Bio-asphalt on Asphalt Mixture containing RAP

A V R Sihombing1*, B S Subagio2, E S Hariyadi1 and A Yamin3
1Doctoral Student, Civil Engineering Department, Faculty of Civil and Environmental Engineering Bandung Institute of Technology, Indonesia
2Lecturer, Civil Engineering Department, Faculty of Civil and Environmental Engineering Bandung Institute of Technology, Indonesia
3Research and Development Centre for Road and Bridge, Ministry of Public Works and Public Housing, Indonesia

Email: atmyvera@gmail.com

Abstract. This study investigates the use of bio-asphalt, derived from coconut shell (BioCS) and straw (BioST) as an additive to determine its benefits in asphalt mixtures containing reclaimed asphalt pavement (RAP). The study was conducted by determining and comparing the laboratory performance properties of four mixtures and the binders extracted from the mixes. The four mixtures evaluated in this study included 30% RAP mixtures with and without bio-asphalt (BioCS and BioST) and comparable virgin mix. The result showed that bio-asphalt was effective in improving mixture performance of 30% RAP mix close to those of the virgin mix.

1. Introduction
The need for road infrastructure in Indonesia has so far increased along with the increasing human need for mobilization. In general, the road construction used is flexible pavement or asphalt pavement technology, it is known that asphalt requirements for road infrastructure from 2011 to 2014, respectively are 1.25 million tons, 1.315 million tons, 1.55 million tons, and 1.46 million tons [1]. Fulfilment of domestic asphalt needs is only 50% of which the remainder is met through imports which of course has an impact on the high price of bitumen. One alternative to overcome the constraints of asphalt shortages is the use of Reclaimed Asphalt Pavement (RAP), especially for paved pavement maintenance work using the cut and fill method which is a green technology method and is sustainable because it utilizes waste from road pavement. The use of this RAP can reduce the use of new asphalt so that it can streamline the use of products from petroleum fractions. In addition, it can save on the use of new aggregates, whose existence is diminishing over time.

In line with the environmentally friendly and sustainable technology, the use of bio-asphalt as a rejuvenating material can be juxtaposed with the use of RAP, because bio-asphalt is a plant-derived asphalt which is a fraction of bio-oil derived from biomass obtained from the pyrolysis process (rapid heating of waste materials oxygen-free farms, as well as carbonization processes) waste farms such as leaves, twigs and grass [2], agricultural or plantation waste containing lignin [3] or industry and livestock. Some materials that have been used to produce bio-asphalt are straw [4], pine wood [5], cooking oil, sawdust and coconut shell [6]. Aside from being an anti-oxidant on asphalt, bio-asphalt can also be used as a rejuvenator, modifier and partial replacement or as a substitute for asphalt (full replacement) [7].
Based on data from Directorate General of Agriculture in 2017 the amount of coconut shell waste reaches 2324.7 million tons/year, if 10% of coconut shell waste is used to obtain bio-asphalt, the bio-asphalt production potential annually reaches 1 million tons/year. This potential certainly needs to be utilized as one of the alternatives to meet domestic asphalt needs, so that it is necessary to conduct research on bio-asphalt, especially coconut shell bio-asphalt as a rejuvenating material. Sihombing et al. (2018) has conducted research on the potential of coconut shell bio-asphalt (BioCS) and straw bio-asphalt (BioST) as fluxing material based on rheology test, chemical structure test, and asphalt morphology test, this study concluded that bio-asphalt has the potential as a rejuvenating agent for aged asphalt (RAP bitumen).

In this study, testing was carried out to determine the effect of bio-asphalt as a rejuvenating material on the performance of hot asphalt mixtures containing asphalt recycled material (RAP).

