Performance of Asphalt Concrete Wearing Course (AC-WC) Utilizing Reclaimed Asphalt Pavement from Cold Milling Bound with 80/100 Pen Asphalt

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Abstract. Demands on natural aggregate materials for road pavement can be reduced by utilizing reclaimed asphalt pavement (RAP). This research was aimed at evaluating the performance of AC-WC mixture using RAP materials from cold milling, bound with 80/100 pen asphalt. The RAP aggregate gradation was adjusted by adding the required amount of natural aggregates to meet the specification in Indonesia. The RAP and added aggregates were hotmixed and compacted with Marshall hummer at 2x75 blows. The asphalt content were varied. It was found that the optimum asphalt content was 6.05 % with the following Marshall characteristics: stability 1237.08 kg; flow 3.36 mm; Marshall quotient 324,73kg /mm; void in mix (VIM) 3,360% ; void in mineral aggregate (VMA) 15.103; and void filled with bitumen (VFB) 77.759% and residual stability 91.04; all met the Indonesian specification. The cantabro abration loss (CAL) at 30°C was 9,02%. The indirect tensile stiffness modulus (ITSM) at 20 ^{0}C was 7961.4 MPa; dynamic creep with 100 kPa pressure at 40°C gave slope 0.0112 microsstrain/pulse which is suitable for heavy load traffic. The fatigue test results was obtained at increased stress level, i.e. at 900, 1100, and 1300 kPa. Based on the equation derived from the fatigue strain and repeated loading relationship, at 100 microstrain (με) the repeated load was 434,661.58 times, and at one million (10^6) repeated loading, the samples could withstand strain of 92,38 microstrain. The performance of the samples were overall better than AC-WC mixture using virgin aggregates bound with 60/70 pen asphalt.

Keywords: AC-WC; cantabro; creep; fatigue; ITSM; Marshall; 80-100 pen asphalt; RAP

1. Introduction

Effort in finding out more alternative materials resources for road materials had been done for some years. A potential material that can be used is the reclaimed asphalt pavement (RAP). The use of RAP for road pavement, requires sufficient amount of RAP materials. In developed countries recycling of road asphalt pavement had been done in regular bases so sufficient RAP materials would be available. However, in developing countries, recycling of road pavement has not yet been carried out systematically and regularly. Only heavily damage road section is usually milled in limited amount then overlaid using asphalt mixture with materials from natural aggregates. This practices results in increasing elevation of road way surfaces compare to the road shoulder and surrounding areas which can cause driving and drainage problems.

Researchers and road authorities had done some studies utilizing RAP. Performance hot mix recycled asphalt using RAP greatly affected by binder content. High RAP content can worsen fatigue resistance of the mixture [1]. Meanwhile, studied the use of glass fibre modified warm mix asphalt that contain RAP up to 50% had also been done [2]. The mixture gave a good resistance to rutting and moisture susceptibility. RAP also effect the fatigue performance of the mixture. Higher RAP content up to 40% worsen the fatigue performance [3].

In Spanish General Technical Specifications for Highway Rehabilitation allows max 50 RAP content. [4] G. Valdés et al. (2011) used up to 60 % RAP (10 % higher than the specification). The new added binder was using 250 pen grade new bitumen. Overall the mixture gave satisfactory results.

I is suggest that the preheating temperature of RAP is 100°C; the preheating temperatures of aggregate recommended to be 190°C, 205°C and 215°C at RAP contents of 30%, 40% and 50% respectively, and adding the rejuvenator to the RAP first before mixing with the aggregates and the newly added asphalt [5].

Meanwhile some studies had been done in using higher RAP content. Common methods in using a high percentage of RAP and the principles are use of softer binder, addition of softening additives or rejuvenators [6]. It was also found that it is possible to use RAP up to 90%, through the use of rejuvenators and development of careful blend design [7]. The performance of a seven year old road section using 100% recycled RAP, gave satisfactory performances [8]. The performance hot asphalt mixture with 100 % RAP in a road section compared to the control section, showed little difference. This results encourages the utilization of RAP [9].

This research was aimed at evaluating the performance of Asphalt Concrete Wearing Course (AC-WC) utilizing RAP from Cold Milling bound with 80/100 pen asphalt. Softer grade asphalt was used to rejuvenate the binder in the final mixture.

