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Basic Properties of Post-Disaster Recycled Material in Palu City as Flexible Pavement Materials

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Abstract. The massive infrastructure damage due to the earthquake on September 2018 in Central Sulawesi, had a significant impact to Palu City. Several rehabilitation efforts have been carried out and resulted in quite a lot of old road pavement material. Optimizing this old material utilization into new pavements needs to be done, which aims to reduce the use of new materials. However, it is necessary to consider in utilization of post-disaster road pavement materials, due to that the properties of these materials have changed. Therefore, the objective of this research is to determine the basic properties of recycled pavement materials after disaster in Palu City. The method used was Extraction of recycled material using Reflux Extraction Test to separate the aggregate and bitumen. Then an evaluation of its basic characteristics was carried out based on Indonesian standard specifications. The results showed that the basic properties of recycled aggregates still met the specifications in general, except aggregate gradation. Meanwhile, the recycled bitumen did not meet the 60/70 penetration bitumen specifications. So that, utilization of recycled material in new pavement mixture requires some adjustments, such as limiting the use of the percentage in new pavement or using additives/rejuvenators to restore the viscoelastic properties of recycled bitumen.
Keywords : *Recycled Material; Post Disaster Material; Flexible Pavement; Basic Properties*

INTRODUCTION

Sustainable development has become a highly thriving issue in the last few decades. Research related to conserving, reusing, and recycling of construction materials is of great interest. Research and investigations are carried out to maximize the mechanical properties of recycled materials, especially in road pavement materials [1-5].

Road pavement recycling is often referred to as Reclaimed Asphalt Pavement (RAP). According to The U.S. Department of Transportation Research Federal Highway Administration Research and Technology, Reclaimed Asphalt Pavement (RAP) is removed and/or reprocessed pavement materials containing asphalt and aggregates [6]. Recycled pavement is a pavement that reuses old pavement materials (aggregate and bitumen) to be used as new pavements by adding new materials and/or rejuvenating materials. The damaged material can be reused, its characteristics can be repaired, recycled, and improved. Old materials can be used with the same application as the initial application, or as part for new materials [7]. So that the post-disaster pavement material can be referred to as Reclaimed Asphalt Pavement.

The use of RAP material is one of the green technologies in road construction, specifically the use of road waste in addition to saving bitumen and aggregate materials used in road construction [8-10]. The use of recycled materials has the advantage that it can contribute to energy conservation efforts, but on the other hand it can also reduce the quality of the mixture that uses the recycled asphalt. This RAP material has certainly experienced a decline in quality during its service life. For this reason, it is necessary to examine and analyze the physical properties of the recycled material so that its feasibility to be reused as a new road pavement material can be seen.

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The material used for the recycling method is asphalt strip material and if necessary, new bitumen and aggregate are added. This asphalt stripping material contains bitumen and old aggregate. To achieve adequate results, generally, old bitumen and aggregate need to be updated both in terms of properties and gradation. The decrease in the properties of recycled materials is only allowed up to a certain limit, if there is a decrease that is too large and significant then the material cannot be reused because it will have a significant effect on the results of the new mixture [11, 12]. Some of the RAP material properties that can be used as restriction are as follows:

- Aggregate still has good enough durability to maintain gradation (amount, size, shape, and composition of grains).
- The rheological properties of the bitumen (penetration or viscosity) have decreased, but this can be reversed by the addition of a rejuvenating agent. [11, 12].

Even though the technology of utilizing recycled materials has several benefits, in Indonesia this technology still requires further research. In this regard, this research, which is the initial part of the evaluation of asphalt mixtures using post-disaster recycled materials, is expected to provide an overview of the basic properties of recycled road pavement materials after the disaster.

MATERIALS AND METHODS

Materials

The recycled material used in this research was the material from the post-disaster stripping of the road from Balaroa, Palu City, Indonesia, as shown in Fig. 1. Recycled materials (RAP) as seen in Fig 2.

