Comparison of cantabro test using *Arenga pinnata* fiber and coconut fiber in porous asphalt

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Abstract. This paper presents the results of a preliminary investigation on using *Arenga pinnata* fiber (APF) and coconut fiber (CCF) in porous asphalt (PA). The samples were prepared with various percentages of fibers (0%, 1%, 3%, and 5%) by weight of bitumen and evaluated. The laboratory tests included air abrasion loss and water abrasion loss. The results indicate that the addition of fibers provides a positive effect on the properties of PA. A certain amount of fibers as an additive appears to improve resistance to raveling and stripping. However, adding too much fiber would result in higher abrasion loss value and increase the air void.

1. Introduction

Porous asphalt (PA) is widely used for noise reduction and water drainage in order to improve traffic safety and comfort for both drivers and the residents living in the vicinity of roads [1]. Porous asphalt was developed in the early 50s in Europe and the United States. It is composed predominantly of narrowly graded crushed coarse aggregate without significant fines, which results in increased surface friction and permeability and noise reduction [2]. This kind of asphalt has also been called drainage asphalt, whispering asphalt, popcorn asphalt, open friction course, and porous friction course.

In general, there are several advantages, and also limitations of PA include the elimination of glare, splash, and spray, improvement in visibility, increased skid resistance of the road surface [3][4]. Nevertheless, PA the limitations of PA, such as air void can quickly be filled with detritus where pressure washing does not clear the voids and the only alternative is to remove the contaminated surface and relay new material, the unit cost of porous asphalt is far higher than conventional dense wearing course and predicted lifetime for porous asphalt is about 8 years against 20 years for conventional method [2][4]

Various kinds of fibers have been utilized as fillers in asphalt mixes to improve performances of certain properties of the mix. There are several types of fibers that could be used in asphalt mixtures, such as polyester fiber, cellulose fiber, glass fiber and mineral fiber [5][6]. This exploratory study aims to use *Arenga pinnata* fiber (APF) and coconut fiber (CCF) in its natural form in bituminous mixes primarily to help increase binder film thickness around aggregates without excessive binder drainage. As fiber may be considered as waste material its successful utilization in pavement mixes helps address the issue of waste management and environmental conservation. In this study, the samples were prepared and tested to evaluate cantabro on air cured samples and cantabro on water cured sample of porous asphalt.
2. Experimental program

2.1. Materials
In this study, aggregates employed were from locally crushed granite aggregates. The aggregates were selected based on the selected gradations which have been obtained from Australian Asphalt Pavement Association (AAPA) as shown in Table 1 to Table 4. The conventional bitumen penetration-grade 80/100 was used. Meanwhile, Arenga Pinnata Fiber (APF) and coconut fiber (CCF) are used as natural fiber (Figure 1). The fiber is washed thoroughly in clean water and dried at room temperature of 80°C for an hour until a constant percentage value of water loss was obtained.

![Figure 1. Arenga pinnata fiber (a) and coconut fiber (b)](image)

Table 1. Gradation of PA based on the Australian Asphalt Pavement Association

| Sieve size (mm) | Specification passing range (%) | Used passing (%) |
|----------------|---------------------------------|------------------|
| 19             | 100                             | 100              |
| 13.2           | 85-100                          | 92.5             |
| 6.7            | 45-70                           | 57.5             |
| 4.75           | 25-45                           | 35               |
| 2.36           | 10-25                           | 17.5             |
| 1.18           | 7-15                            | 11               |
| 0.6            | 6-12                            | 9                |
| 0.3            | 5-10                            | 7.5              |
| 0.15           | 4-8                             | 6                |
| 0.075          | 2-5                             | 3.5              |

Table 2. Physical properties of crushed granite aggregate.

| Properties                             | Test Value (%) |
|----------------------------------------|----------------|
| Flakiness index                        | 21.8           |
| Elongation index                       | 23.2           |
| Impact value                           | 26             |
| Los Angeles abrasion value             | 16.9           |
| Soundness                              | 7              |
| Aggregate crushing value               | 17             |
Table 3. Physical properties of asphalt binder.

| Properties       | Unit | Test Value (%) |
|------------------|------|----------------|
| Penetration at 25°C | 1/10 mm | 64             |
| Ductility at 25°C  | cm   | >120           |
| Softening point   | °C   | 48             |

Table 4. Chemical properties of Fibers

| Properties          | Arenga pinnata fiber (%) | Coconut fiber (%) |
|---------------------|---------------------------|------------------|
| Alpha Cellulose      | -                         | 37.36            |
| Ash                 | 2.54                      | 2.87             |
| Cellulose            | 51.54                     | -                |
| Hemi Cellulose       | 15.88                     | 27.68            |
| Holo Cellulose       | -                         | 65.04            |
| Lignin               | 43.09                     | 48.21            |
| Water               | 8.9                       | 18.2             |

2.2. Specimen preparation
The amount of binder contents (BC) used in the mixes is 4.5%, 5%, 5.5%, and 6% by weight of aggregates. Various percentages of APF and CCF (1%, 2%, and 3%) were used and compared with control sample (no fibers). The fibers were clean for other materials and sieved through a 500 µm sieve. The samples were prepared using Marshall Compactor by applying 50 blows per-face and tested for raveling, and water damage.

