Evaluation of asphalt porous mixture properties due to addition of Arenga pinnata and coconut fibers

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Abstract. Traffic condition, as well as tropical climate condition in Indonesia, demands high care to produce water resistance based surface layer in the flexible pavement industry. Asphalt porous is one of various technologies that could become promising prospects in this regard. However porous asphalt features might result in lower ability of pavement to endure traffic load. Thus, this study tries to find solution to previously mentioned issue by adding natural fibers to porous asphalt mixture by measuring the permeability, binder drain down, and void in mixture. The natural fiber is known to have in own strength to endure tensile force, and among many natural fibers available, we choose two of the most abundant material in Indonesia, which are Arenga Pinnata fibers and Coconut fibers. The result in this study is the addition of Arenga Pinnata fibers, or Coconut fibers results in decrease of both permeability and binder drain down test value for 8% to 35% and 32% to 73% respectively while it increases the void in mixture

1. Introduction
Road infrastructure is critical to support social activities and economic improvement. Damage to the surface layer will have an impact on the construction of pavement structures and the use of materials used [1]. In Indonesia, excessive traffic loads, high air temperature, and high intensity of rain are often that result to flooding in several areas, while it is well-known that flexible pavement is susceptible to water, thus consideration should be given in planning the asphalt mixture. One type developed flexible pavement technology on the surface layer is porous asphalt.

Porous asphalt is closely related to the properties of an asphalt mixture using aggregate gradation with a coarse fraction amount of 70-85% and fine aggregate ranges of 15 - 30% to the total weight of the mixture so that the resulting structure is hollow. The existing cavity provides the ability to flow water properly for both vertical and horizontal directions so that it will keep the surface layer dry.

From several literature studies and research, it was found that natural fibers can be used as modifier for asphalt mixtures either as additive, stabilizer or reinforcement [2]-[6]. In his research, natural fiber in the form Arenga Pinnata fiber and Coconut fiber is used as the material of reinforcement. Reinforcement herein meant as a process in which behavior is reinforced by the consequences that immediately follow such behavior Arenga Pinnata fibers and Coconut fibers both have the comportment to bind each other and made the fibers strengthen.

The purpose of this study is to find out how much influence the use of Arenga Pinnata as well as Coconut fibers on porous asphalt mixtures that utilize natural fibers available as an added ingredient.
2. Materials and Method

2.1. Material Selection

There are four primary materials used in this study which is, Aggregate, Asphalt Binder, Arenga Pinnata fiber and Coconut fiber. Aggregate is obtained from a stone quarry located at Blang Bintang, Aceh Besar District. While Asphalt used in this study is penetration grade asphalt 60/70 (Pen 60/70), which is commonly used asphalt material for road construction in Indonesia, this binder was provided by Syiah Kuala University.

As for Arenga Pinnata fiber and Coconut fiber, we obtain those items from the community's own land field at Darul Imarah Sub-District, Aceh Besar District, and Gampong Tiba Mesjid Beureunun, Pidie District respectively. The physical and chemical properties of all material used in this study are shown in Table 1, Table 2, and Table 3.

| Table 1. Average Chemical Composition of Selected Fibers [7] |
|-----------------|-----------------|-----------------|
| Constituent     | Arenga Pinnata Fiber (%) | Coconut Fiber (%) |
| Alpha Cellulose | -                | 37.36           |
| Hemi Cellulose  | 15.88            | 27.68           |
| Holo Cellulose  | -                | 65.04           |
| Cellulose       | 51.54            | -               |
| Lignin          | 43.09            | 48.21           |
| Water           | 8.9              | 18.2            |
| Ash             | 2.54             | 2.87            |

| Table 2. Properties of Aggregate |
|-------------------------------|-----------------|
| Test                          | Result          |
| Aggregate Specific Gravity (ASTM C 127) | 2.741 gr/cm³ |
| Aggregate Absorbtion (ASTM C 127)      | 1.0708 %        |
| Aggregate Unit Weight (ASTM C 29-71)   | 1.568 (kg/dm³) |
| Resistance to Degradation (AASHTO T 96-74) | 16.908 % |
| Flat Particle in Coarse Aggregate (D 4791) | 21.98 %     |
| Elongated Particle in Coarse Aggregate (D 4791) | 23.86 %     |

| Table 3. Properties of Asphalt Binder |
|-------------------------------|-----------------|
| Test                          | Result          |
| Asphalt Specific Gravity (ASTM D 2041) | 1.020 gr/cm³ |
| Penetration Test (ASTM D 5)     | 64 (0.1 mm)     |
| Asphalt Softening Point (ASTM D 36) | 48°C            |
| Ductility (ASTM D 113)          | 130 cm          |
| Flat Particle in Coarse Aggregate (D 4791) | 21.98 %     |
| Elongated Particle in Coarse Aggregate (D 4791) | 23.86 %     |