2. Methodology

2.1. The materials used, aggregate gradation and properties

The materials used was RAP from cold milling stored at a stockpile in central of Bali. Added material used was natural aggregates taken from a quarry site in eastern part of Bali. The RAP and aggregate gradation of Asphalt Concrete-Wearing Course (AC-WC) mixture is shown in Figure 1. The RAP aggregate gradation was modified by adding the correct amount of materials required to meet the middle gradation of AC-WC mixture. The RAP was 42% and the added aggregates were 58% of the total weight of RAP and added aggregates.

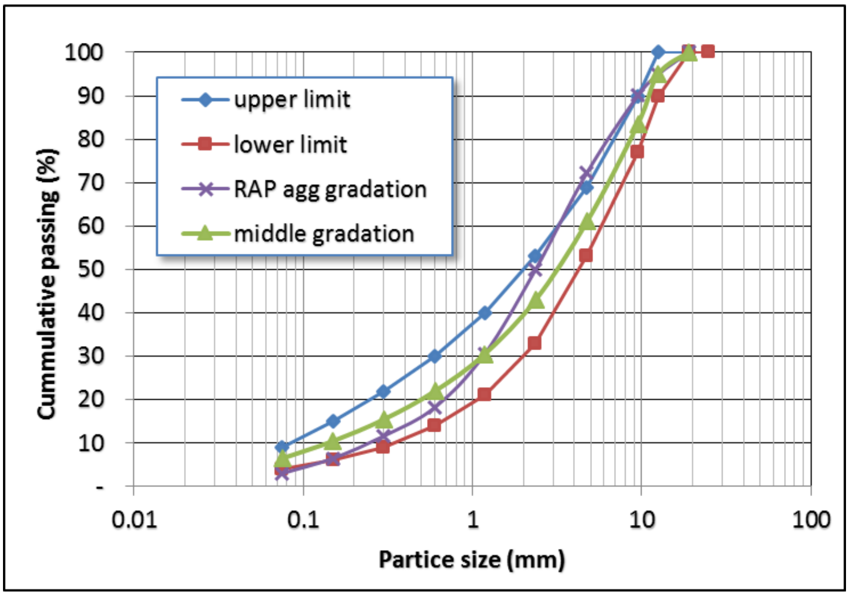

Figure 1. Aggregate gradation of AC-WC mixture.

The asphalt content of the RAP was extracted, and gave 6.01% asphalt content by weight of the RAP or about 2.55% by weight of total mixture. The added asphalt was 3.5%. It had been calculated that the The properties of the added aggregate materials is given in Table 1. The added asphalt used was a 80/100 pen grade asphalt penetration that had met all specification.

Table 1. Properties of the added aggregates.

Properties	Result			Spec
Secific gravity	Bulk	SSD	Apparent	
	2,53	2,59	2,70	
Water absorption	2,46%			Max. 3%
Angularity	50,94%			Min. 40%
Mud content	0,40%			Max.1.0%
Sand Equivalent	92,42%			Min. 60%

2.2. Sample production and testing

The RAP and added aggregate materials were proportioned and hotmixed with the 80/100 pen asphalt. The added asphalt was varied and the samples were tested by Marshall test procedures and compacted 2x75 Marshall blows. The properties of the samples were analysed and the optimum added asphalt was determined. Samples with optimum asphalt content were tested for its Cantabro Abrasion Loss (CAL), stiffness, dynamic creep, and fatigue. The results were compared with AC-WC mixture using natural aggregates and 60/70 pen asphalt. For the CAL, 3 samples were rotated for 300 rotation without steel ball which is usually used for testing aggregate abrasion values. The Loss Angeles abrasion test was carried out at room temperature 30°C The percentage loss of weight due to abrasion then determined.

For testing indirect tensile stiffness modulus-ITSM (stiffness), dynamic creep, and fatigue test were done using a Universal Testing Machine 30 (UTM 30) Dynapave. The ITSM test was done at temperature of 20°C; loading pulse width 250ms (millisecond); pulse repetition period 3000ms; conditioning pulse count 5; estimated poisson's ratio 0.35; estimated modulus 3000 MPa; target strain 50 micronstrains; seating force 20N; dan havershine loading shape [10]. The dynamic creep test was done at temperature of 40°C; havershine loading shape; 100 kPa loading stress; 5 kPa seating stress; 1000ms cycle duration; 1000ms cycle repetition time; 20 kPa preload stress; 600s preload time; cycle count 3600. The samples was cylindrical with diameter of 4 inches (101.6 mm) , height 60-70 mm, loaded trough a top steel plate [11]. The fatigue test was done with 10 N seating force; 100ms cycle width; 500ms cycle repeat time; dan temperature of 20°C. The test was done at three level of stresses. Initially 700 kPa stress was applied, but the sample did not fail until after 40.000 load cycles. Then the stresses were increased at 900, 1100, dan 1300 kPa [12].

