maximum limit for RAP use in the mixture combination for Class S, an analysis using the regression approach was made which was described in the form of a graph illustrating the relationship between the RAP percentage and the CBR value as shown in Fig. 4.

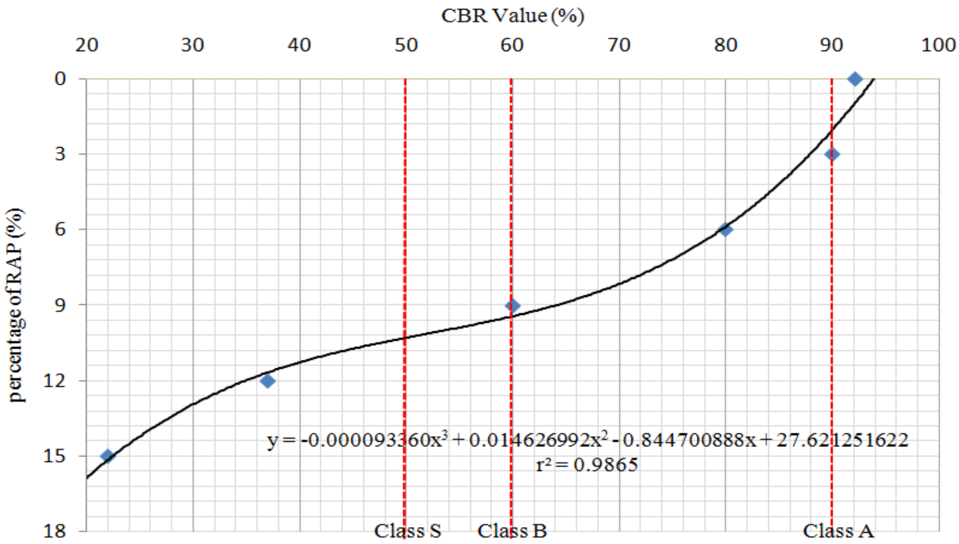

Figure 4. The Graph Illustrating the Relationship between the RAP Percentage and the CBR Value

As can be seen in Fig. 4, the relationship between the CBR value and the RAP percentage forms a quadratic relationship; y = -0.000093360x3 + 0.014626992x2 - 0.844700888x + 27.621251622 where y represents the RAP percentage and x represents the CBR value. The obtained value of the correlation coefficient is equal to 0.993, indicating a very strong correlation [19]. Using the mathematical function, the obtained value for CBR 50 percent is on the RAP percentage by 10.28 percent. Thus, the RAP materials can be used for the aggregate Class S under the condition that the RAP use is not more than 10.28 percent or rounded to 10 percent as a safe rate.

V. Conclusion

Based on the results of the laboratory examination, it is shown that RAP materials can be used as an addition to the foundation materials. The characteristics of these RAP materials are as follows: asphalt content by 3.98 percent, abrasion by 35.93 percent, specific gravity by 2.319 kg/ cm^3, and CBR 16.6 percent, while the characteristics of the virgin aggregates are as follows: abrasion by 24.35 percent, specific gravity by 2.962 kg/ cm3, and CBR by 92.2 percent. With the combination of both materials, the permitted limit of the RAP percentage used as course materials can be determined as follows; (1) for the base course under the asphalted course (Class A), the RAP materials should be used by not more than 3 percent; (2) for the sub-base course (Class B), the maximum limit of the RAP materials is not more than 9 percent; and (3) finally, the use of RAP materials as course materials for the shoulder of the road without asphalt coverings (Class S) should be not more than 10 percent.

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