FIGURE 1. *Sampling Location (Source: Google Earth, 2021)*

Methods

This research began with extraction test using a Reflux tool which aimed to separate mineral aggregates and bitumen from recycled materials (RAP). This test used a liquid Trichlorethylene (TCE) as a solvent medium. From this test, the bitumen content of the RAP material was also obtained. Then to separate the bitumen and TCE liquid, a Rotary Evaporator was used. This test method entirely referred to the ASTM method [13, 14]. After obtaining the

evaporated RAP bitumen, the basic characteristics of the RAP bitumen were tested, including specific gravity, penetration and softening point tests. Likewise, the mineral aggregates of RAP obtained from the extraction results were also examined for gradation, specific gravity values, absorption, and microstructural tests. Microstructural tests include X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) tests. XRD is a test used to see the structure of certain materials. The information obtained from the XRD test is in the form of the material's crystallinity. While the XRF test provides information about the content of the constituent elements of the material [15].

FIGURE 2. *RAP of Balaroa, Palu (Source: Research Documentation, 2021)*

RESULT AND DISCUSSION

Reclaimed Asphalt Pavement (RAP)

From the extraction results of the Reclaimed Asphalt Pavement (RAP), the results showed that the average bitumen content contained in the RAP material was 5.16%. The bitumen content was obtained from the ratio of the weight of the asphalt in the sample to the total weight of the sample. This bitumen weight was the reduction of the total sample weight to the weight of the aggregate separated in the extraction process. The results obtained are shown in Table 1.

TABLE 1. *Bitumen Content of RAP Material Extraction (Source: Research Data, 2021)*

Sample Number	Weight (gram)			Bitumen Content (%)
	Sample	Aggregate	Bitumen	
A	B	C	D= B-C	E=(D/B)x100
1	684	648,2	35,8	5,23
2	680	645,4	34,6	5,09
Average Bitumen Content				**5,16**

RAP Aggregate

The RAP aggregate was tested for sieve analysis to obtain the grain size gradation of the RAP material considering that the RAP material had received accumulated vehicle loads during its service life so that there might be changes in the composition of the grain size. The gradations obtained were then compared with the specifications according to the planned gradation design. The gradation of the extracted aggregate can be seen in Table 2 and Fig. 3.

TABLE 2. RAP Aggregate Sieve Analysis Test Results (Source: Research Data, 2021)

Sieve Size		Detained Weight (gram)			% Detained	% Passing	Gradation Specification	
ASTM	mm	Sample 1	Sample 2	Average			Max	Min
1"	25,000	0	0	0	0,00	100,00	100	100
3/4"	19,000	9,1	38,2	23,65	1,57	98,43	90,00	100,00
1/2"	12,500	138,4	132,4	135,4	9,00	89,43	75,00	90,00
3/8"	9,500	114,5	101,1	107,8	7,16	82,27*	66,00	82,00
No.4	4,750	231,8	237,7	234,75	15,60	66,68*	46,00	64,00
No.8	2,360	256,3	249,9	253,1	16,81	49,86*	30,00	49,00
No.16	1,180	193,3	197,7	195,5	12,99	36,87	18,00	38,00
No.30	0,600	147,7	152,5	150,1	9,97	26,90	12,00	28,00
No.50	0,300	163,3	177,4	170,35	11,32	15,59	7,00	20,00
No.100	0,150	130,5	125	127,75	8,49	7,10	5,00	13,00
No.200	0,075	46,7	50,7	48,7	3,24	3,86*	4,00	8,00

*: does not meet specification

Based on Fig. 3, the RAP gradation did not meet the gradation specifications for the Asphaltic Concrete Binder Course (AC-BC) pavement, especially at the sieve size of 3/8", No.4, No.8 and No.200. This was because the composition of the aggregate had changed due to traffic loading, disaster possible reason and was possible due to the use of the latest specifications, considering that the previous RAP gradations still used gradations based on the previous specifications of the Department of Public Works. However, in general, the gradation of the extracted RAP aggregate still met the latest specification limits of the Ministry of Public Works and Public Housing, 2018 [16] except for some aggregate sizes as previously mentioned (3/8", No.4, No.8 and No.200). To meet the required gradations, modifications were made to the composition of the RAP aggregate by adding new aggregates.