3. Results and discussion

The properties of mixture at optimum asphalt content are given in Table 2.

Table 2. The properties of the AC-WC RAP mixture at optimum asphalt content.

Properties of AC – WC RAP mix (Soaked at 60°C in a water bath)		Optimum asphalt content = 6,05%		Specification
		30-40 minutes	24 hours	
Stabilitas	(Kg)	1358.76	1237.08	Min. 800
Flow	(mm)	3.92	3.360	Min.3
Marshall quotient	(kg/mm)	351.82	324.73	Min. 250
VIM	(%)	3.919	3.360	3,0-5,0
VMA	(%)	15.594	15.103	Min. 15
VFB	(%)	74.904	77.759	Min.65
Retained stability	(%)	= (1273.08/1358.76) x100 % = 91.04%		Min 90%

The Cantabro Abrasion Loss (CAL) at 30°C gave 9.02 % which is below the allowed 16% [13]. This indicates that the samples have a good bond. The stiffness of the AC-WC with RAP and 80/100 pen asphalt was 7961,4 MPa was higher than the AC-WC 60/70 pen using natural aggregates with stiffness of 5022 MPa. This is because the samples were stiffer due to the RAP content with aged asphalt and rejuvenated by the 80/100 pen asphalt. Although the mix contain RAP, it appear to be still flexible enough.

The dynamic creep test gave results as shown in Figures 2 and 3. The AC-WC, RAP, 80/100pen, gave lower strain hence higher stiffness, i.e. stress over strain, compared to AC-WC mix using natural aggregate with 60/70 pen asphalt [14].

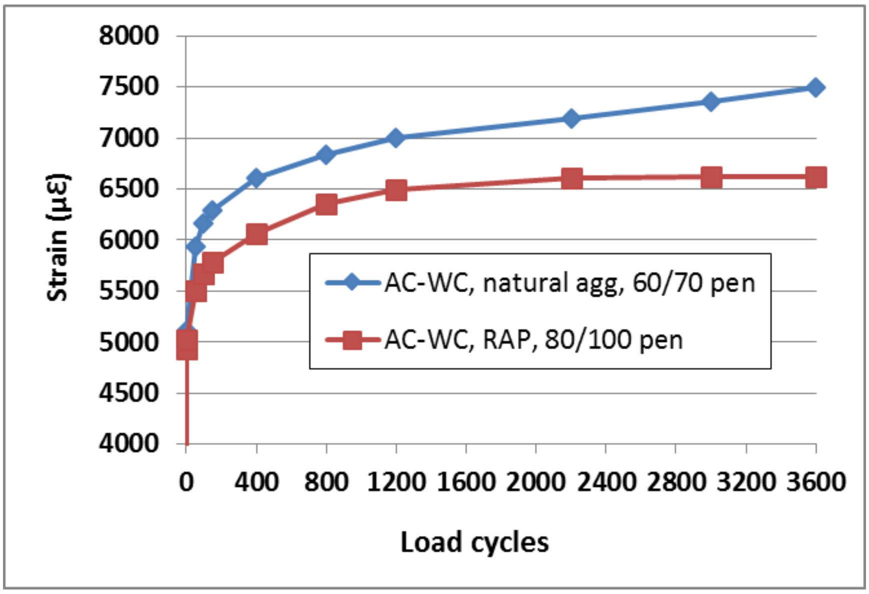

Figure 2. The strain of the sample under dynamic creep test.

The linear part of the strains as shown in Figure 2 are plotted in Figure 4 where linear trend line equation was produced. The x coefficient of the equation of mix AC-WC, RAP, 80/100pen, i.e. 0.0112, was far lower then the AC-WC mix using natural aggregate with 60/70 pen asphalt (i.e. 0.2156). This coefficient indicate the dynamic creep slope of the mixture. In line with data in Table 3, the AC-WC, RAP, 80/100pen can accommodate higher traffic load and suitable for pavement for heavy traffics.

