Characterization of Reclaimed Asphalt Pavement (RAP) as a road pavement material (National Road Waru, Sidoarjo)

Ari Widayanti^{1,*}, Ria A. A. Soemitro¹, Januarti Jaya Ekaputri¹, and Hitapria Suprayitno¹

¹Institut Teknologi Sepuluh Nopember, Depart. Civil Engineering, Surabaya, Indonesia

Abstract. Reclaimed Asphalt Pavement (RAP) is a dredging pavement material using Cold Milling Machine. The application of Reclaimed Asphalt Pavement is increased year by year. Due to the increasing application of RAP year by year which implicates environment condition, especially in damaging natural resources, the research on material used in RAP needs to be conducted, so RAP can be optimally utilized. To achieve optimal performance, data of RAP characteristics reviewed from microstructural analysis is necessary. The objective of this research is to obtain the characteristics of Reclaimed Asphalt Pavement. The method used was literary study based on previous research. Material tests used were XRF, SEM and FTIR. The object of study was RAP material taken from national road Waru Sidoarjo. The major compositions of Reclaimed Asphalt Pavement obtained were Kaolin, Lithium, Tetraborate, Dextrin. SEM graphics showed the morphological and surface texture of RAP. FTIR graphic presented the functional group of Reclaimed Asphalt Pavement showing O-H C-O acid in the peak of graphic. From XRD result, the major compounds of Reclaimed Asphalt Pavement obtained were Calcium, Sodium, Aluminum, Silicate.

1 Introduction

Road is one of the supporting infrastructure to support community activities. Reclaimed Asphalt Pavement is a dredging road pavement material using Cold Milling Machine. The accumulation of Reclaimed Asphalt Pavement materials is averages 50000 ton/annual, in order to optimize RAP utilization efforts [1].

Thought to process and utilize Reclaimed Asphalt Pavement in other countries has been widely studied. Many countries such as America, India, Taiwan and Japan used 10-40% of RAP as road pavement. Even in Singapore has managed to utilize RAP of 100% for pavement layer material. Based on research [2] in the FHA/Federal Highway Administration and NCHRP/National Highway Cooperative Research Program (provide input to AASHTO to update existing standards for use of Reclaimed Asphalt Pavement). Use of RAP is limited to the base and usage. RAP in road pavement that requires new material should also. Reclaimed Asphalt Pavement percentage is used 25-30% in 2010,

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* Corresponding author: ariwidayanti1973@gmail.com

even close to 50%. RAP usage application can be up to 30% for surface layer on Asphalt Concrete, 100% RAP in hot mix, warm and cold mix on low traffic road, parking area, bicycle and pedestrian area. Use of 30% RAP on base and sub base on primary road, and use 100% RAP on the shoulder of the road [3]. Use of RAP must be cost effective, environmental friendly and produce optimum performance of pavement layers.

Some research results that have been done include testing the nature of RAP by mixing RAP with lime added materials. From this mixing result, obtained asphalt pavement extracted asphalt pavement equal to 4.16%. The addition of lime is 4.5%. From the test results obtained increase in mixed properties can be improved by gradation engineering and lime addition [4].

The other research used RAP with 20%, the addition of filler fly ash by 4%, 5%, 6%. From the results of this research, the use of RAP 20% with the most optimal mixed performance result is 5% filler can produce flow, stability Marshall in accordance with standard [5]. The use of 25% reclaimed asphalt pavement can meet the requirements of grain AC-WC gradation resulting in 6% Optimum Bitumen Content with 60-70% and 5.9% asphalt Pen with asphalt TRS 55 type modification [6]. The composition of 20% RAP from Pilang - Probolinggo road, 6.5% coarse aggregate, 25% medium aggregate, 45% fine aggregate and 1% cement in hot asphalt mixture with modified asphalt can meet the requirements of asphalt concrete layer with Optimum Bitumen Content 5.6% with synthetic Elastomeric asphalt and 6.2% with asphalt processed [7].

Initial mixing with 40% RAP and 60% new material is had consideration of aging effect of pavement layer. Optimum composition is obtained 30% RAP Gemekan – Jombang road and 70% new material with Optimum Bitumen Content of 5.70%. While 20% RAP and 80% new material with Optimum Bitumen Content 5.9% [8]. Composition 25% RAP Pandaan - Malang road and 75% new material with abrasion value of 19.73% meet the requirements of specification with Optimum Bitumen Content of 6.35% [9].