2. Material and methods
The material that used in this study are: The asphalt mixtures were produced with specification of AC-WC asphalt mixture continuous grade; the virgin binder with 60/70 penetration grade obtained from PT. Pertamina; Aggregates were procured from PT KADI quarry; bio-asphalt as a modifier/rejuvenator, that are bio-asphalt from coconut shell (BioCS) and bio-asphalt from Straw (BioST); and Aged asphalt is a binder from extraction RAP which separates bitumen and rock with the help of trichloroethylene (TCE) using a centrifugal extractor, RAP was taken from Karawang, West Java.

The method used in this study is the effect of adding bio-asphalt on the performance of hot asphalt mixture tested by Volumetric and Marshall testing (Stability and Flow) which refers to the General Specifications of Bina Marga Roads and Bridges 2010 Revision 3 [9].

2.1. Determine optimum content of bio-asphalt and rejuvenation process
The objective of this study is to rejuvenate RAP binders using bio-asphalt to obtain a binder similar to virgin binder. The rejuvenation process can be seen by comparing the changes that occur in the RAP binder before and after adding various percentage of bio-asphalt. Bio-asphalt as rejuvenating agent is supposed to enhance and cure the RAP binder in terms of physical and chemical properties. The optimum content of bio-asphalt was determined when the content of bio-asphalt can achieve RAP binder that have the same specification as virgin binder.

Samples were prepared by mixing bio-asphalt and RAP binder using magnetic stirrer with speed rotation 0.4 kr/sec ~ 0.6 kr/sec and mixing temperature of 120 °C for 15 – 20 minutes [3]. While the variation of bio-asphalt percentage to the weight of aged asphalt is 2%, 4%, 8%, 16%, 20%, 25%, 30%. Optimum composition of BioCS and BioST are 23% and 17%, with that composition mix binder has the same penetration and softening point as virgin binder (pen 60/70 (PG 64)).

2.2. Mixture sample preparation
Mixing temperature and compaction temperature can be obtained from the relationship of asphalt viscosity to temperature, mixing temperature and compaction temperature used as temperature controls are 153 °C and 143 °C, respectively. For asphalt mixtures, taking into account the results of the calculation of binder content (Pb), which is equal to 5.8%, the test is carried out on variations in binder levels of 5%, 5.5%, 6%, 6.5% and 7%. In the AC-WC control mixture was made with fresh aggregates and virgin binder which was heated at 153 °C according to the mixing temperature of the plan. Binder is mixed and stirred with aggregate at mixing temperature (148 °C) with an average stirring time is 30 to 60 seconds. After the mixture temperature reaches 143 °C compaction is carried out.

Whereas the asphalt mixture containing RAP is made using fresh aggregates, virgin binder, RAP, and bio-asphalt as rejuvenating material. RAP is preheated to a temperature of 150 °C (RAP heating temperature based on the test results). Then the RAP is combined with the fresh aggregate (preheated ±181°C), binder (preheated 153 °C), and bio-asphalt are mixed at mixing temperature (148 °C) with an average stirring time is 30 to 60 seconds. After the mixture temperature reaches 138 °C compaction
is carried out. Compaction method is carried out by Marshall Compactor. The number of collisions used is 75 each side (SNI-06-2489-1991).

Based on the results of the RAP test, it was found that the binder content contained in the RAP was 5, 15%. While the RAP aggregate filter analysis is as done in table 1.

### Table 1. Sieve Analysis of RAP aggregates

| Sieve Number | Retained (%) | Passing (%) | Spec Limits (%) |
|--------------|--------------|-------------|-----------------|
| ¾"           | 0.0          | 100.00      | 100             |
| ½"           | 8.1          | 91.88       | 90-100          |
| 3/8"         | 11.0         | 80.86       | 77-90           |
| No.4         | 17.9         | 62.98       | 53-69           |
| No.8         | 19.5         | 43.48       | 33-53           |
| No.16        | 12.2         | 31.29       | 21-40           |
| No.30        | 8.0          | 23.24       | 14-30           |
| No.50        | 6.7          | 16.58       | 9-22            |
| No.100       | 10.0         | 6.57        | 6-15            |
| No.200       | 3.1          | 3.50        | 4-9             |
| Pan          | 3.5          |             |                 |