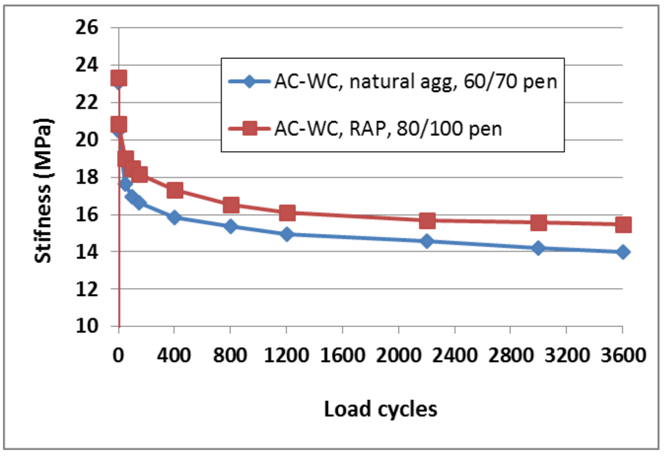

Figure 3. The stiffness of the sample under dynamic creep test.

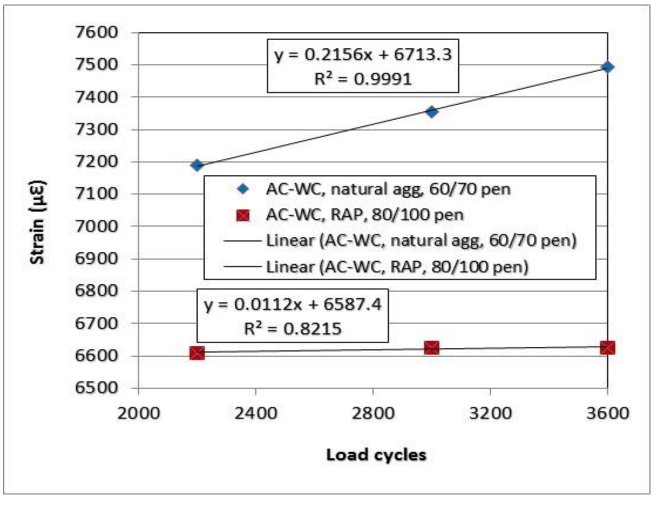

Figure 4. The slope of the mixture from dynamic test.

Table 3. Typical of minimum slope value of dynamic creep test [15].

Annual avg pavement temp (°C)	Heavy traffic load $> 10^6$ ESA	Medium traffic load 5×10^5 to 10^6 ESA	Light traffic load $< 5\times10^5$ ESA
> 30	< 0.5	0.5 - 3	> 3 - 6
20 - 30	< 1	1 - 6	> 6 - 10

10 - 20	< 2	2 - 10	Not Applicable

The fatigue test gave results as shown in Figures 5 and 6. If the lines in Figure 5 extrapolated, at certain stress the AC-WC, RAP, 80/100pen mix fails at far higher load cycles compared to the AC-WC mix using natural aggregate with 60/70 pen asphalt [15], which indicates that the mix is a lot stronger.

Based on results in Figure 6 using the related equation, at 100 micro strain commonly used for pavement design the load cycle required is shown in Table 4. Table 4 also shows, the strain can be accommodated by the mixtures at 10^6 load cycles, where the trend line equation was obtain by swapping the x and y axis in Figure 6, to produced graph as shown in Figure 7. It is shown that mixture of AC-WC, RAP, 80/110pen can withstand 92.28 microstrains which is higher than 70.31 microstrains of mixture AC-WC, natural agg, with 60/70 pen asphalt.

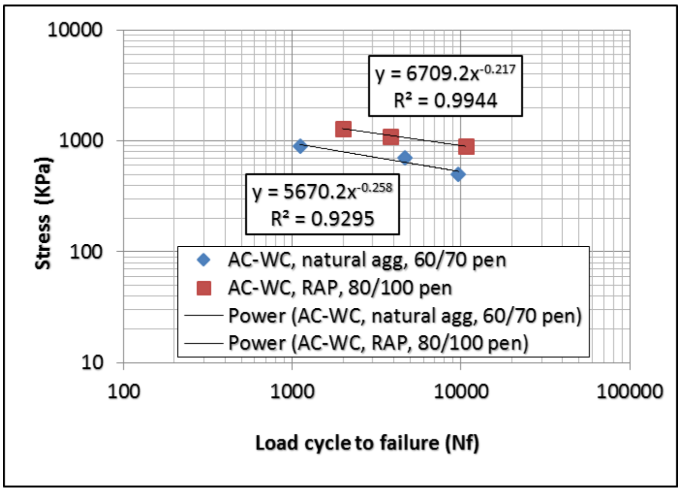

Figure 5. Load cycle vs. stress of fatigue test.