2.3. Test Method

2.3.1. Cantabro Test on Air Cured Samples
The Cantabro test is a special test for porous asphalt to evaluate the resistance to particle loss by abrasion and impact. The Cantabro loss is used as an important indicator of bonding properties between aggregate and bitumen [7]. In this study, the samples were tested at temperature of 25°C and the weight of the Marshall sample was recorded before placing it in a Los Angeles drum without the steel balls. The drum goes through 300 rotations with a speed of 30 to 33 rpm and then the weight loss was calculated as illustrated in equation (1).

\[
\text{Weight Loss (\%)} = \left[ \frac{(M_i - M_r)}{M_i} \right] \times 100
\]

Where; \( M_i \) and \( M_r \) are respectively the initial mass of sample and mass of the sample after rotation.

2.3.2. Cantabro Test on Water Cured Samples
The Cantabro test on water cured samples were used to measure the resistance of mixes to stripping and water damage. In this study, the initial weight of the Marshall sample was recorded and then samples were placed in a water bath for four days at 49±1°C. The samples were taken out of the bath on the fifth day and leave for 18 hours. The Cantabro test was then conducted according to the same procedure, as explained earlier.

3. Results and Discussion

3.1. Air Abrasion Loss (Air Cured Samples)
The effects of various percentages of binder on air cured samples are summarized in Figure 2. The maximum permissible abrasion loss should be no more than 18%. The results show that the abrasion loss decreases with increase binder content. It was also observed that the specimens made with APC
content had higher abrasion loss than the specimens containing CCF content. Moreover, sample made by 5%, 5.5% and 6% binder content shows the best resistance to abrasion in porous asphalt. It clearly shows that the increasing amount of binder is sufficient to coat aggregates and fibers.

Figure 3 shows that at any particular fiber content, the air abrasion loss will decrease as the binder content is increased. As such, the use of fiber in porous asphalt requires a bit more binder in order to avoid abrasion loss. This was due to the greater adhesion between the binder and aggregates because of the increased availability of binder to coat both the aggregates and fibers. The fluctuation in abrasion loss across the range of fibers content was found to be more pronounced as the binder content decreased. As the binder content increased, this fluctuation in abrasion loss across the range of fibers contents diminished (Figure 3). As such, there was a critical link between the number of fibers used in porous asphalt and the binder content in order to ensure that the durability of the porous asphalt pavement was not compromised.

![Figure 2. Abrasion loss value for various binder content](image2.png)

![Figure 3. Abrasion loss value for various fiber content](image3.png)

3.2. Water Abrasion Loss (Water Cured Samples)
The standard tests on water cured specimens were conducted according to ASTM C131-96. The Cantabro test on water cured specimens were used to measure the resistance of mixes to stripping and water damage. The maximum permissible water abrasion loss should be no more than 40%. The values of water abrasion losses are given in Figure 4. The results revealed that in general, only
specimens prepared with 5%, 5.5% and 6% binder content satisfy the recommended limit value. The content weight loss for water cured specimens was greater than that of air-cured specimens. This may be due to water influence, the abrasion resistance and also the binder-aggregate bonding in the porous asphalt. This also indicated that water is a serious factor in affecting the stripping.

The effects of the different fiber's contents on water cured specimens are summarized in Figure 5. The available results displayed the same trend as the revolution results of air abrasion loss with different fiber content. However, the abrasion loss value on water cured specimens was higher than the air-cured specimens. The general trend from Figure 5 shows that the addition of fiber decreased loss abrasion values when compared to specimens with no fiber (0%-APF & 0%-CCF), but the mix with more fiber content gave the abrasion loss of specimen’s increases back. The sample made CCF content has better resistance to water abrasion loss than APF content. The percentage weight loss for water cured samples is greater than that of air-cured samples. This indicated that water did influence the abrasion resistance and also the binder-aggregate bonding in the porous asphalt.
4. Conclusion
From the exploratory laboratory investigations, the use of fibers affects the properties of the porous asphalt mix. For any particular binder content, the abrasion loss of the porous mix improves as the amount of fibers is increased. As the amount of fibers to be used increases, more binder is needed to avoid excessive abrasion loss. However, as the amount of binder to be used increases, the binder began to clog the air voids. As such, there is a need to strike a balance between the two opposing requirements if fibers (APF & CCF) are to be used as an additive in porous asphalt. Nevertheless, this initial study would hopefully open the door to more in-depth study on this matter.

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