The design of AC WC hot mixed grade with and without RAP is showed in figure 1 and figure 2.
3. Result and discussion

3.1. Binder Test Results

The results of RAP binder rejuvenation using the optimum content of BioCS and BioST are shown in table 2. Based on the results of these tests it can be seen that, bio-asphalt can increase the penetration value and reduce the softening point value according to the specifications of pen 60/70 binder. In figure 3, the penetration values of RAP asphalt are shown using variations in the amount of BioCS and BioST, from that variation, the optimum rejuvenator content results in a mix binder with penetration and softening point similar to virgin binder. As seen on the figure 3, the penetration values track an increasing polynomial trend-line as rejuvenator content increases. It is possible to gain a desired penetration by adding adequate content of BioCS and/or BioST to RAP binder. The results for BioCS and BioST were similar to each other in terms of penetration. BioST represented slightly higher values than BioCS in terms of penetration.

Table 2. Properties of binder

| Test                              | Unit       | Result                  | 60/70 (%) | RAP bitumen | BioCS (23%) | BioST (17%) | Specification |
|-----------------------------------|------------|-------------------------|-----------|-------------|-------------|-------------|---------------|
| Penetration, 25 °C, 100 gr, 5 sec | 0.1 mm     | Pen 60/70               | 65        | 10          | 65          | 65          | 60 - 70       |
| Kinematic Viscosity 135 °C        | cSt        | Pen 60/70               | 409,6     | -           | 463,5       | 421,1       | > 300         |
| Softening Point ³C               | C          | Pen 60/70               | 51        | 80          | 54          | 53,8        | > 48          |
| Ductility, 25 °C, 5 cm/minute     | cm         | Pen 60/70               | > 100     | 38          | > 100       | > 100       | > 100         |
| Flash point with Cleveland Open Cup | °C       | Pen 60/70               | 340       | 240         | 325         | 335         | > 232         |
| Solubility in Trichloroethylene   | %          | Pen 60/70               | 99,868    | -           | 99,735      | 99,805      | > 99          |
| Specific gravity                  |            | Pen 60/70               | 1,024     | 1,061       | 1,015       | 1,022       | > 1           |
| Mass Loss                         | % weight   | Pen 60/70               | 0,15      | 0,75        | 0,51        | 0,35        | < 1           |
| Penetration RTFO                  | % initial  | Pen 60/70               | 58,80     | -           | 54          | 58          | > 54          |
| Ductility RTFO                    | cm         | Pen 60/70               | 110       | -           | 115         | 105         | > 100         |
3.2. Mixture test results

The results of testing the ACWC hot mix showed a difference between ACWC asphalt mixtures containing 30% RAP with and without bio-asphalt (figure 4). Without using bio-asphalt, mixtures containing 30% RAP do not obtain OBC (optimum binder content) whereas if using bio-asphalt as a rejuvenator either BioCS or BioST, both produce OBC values. The original mixture produced OBC 6.1%, 30% RAP with BioCS 5.75% and 30% RAP with BioST 5.8%. This condition shows that adding bio-asphalt can triggered the RAP to contribute its binder to the mixture which indicates the process of rejuvenation on aging binder.

| Criteria         | Specification | Bitumen Content, % |
|------------------|---------------|--------------------|
| Stability (Kg)   | 800           |                    |
| Flow (mm)        | 2 – 4         |                    |
| VIM (%)          | 3 – 5         |                    |
| VFA (%)          | Min 65        |                    |
| VMA (%)          | Min 14        |                    |
| Pass 200/Pbe     | 1 – 1.4       |                    |
| VIMRef (%)       | Min 2         |                    |

Figure 4. Volumetric analysis and mechanical test Result of the Marshall specimens.