In order to maintain the effectiveness of this paper, this section aims to give information about the sample combination and how the sample name structure used in this test. Table 4 shows the combination of samples uses for this study.
Table 4 Samples Combination and Samples Name

| Fibre Type  | Fibre Content | Sample Name |
|-------------|---------------|-------------|
| -           | 0%            | 0%          |
| Arenga Pinnata | 1%        | 1% AF       |
| Arenga Pinnata | 3%        | 3% AF       |
| Arenga Pinnata | 5%        | 5% AF       |
| Coconut     | 1%            | 1% CF       |
| Coconut     | 3%            | 3% CF       |
| Coconut     | 5%            | 5% CF       |

2.2. Experimental Plan

In this study the permeability test, as well as Binder Drain down tests, were performed in order to investigate the effect of adding Arenga Pinnata fiber or Coconut fiber to the porous asphalt mixture aside from that standard Marshall testing also performed, however only the result of Void in Mixture testing was discussed in this paper.

2.2.1. Fibers Preparation

Before adding into the porous asphalt mixture, the Arenga Pinnata fiber and Coconut fiber were retrieved from the field and cleaned in order to free it from any unwanted materials; then, the fibers were dried in the oven until it completely free from moisture. After that, Arenga Pinnata fiber, as well as Coconut fiber, was cut until its only around 1 cm to 1.5 cm length. Then the fibers were added into the mixture with a quantity of 1%, 3%, and 5% of asphalt binder weight.

2.2.2. Permeability Test

This testing procedure aims to investigate the capability of porous asphalt mixture is draining underground water; the proposed steps for this testing are ASTM C1781/C1781M [8][9].

2.2.3. Binder Drain down Test

This test aims to determine the amount of drain-down occurring on un-compacted asphalt mixtures, during the production, transport, and mixing placement with the test probe following the standard of AASHTO T 305 [10].

2.2.4. Marshall Test

This examination is intended to determine the resistance (stability) to the plastic melt (flow plastic) of the asphalt mixture. This test is based on AASTO-245-74. Marshall tests include stability tests, plastic melt (flow), density, VIM, and Marshall quotient. However, in this study, only VIM value was discussed.

3. Result and Discussion

Analysis of Variant (ANOVA) was done in order to identify the significant factors that affect the testing result to be further analyzed. The analysis was performed using Microsoft® Excel® software.

The ANOVA test assumed the null hypothesis (H0) that all the mean of samples is equal. The confidence interval of 95% (α = 0.05) was chosen in this study. In order to reject the null hypothesis, the p-value obtain should be smaller than the level of confidence (α =0.05). In this study, it is mean that the difference in result in regards to discussed variable is significant.

3.1. Permeability Test

The Permeability testing result shows in Figure 1 indicates that the addition of Arenga Pinnata fiber or Coconut fiber results in decrease of permeability value in porous asphalt mixture, moreover the augmentation of fibers concentration in mixture adding to more decrease of Permeability value. This result was expected since the fibers were filling the void in mixture thus result in less air void happen in
asphalt mixture. Even though asphalt porous mixture feature expected higher permeability in order to fasten the water drainage process. In this study, almost combinations with asphalt content 4.5% to 5.5% still give desired permeability value of 0.0575 cm/sec – 0.2493 cm/sec [11]. In the study, AF group show the lowest decrease of Permeability value with the average range of 9.37% to 35.65% compared to control mixture while CF group results from 8.54% to 33.2%.

![Permeability Testing Result](image1)

**Figure 1.** Permeability Testing Result

3.2. Binder Drain down Test

Figure 2 visibly shows that the addition of Arenga Pinneta fiber or Coconut fiber will result in less Binder Drain down value. The Binder Drain down testing results in this study evident that AF group perform the best since it has the lowest result in average 0.053 gr, 0.049 gr, and 0.045 gr for 1%AF, 3%AF, and 5%AF respectively, while the result of CF group is 0.125 gr, 0.067 gr, and 0.05 gr for 1%CF, 3%CF, and 5%CF respectively. Overall, only control mixture at 6% binder content that did not meet the maximum requirement of 0.3 gr. We believe that this result indicates that Arenga Pinnata fiber and Coconut fiber can bind a portion of asphalt binder, thus result in less Binder Drain down testing results compare to control mixture.