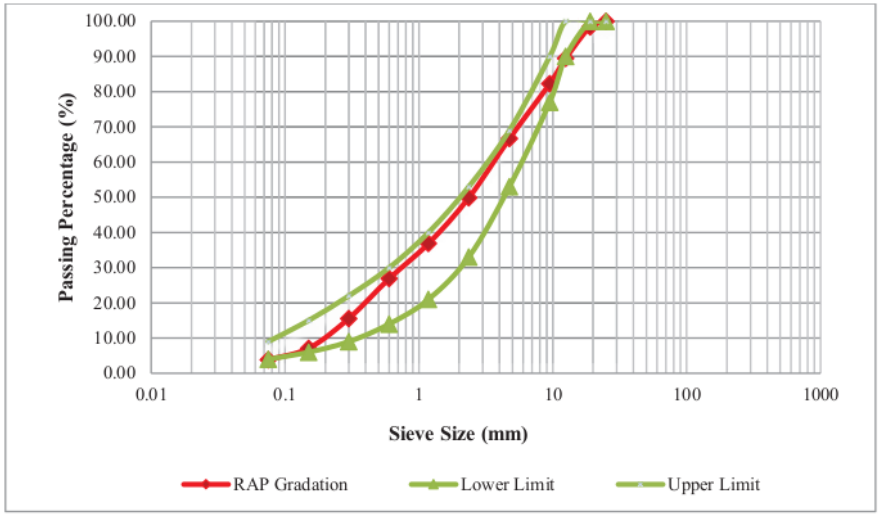

***FIGURE 3.** Gradation of RAP Aggregate (Source: Data Analysis, 2021)*

TABLE 3. *RAP Aggregate Characteristic Test Results*

No	Test	Test Method	Requirements		Test Results
			Min	Max	
1	Specific Gravity				
	Coarse RAP Aggregate				
	a. Bulk Specific Gravity	SNI 03-1969-1990	2,50	-	2,669
	b. SSD Specific Gravity		2,50	-	2,697
	c. Apparent Specific Gravity		2,50	-	2,745
	d. Effective Specific Gravity		2,50	-	2,707
	Fine RAP Aggregate				
	a. Bulk Specific Gravity		2,50	-	2,631
	b. SSD Specific Gravity	SNI 03-1970-1990	2,50	-	2,655
	c. Apparent Specific Gravity		2,50	-	2,697
	d. Effective Specific Gravity		2,50	-	2,664
	Filler	SNI 03-1970-1990			
	Specific Gravity		2,50	-	2,631
2	Absorption (%)				
	Coarse RAP Aggregate	SNI 03-1969-1990	-	3,00	1,033
	Fine RAP Aggregate	SNI 03-1970-1990			0,935

(Source: Research Data, 2021)

For the Specific Gravity and Absorption testing, the results obtained still met the minimum specifications for aggregate specific gravity of 2.5 and maximum absorption of 3%. The difference in specific gravity between fine and coarse aggregates met the requirements of not more than 0.2. In general, the specific gravity and absorption of RAP aggregates are shown in Table 3.

Based on the crystallinity analysis using the XRD test, it was found that the RAP aggregate had a high crystallinity phase of 51.55% (Fig. 4). This shows that the RAP aggregate still has a good intermolecular bond so that it still has strength as a road pavement constituent material. The XRF test gave the result that the dominant element in the RAP aggregate was Silica (Si) of 54.7% (Table 4). Based on the results of XRD and XRF tests, the reference minerals for the RAP aggregate and RAP material before extraction were obtained, as shown in Fig. 5. Based on what showed in the Fig. 5, the minerals which composed the two material samples were similar, namely Anorthite, Forsterite, Augite and Quartz (SiO_2).