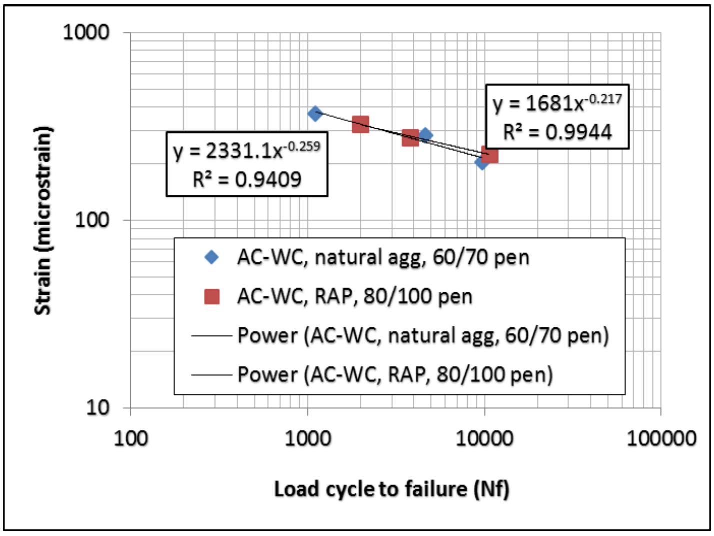

Figure 6. Load cycle vs. strain of fatigue test.

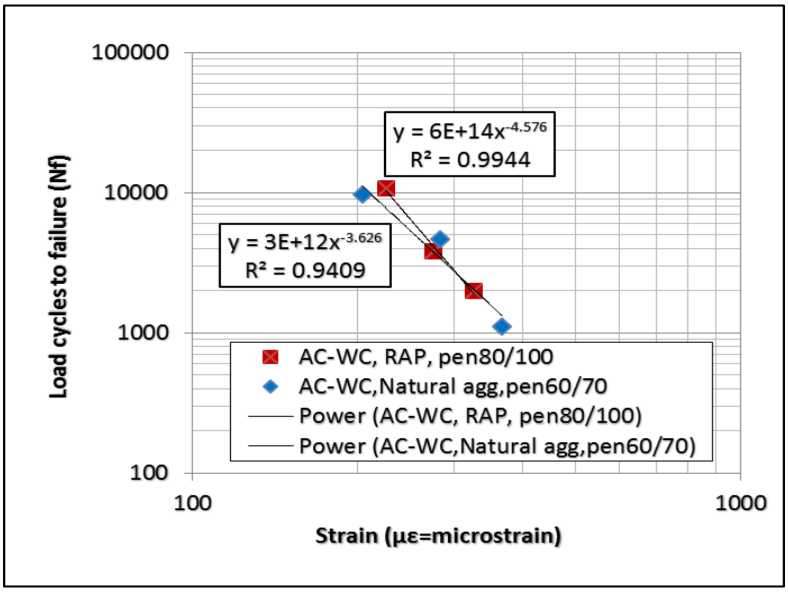

Figure 7. Strain vs. load cycle of fatigue test.

Table 4. Load cycles 100 $\mu\varepsilon$ and strain of the mixture at 10^6 load cycles.

Mixture	Equation based on strain (Figure 6)	Equation based on load cycles (Figure 7)	Load cycles at 100 $\mu\varepsilon$	Strain ($\mu\varepsilon$), at 10^6 load cycles
AC-WC, RAP, pen80/100	$\varepsilon(\mu\varepsilon) = 1681 \times Nf^{-0.217}$	$Nf = 6.0 \times 10^{14} \varepsilon^{-4.576}$	434,661.58	92.38
AC-WC, natural agg, pen 60/70	$\varepsilon(\mu\varepsilon) = 2331 \times Nf^{-0.259}$	$Nf = 3.0 \times 10^{12} \varepsilon^{-3.626}$	172,631.98	73.71

4. Conclusion

Considering the results and analysis, it can be concluded as follow:

1. The AC-WC, RAP, 80/100pen properties can meet Marshall Specification, and gave Cantabro abbrassion loss of 9.01 %, far lower than maks 16% at 30°C.
2. Compared to AC-WC, Natural agg, with 60/70pen asphalt mixture, the AC-WC, RAP, 80/100pen mixture gave:
   - higher stiffness (ITSM), i.e 7961,4 MPa compared to 5022 MPa
   - lower deformation and lower creep slope value under dynamic creep loading. The slope was 0.0112 compared to 0.2156. This indicate that the mixture can withstand higher load repetition.
   - the studied mixture can accomodate higher load cycles and can withstand higher strain of fatigue test. At 100 microstrain (με) the repeated load required was 434,661.58 times, and at one million (10^6) repeated loading, the samples could withstand strain of 92,38 microstrain.

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