Replacement of 100% RAP granular material yields the highest score on Indirect Tensile Strength and Modulus Resilient in both dry and wet conditions. The comparable condition is to use Pen asphalt 60/70 and 80/100, and the better one is to use asphalt Pen 80/100 [10]. Comparison of Reclaimed Asphalt Pavement between 0%, 10%, 20%, 30%, 40%, 100% and natural materials for hot mix asphalt using 60/70. The result is that the percentage of Reclaimed Asphalt Pavement of 30% yields high stability value, and on the other hand increases the possibility of brittle effect on highway pavement mix [11].

Addition of Reclaimed Asphalt Pavement by 20% improves all properties of the asphalt mixture. The addition of Reclaimed Asphalt Pavement produces better performance than using only natural aggregates [12]. Use of 30-48% Reclaimed Asphalt Pavement exhibits better properties (volumetric properties, mechanical and performance properties) than using natural materials [13].

Research in the laboratory used the percentage of RAP by 10%, 20%, 30%, 40% RAP. There is no consistency of change in addition to physical properties (penetration, ductility, softening point) on the mixture. RAP usage ranges within 10-40% can be adopted for use on new roads using RAP [14]. Increasing the percentage of RAP on a mixture is containing tire waste, indicating a higher stability value. The addition of RAP with tire wastes results in a good workability score. The addition of tire waste can increase the resistance to be able to withstand deformation due to traffic load [15].

Addition of RAP by 25% with tire waste variation can add resilient modulus value to temperature variation. This addition is also recommended for areas with high temperature tropical climate. Addition of RAP and tire waste influence the technical life of road and its resistance to fatigue [16].

Chemical composition was obtained by XRF test. The minerals and morphology of material are obtained by XRD and SEM test. The results of the XRF test obtained Calcium

Oxide and Iron Oxide are the two major chemical formers of EAF and BOF slag. The results of XRD show both BOF and EAF slag samples are very complex, with many peak points, of many types of minerals in the sample. XRD analysis showed the presence of MgO and CaO in BOF and EAF sample slag. The SEM micro graph shows the majority of the sand sizes of steel slags are sub angular to the angular. It shows very rough surface texture with different crystal structures. The characteristics of steel slag samples are considered in more detail for review of steel slag properties [17].

Many countries have used RAP, especially to improve the performance of road pavement quality. Compared to the use of natural materials, using RAP has more benefits, such as to save natural materials in which it affects to the sustainability of the environment. These studies review the application of RAP in some countries with a percentage of use from 0% to 100% depending on the source of the RAP and part of the road pavement layer. However, testing of RAP characteristic has not been done in detail. Therefore, it is necessary to test of the RAP material microstructural to support better material properties results, in this case the focus of the review on the performance of composite materials and the attachment between combining material with each other.

2 Discussion

2.1 Method

RAP material can be obtained from milling in Waru National Road - Sidoarjo. Dredging process of road pavement used Cold Milling Machine. The RAP sample was broken and ground to fine powder. The figure of RAP material is given in Figure 1.

Figure 1 Reclaimed asphalt pavement material

Materials test consist of XRF (X-Ray Fluorescence), XRD (X-Ray Diffraction), SEM (Scanning Electron Microscopy) and FTIR (Fourier Transform Infra Red). XRD, FTIR and SEM test did in Material and Metallurgy Laboratory, Institut Teknologi Sepuluh Nopember Surabaya. XRF test did in Energy and Environmental Laboratory, Institut Teknologi Sepuluh Nopember Surabaya.

2.2 Analysis

2.2.1 XRF analysis

RAP material can be obtained from road national Waru, Sidoarjo Indonesia. Material test used XRF (X-Ray Fluorescence). The chemical composition of Reclaimed Asphalt Pavement can be presented in Table 1.

Table 1. Element Compound of Reclaimed Asphalt Pavement

Element Compound	Test result (% by weight)
SiO ₂	38
Fe ₂ O ₃	26.8
CaO	16.3
Al ₂ O ₃	11
SO ₃	2.9
TiO ₂	1.8
K ₂ O	1.73
MnO	0.585
SrO	0.37
CuO	0.13
V ₂ O ₅	0.11
BaO	0.2
Re ₂ O ₇	0.06
ZrO ₂	0.055
ZnO	0.045

Based on XRF test in Table 1 can be obtained major element compound of RAP consist of SiO₂, Fe₂O₃, CaO by weight percentage. Material with high SiO₂ content will produce hard material, commonly found in nature as sand or quartz. For road pavement, this material is water-absorbing or hygroscopic. Relating to its capacity as a refractory material, it can be used as high temperatures protection. SiO₂ has more different crystalline forms (polymorphs) than amorphous forms.