TABLE 4. *The constituent elements of RAP Aggregate and RAP Un*-extraction (Source: Research Data, 2021)

Element	Result (mm/mm %)	
	RAP Un-extraction	RAP Aggregate
Si	46,46	54,70
Fe	24,53	22,36
Ca	6,26	6,77
K	6,98	6,50
Al	4,51	5,96
Ti	2,10	2,12
Sx	6,24	0,00
Px	1,28	0,00

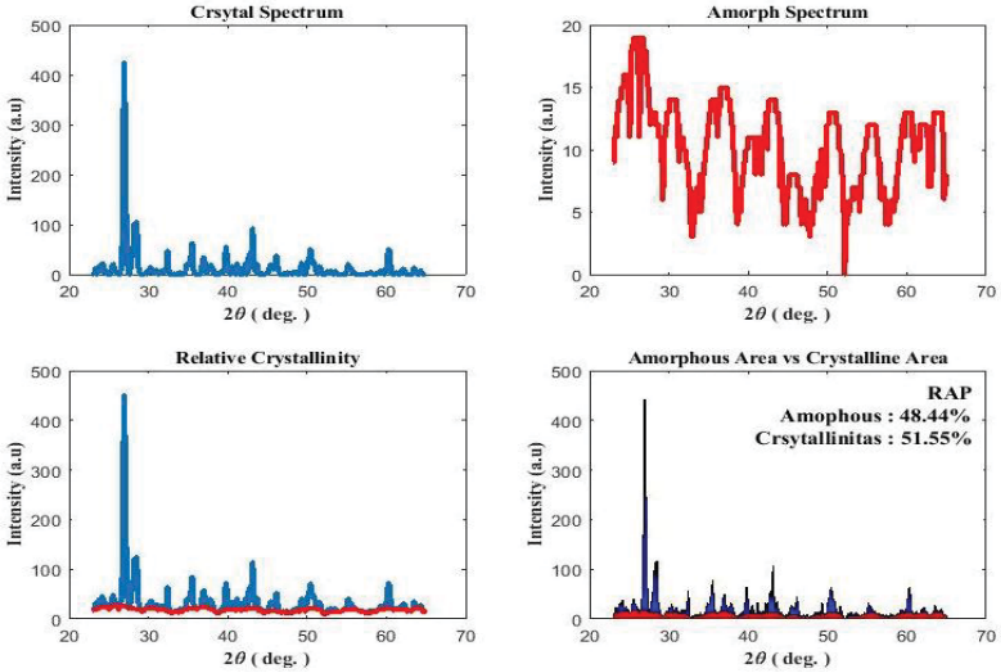

FIGURE 4. *Crystallinity of RAP Aggregate (Source: Research Data, 2021)*

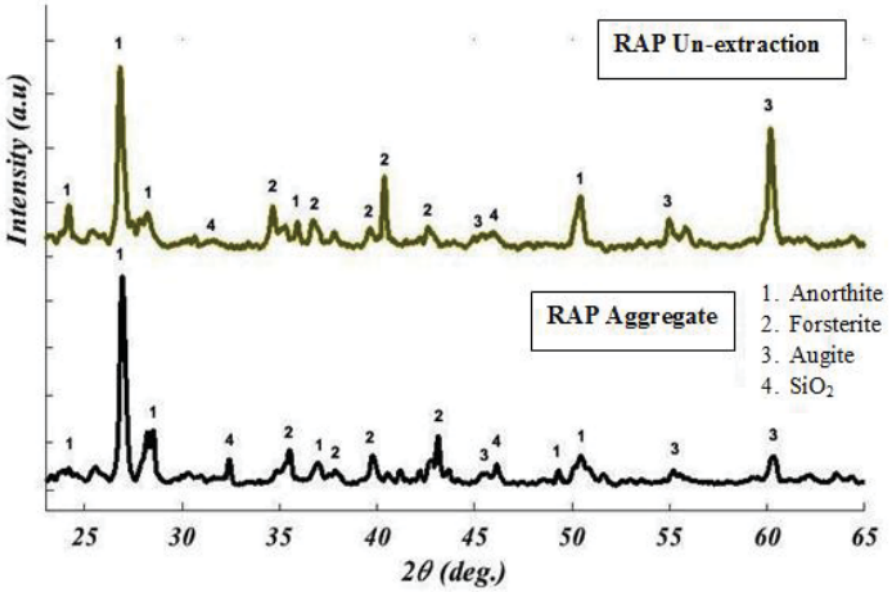

FIGURE 5. *Comparison of RAP Un-extraction Spectrum and RAP Aggregate (Source: Data Analysis, 2021)*

Physically, RAP aggregate is still suitable for use as road pavement material, but in gradation, RAP aggregate still requires adjustment of grain size to be reused. The addition of new aggregates is one solution to improve the gradation of RAP aggregates.