![Binder Drain down Testing Result](image2)

**Figure 2.** Binder Drain down Testing Result
3.3. Void in Mixture (VIM)

Figure 3 shows that addition of fibers regardless whether Arenga Pinnata nor Coconut tend to increase the VIM value compare to control mixture, however the increase was varied in each combination of asphalt content and different type of fibers and this study, all sample result is successfully meeting the desired VIM value of 10% - 25%.

![Figure 3. Void in Mixture Testing Result](image)

In AF group, almost all sample shows the decrease VIM value in 1% and 3% addition of Arenga Pinnata Fibre with the average of 10% compare to control mixture outside the mixture with 6% binder content that gives the result of higher VIM in all samples with addition of Arenga Pinnata fiber. This trend might be due to the larger surface area occurs when more fibers were added into the mixture, and it must be covered by asphalt binder, thus result in higher air void in the mixture. These findings were similar to previous research [12] that demonstrates a similar trend when adding oil palm fibers into porous asphalt mixture.

On the other hand, the CF group shows more obvious trends in the escalation of VIM value with an average of 5% to 10% increase compared to a control mixture from 1%CF to 5%CF, respectively. This result strongly suggests that in this study the addition of Coconut fiber in mixture up to 5% can increase VIM value that results in more void in mixture.

Table 5 and Table 6 show that statistically, the addition of Arenga Pinnata fiber or Coconut fiber into asphalt porous mixture result in significant differences of VIM value, which is shown in F value that higher than F-Crit and P-value that lower than 0.05 (95% confidence interval) at both tables.

| Source of Variation | SS   | df | MS | F   | P-value | F crit |
|---------------------|------|----|----|-----|---------|--------|
| Asphalt Content     | 41.76| 3  | 13.92 | 19.04 | 0.000309 | 3.86   |
| AF Group            | 10.03| 3  | 3.34 | 4.57 | 0.032   | 3.86   |
| Error               | 6.57 | 9  | 0.73 |     |         |        |
| Total               | 58.37| 15 |     |     |         |        |

| Source of Variation | SS   | df | MS    | F       | P-value | F crit |
|---------------------|------|----|-------|---------|---------|--------|
| Asphalt Content     | 62.73| 3  | 20.91 | 92.77   | 4.35E-07 | 3.86   |
| AF Group            | 4.51 | 3  | 1.50  | 6.67    | 0.01    | 3.86   |
| Error               | 2.02 | 9  | 0.22  |         |         |        |
| Total               | 69.27| 15 |       |         |         |        |
4. Conclusion and Suggestion

4.1. Conclusion
Permeability, Binder Drain down, and Void in Mixture value are some of the most important measurements in analyzing Asphalt Porous Mixture properties and also closely other. From those three measurements, the following can be concluded;

a) Permeability test result:
- Accept of 6% asphalt content mixture, almost all samples in this study meet the requirement for the Permeability test which is in the range of 0.0575 cm/sec – 0.2493 cm/sec.
- The addition of Arenga Pinnata fibers of 1%, 3%, and 5% to the weight of asphalt binder results in the decrease of permeability value of 9.37%, 24.58%, and 35.65% respectively compared to control mixture.
- Similar to addition of Coconut fibers that also decrease permeability value for 8.54%, 27.11%, and 33.20% due to the addition of 1%, 3%, and 5% Coconut fibers respectively.

b) Binder Drain down result:
- All samples in this study successfully meet the standard for Binder Drain down test result that is a maximum of 0.3 grams with the exception of control mixture at 6% Asphalt content.
- The addition of Arenga Pinnata fibers results in the decrease of Binder Drain down value to 68.27%, 70.88%, and 73.43% in comparison to control mixture for each addition of 1%, 3%, and 5% Arenga Pinnata Fibers respectively.
- The addition of Coconut fibers also results in a similar trend that tends to decrease Binder Drain down testing value to 32.23%, 58.39%, and 69.87%, respectively, to the addition of Coconut fibers of 1%, 3%, and 5%.

c) Void in Mixture (VIM) measurement result:
- In the Arenga Pinnata group, void in mixture measurement shows a decreasing trend when the fibers were added at the rate of 1% to 3%, however VIM value increases when Arenga Pinnata fiber added at 5% of asphalt binder weight.
- In the Coconut fibers group, the trend is entirely consistent that is the VIM value keeps increasing when higher percentage of Coconut fiber was added.

4.2. Recommendation
For future recommendation, it is necessary to conduct time base measurement to investigate the medium or long-term effect of adding natural fibers to Asphalt Porous Mixture.

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