Table 2. Oxide compound of reclaimed asphalt pavement

Oxide Compound	Test result (% by weight)
Fe	36.6
Si	26.7
Ca	19.8
Al	8.3
K	2.36
Ti	1.92
S	1.9
Mn	0.868
Sr	0.65
Ba	0.4
Cu	0.22
V	0.11
Zn	0.096
Zr	0.083
Re	0.06

Based on XRF test in Table 2 can be obtained major oxide compound of RAP consist of Si, Fe and Ca by weight percentage. Silica is hard mineral, chemical inert (no reaction to

any chemicals), and has low melting point. Its condition shows the strong bond among thatoms.

Figure 2. SEM micrograph of reclaimed asphalt pavement (1000x, 5000x, 10000x)

2.2.2 SEM analysis

The SEM image for the RAP sample is presented in Figure 2. It shows morphology and surface texture of RAP material.

The SEM micrographs shows that the majority of Reclaimed Asphalt Pavement materials were sub-angular and angular, very rough surface textures and good to be used in road pavement as it improved the interlocking aggregate in road pavement material as well as the asphalt concrete mixtures quality.

2.2.3 FTIR analysis

An FTIR analysis was performed on Spectrum RAP. FTIR spectrometer in the range of 4000 – 400 cm⁻¹ at room temperature. The result of FTIR analysis can be presented in Table 3.

Table 3. FTIR Test Result of RAP

Index	Match	Compound Name
18452	35.30	Kaolin
18201	34.95	Lithium tetraborate
1151	34.55	Dextrin
18371	33.76	Potassium heptafluoroborate
18206	33.71	Ammonium tetrafluoroborate
49	33.63	TRANS-PIPERYLENE
18162	33.31	Metaphosphoric acid
1579	33.17	Glyoxal trimeric dihydrate
18280	32.28	Ammonium-d4 dideuteriumphosphate
18292	32.13	Sodium bismuthate

Figure 3 FTIR spectra of reclaimed asphalt pavement sample

Figure 3 shows that FTIR spectrum of the RAP sample. The strong peak at ~1000 cm⁻¹ was related to Al-O and Si-O asymmetric stretching vibrations. The bands seen bond molecule of RAP. It shows O-H C-O acid.

Table 4 Wavenumber of FTIR result

Wavenumber (cm ⁻¹)	Functional Group	Peak Description
3384.43	O-H (alcohol)	Strong and broad
2920.11	C-H (sp ³ carbon)	Strong, broad and multi banded
2850.74	C-H (sp ³ carbon)	Strong, broad and multi banded
1628.83	C=C (alkene, aromatic ring)	
1452.15		
991.75		
751.45	Phenyl group	Strong
672.30	Phenyl group	Strong
532.19		

2.2.4 XRD analysis

XRD analysis was presented in Figure 4 and Table 4.

Figure 4. XRD of reclaimed asphalt pavement sample

Table 5. Result of XRD test

Ref. Code	Score	Compound Name	Displacement (°2Th)	Scale Factor	Chemical Formula
01-083-1370	45	Calcium Sodium Aluminum Silicate	0.213	0.484	Ca 0.65 Na 0.35 (Al 1.65 Si 2.35 O 8)
01-089-2835	21	Urea	0.203	0.124	C O (NH ₂) ₂
01-083-1392	20	Magnesium Iron Calcium Sodium Silicate	0.180	0.404	(Mg 0.964 Fe 0.036) (Ca 0.94 Na 0.06) (Si ₂ O ₆)

3 Conclusions

In conclusions, the results of this research were:

1. Major compositions of Reclaimed Asphalt Pavement in object taken were Kaolin, Lithium Tetraborate and Dextrin
2. SEM graphic presented morphology and surface texture of Reclaimed Asphalt Pavement. The SEM micrographs showed majority of Reclaimed Asphalt Pavement material were sub-angular and angular and very rough surface texture which were good to be road pavement structure because it improved the interlocking aggregate in road pavement material
3. Reclaimed Asphalt Pavement molecule banding at peak graphic showed O-H (alcohol) and C-H (carbon).
4. XRD result showed that the major components of RAP were Calcium, Sodium, Aluminum, Silicate.

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