Table 3. Optimum Binder Content

| No. | Mixed Asphalt          | OBC values (%) |
|-----|------------------------|----------------|
| 1   | AC-WC Asphalt Mix      | 6.10           |
| 2   | AC-WC 30%RAP with BioCS| 5.75           |
| 3   | AC-WC 30%RAP with BioST| 5.80           |
| 4   | AC-WC 30%RAP without Bio-asphalt | -             |
Furthermore the analysis was carried out on the asphalt mixture in OBC conditions. The test results showed that, the addition of bio-asphalt to mixtures containing 30% RAP could improve the performance of the mixture so that it was in accordance with the specifications of the AC-WC asphalt mixture (table 4).

| Property                        | AC-WC mix | AC-WC 30% RAP with BioCS | AC-WC 30% RAP with BioST | Specified Values (BM 2010 Rev 3) |
|---------------------------------|-----------|--------------------------|--------------------------|---------------------------------|
| Corrected Stability, Kg        | 1424.8    | 1615                     | 1415                     | Min 800                         |
| Avg Flow, mm                   | 3.62      | 3.6                      | 3.5                      | 2 – 4                           |
| Air Voids (Va), %              | 3.7       | 4.1                      | 4.0                      | 3 – 5                           |
| Void Filled with Bitumen (VFB), % | 77.5     | 77                       | 75                       | Min 63                          |
| Avg Density, gm/ml             | 2.344     | 2.296                    | 2.359                    | -                               |

4. Conclusion
Asphalt mixes designed by the method in accordance with the guidelines of BM 2010 Rev 3 specification for AC-WC + 30% RAP with and without bio-asphalt as rejuvenator compare with virgin mix. Without the addition of bio-asphalt in the asphalt mixture containing 30% RAP would not produce OBC value, where RAP binder did not contribute as a binding material, it showed that the RAP binder rejuvenation process did not occur. Addition of bio-asphalt can obtain the OBC value in the mixture, so it can be concluded that bio-asphalt was effective in improving mixture performance of 30% RAP mix close to those of the virgin mix.

Acknowledgments and legal responsibility
This project was sponsored by LPDP BUDI-DN Feedstock evaluation and conversion as well as bio-asphalt production were conducted at PT Tropica Nucifera Industry and Hydro green, the material and Marshall Test were completed at Bandung Institute of Technology. Extreme gratitude goes to Mr. Ateng and Mr. Iman for their contributions toward the completion of the laboratory test program.

References
[1] Kementerian PUPR 2015 World Wide Web Address: https://finance.detik.com/industri/d-3014500/ri-punya-cadangan-aspal-660-juta-ton-tapi-tpah-tahun-masih-impor
[2] Daniel R 2011 *Bio asphalt from urban yard waste carbonization* (Ohio: Case Western Reserve University School of Graduate Studies and OhioLINK)
[3] Williams R C, Satrio J, Rover M, Brown R C and Tang S 2009 *Transportation Research Board 88th Annual Meeting*, (Washington DC, United States; TRB) 19p
[4] Walaa M, Abbas B, Siavash V and Alexander A 2013 *J. Road Material and Pavement Design*. 14 193-213
[5] Mohammad L N, Elseifi M, Cooper S B and Challa H 2013 Laboratory evaluation of asphalt mixtures containing bio-binder technologies (*Sustainable and Efficient Pavement on Airfield and Highway Pavement Conference*) chapter 20 pp 128-152.
[6] Setiadji B 2009 *Uji Produksi Batch Bioaspal sebagai alternatif pengganti aspal minyak bumi* (Yogyakarta: Gajah Mada University Electronic Theses and Dissertations)
[7] Peralta J, Raouf M, Tang S, and Williams C 2012b *Bio-renewable AsphaltModifiers and Asphalt Substitutes Sustainable Bioenergy and Bio products: Value Added Engineering Applications*, (London: Springer-Verlag) pp 89-116.
[8] Sihombing A V R, Subagio B S, Hariyadi E S and Yamin A 2019 *IOP Conf. Ser.: Mater. Sci. Eng.*. 508 012041
[9] General Specifications of Bina Marga Roads and Bridges Revision 3, 2010.