RAP Bitumen

As a result of bitumen recovery using a rotary evaporator, pure bitumen was obtained, hereinafter referred to as RAP bitumen. The RAP bitumen was then examined for its physical properties and compared with the bitumen requirements that were suitable for use in road pavement construction. The tests which were conducted included Penetration Testing, Softening Point and Specific Gravity. The results of testing the properties of RAP bitumen are shown in Table 5.

TABLE 5. *RAP Asphalt Characteristic Test Results (Source: Research Data, 2021)*

No	Test	Test Results	Requirements		Test Method
			Min	Max	
1	Penetration , 25°C (0,1 mm)	12,5	60	79	SNI 06-2456-1991
2	Softening Point, °C	71	48	-	SNI 06-2434-1991
3	Specific Gravity	1,075	1	-	SNI 06-2441-1991

Based on the results in Table 5, it can be seen that the hardness level of RAP bitumen is very high, which is indicated by a low penetration value and a high softening point value and does not meet the PEN 60/70 bitumen specification. From these results it can be concluded that the extracted RAP bitumen cannot be used in road pavement mixtures because the function of bitumen as a form of waterproof layer and adhesive in the mixture can no longer be fulfilled. In order to be used, this RAP bitumen must be modified by using a modifier/rejuvenator that can restore the properties of the bitumen as before.

The results of the RAP bitumen testing showed that the penetration value of the extracted bitumen decreased significantly, namely 12.5 compared to the lower limit of the bitumen specification for Pen 60/70 which was 60 and Pen 40/50 which was 40. This happened because during its service life the bitumen had hardened due to the oxidation and aging process which results in the loss of the light fraction (maltene) in the bitumen composition so that the bitumen tended to become harder. This condition was also seen in other physical properties, namely a very high softening point of 71°C, so a higher heating temperature was needed so that the bitumen could soften. This was possible because the content of solid fraction (asphaltene) was quite high in RAP bitumen. The amount of asphaltene content in RAP bitumen resulted the value of penetration was lower, consequently, the value of specific gravity was higher. The specific gravity value of the experimental results met the requirements of the Ministry of Public Works and Public Housing [16], which was a minimum of 1.0.

In the use of RAP bitumen in new pavement mixtures, it is necessary to add new bitumen. This needs to be done because the bitumen content in the RAP material cannot completely envelop the aggregate and bind between the aggregate grains. RAP bitumen is often still trapped in the pores of the aggregate grains due to the compaction process during the construction process or secondary compaction by traffic loads. So that when RAP bitumen is used in a road pavement mixture without the addition of new bitumen, it will be obtained a mixture with low bitumen content, or it will be obtained a mixture with tends to dry bitumen content. When this mixture is used as a road pavement construction, it will provide low workability and a short service life because the pavement will easily become brittle. With the addition of new bitumen, it is expected to improve the function of bitumen as a binder and forming a waterproof layer in the road pavement mixture. In addition, with the addition of a rejuvenator/modifier, the physical properties of RAP bitumen can be improved to a minimum close to the physical properties of new bitumen.

CONCLUSION

Based on the analysis and discussion of post-disaster recycled material's basic properties in Palu as flexible pavement materials, the following conclusions were obtained:

- Utilization of recycled material is one of the green technologies in road construction, namely the use of road waste in addition to saving the bitumen and aggregate materials used in road construction.
- Bitumen content in the extracted RAP material was 5.16%.
- The physical properties of the RAP aggregate met the required specifications, except that the gradation did not meet the requirements for the AC-BC mixture grading, which required grading improvement.
- Physical properties of RAP bitumen did not meet the required specifications. The penetration value was 12.5 dmm and the softening point value was 71°C. However, the specific gravity value of the bitumen still met the specifications, namely 1.075. So that, if it is to be used, it is recommended to add new bitumen and/or rejuvenator/modifier.

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