IVESTIGATION THE EFFECT OF COCONUT FIBER'S LENGTHS ON STABILITY OF STONE MASTIC ASPHALT

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ABSTRACT

Stone mastic asphalt which is defined as a gap-graded hot mix asphalt consists more air void content and requires higher concentration of binder. This gap-graded hot mix asphalt can be designed using modified asphalt and/or unmodified asphalt with additive fibers. Coconut fibers consisting the certain amount of cellulose have been mostly used to reinforce pavements property. In stone mastic asphalt, coconut fibers have been reported with the significant improvement in terms of strength to the mixtures. In this study, coconut fiber of 5 – 20mm and 20 – 40mm are selected in order to compare their performance in stone mastic asphalt mixtures based on Marshall stability results. AC60/70 with the concentration of 6 – 7% (0.5% increment) is designated to be the binder of the mixtures. To meet the objective of the study, draindown and Marshall stability tests have been applied. The results indicate that mixtures containing 5 – 20mm coconut fiber perform better (increase approximately 5% of strength and provides more workability during mixing and compacting time) than those containing 20 – 40mm coconut fiber. The findings of this study would be beneficial to tropical regions because (1) as coconut fiber is mostly available in tropical regions, it is therefore the local authority can reach it easily so that they will have more alternative materials, (2) be able to provide more jobs to farmers as the needs of coconut fiber increase, (3) and environmental friendly as it is able to reduce the waste of coconut fruits.

Keyword: - *Coconut fiber, draindown, Marshall stability, stone mastic asphalt*

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1. INTRODUCTION

Stone mastic asphalt (SMA) is originally developed in Germany during the mid – 1960s. In recognition of its excellent performance a national standard was set in 1984. Since then it has spread throughout Europe (it has been applied successfully in Europe for more than 40 years). Nowadays, SMA has been widely used as a surface course for heavily trafficked roads, airfields and other pavements in many countries such as USA, Australia, Canada, Japan, and other countries around the world [1]. These countries report a good experience with SMA based on its surface characteristics, riding comfort and durability. Moreover, the performance of SMA on heavy duty pavements is excellent.

As SMA requires stone to stone contact, it is therefore needed 70 – 80% of coarse aggregate (retained on 4.75 mm sieve), 12 – 17% of fine aggregate (passing 4.75 mm sieve), 8 – 13% of filler (passing 0.075 mm sieve over 90% of the total weight), 6 – 7% of binder, and about 0.3% of stabilizing agents. The stabilizing agents can be polymer and/or fiber [2-4].

Normally, SMA can be designed using modified asphalt and/or unmodified asphalt with additive fiber. When SMA designs with unmodified asphalt, fibers such as natural or synthetics fiber are needed to prevent draindown of the mixtures [5]. The cellulose fiber is often added to prevent draindown in the mixture due to its high asphalt content, which can result in fat spots (isolated areas in the mat where excess asphalt binder is visible on the surface) on the pavement surface [6]. Coconut plantations are extensively found in tropical regions and many other countries. In Thailand and Cambodia, the ripe coconut fiber is not fully utilized for different purposes and hence goes as waste. By seeing the certain advantages of coconut fiber, an attempt has been made in this study to utilize this naturally and abundantly available material in preparation of SMA mixtures.

Advantage of SMA compares to Hot Mix Asphalt (HMA):

The primary advantage of SMA compares to conventional hot mix asphalt (dense graded asphalt) is the extended life with the improvement of pavement performance [7]. It is because of SMA:

- Resistant to permanent deformations: helps to reduce permanent deformations of about 30 – 40% because SMA consists of higher asphalt content (6 –7%) and coarse aggregates (70 – 80%)
- Durability: has slower ageing which can prolong its service life up to 20%
- Resistant to fatigue: increases 3 – 5 times of fatigue life
- Better in skid resistant: is good at wearing resistant and surface texture
- Economical for the long term

Disadvantages of SMA compares to Hot Mix Asphalt (HMA):

- Cost: SMA costs more than HMA as it consists of higher asphalt and filler content and stabilizing agents
- Opening to service: SMA possibly delays the opening traffic after its lay down because it needs to cold down to 40 ^{o}C (causing by higher asphalt content) in order to prevent the flushing (bleeding)
- Time consuming: SMA requires more mixing time because of additional stabilizing agents

1.1 Objective of the Study

Previous studies mostly use 20 – 40mm of coconut fibers to investigate the performance of SMA. In spite of the extensive studies, study on the effect of coconut fiber lengths has not been found yet especially on the pavement purpose. Therefore, this study aims to use coconut fiber which classifies into two different variations including 5 – 20mm and 20 – 40mm to investigate the SMA performance in terms of Marshall stability.

2. LITERATURE REVIEW

Recently, fibers have been widely used in the construction in order to reinforce the material properties. Panda *et al.* [8] studied on utilization of coconut fiber in SMA mixing with viscosity grade 30 asphalt (VG 30) and crumb rubber modified 60 grade asphalt (CRMB 60), have selected coconut fiber as the addictive stabilizing agents in their study. They have manually extracted the coconut fiber from local ripe coconut fruits which then the extracted coconut fiber lengths were in the range of 75 – 200 mm and diameters varied from 0.2 – 0.6 mm. Then, the coconut fibers were cleaned and cut into 20 – 35 mm long to ensure proper mixing. In their work, binder concentrations were varied from 4% to 7% (0.5% increment) while fiber concentrations were selected as 0%, and 0.3 – 0.7% (0.2% increment) to assess the optimum binder and fiber requirements respectively for the best possible mix. As the result, 0.3% of coconut fiber was the optimum fiber content all of the job mixes in term of stability.

Another study from Awanti *et al.* [9] studied on the characterization of SMA with coconut and cellulose fiber by utilizing VG 30 grade as the binder asphalt. They selected coconut fiber that had physical properties including length, diameter, and specific gravity of 3 – 8 mm, 0.2 – 0.6mm, and 1.0, respectively. For cellulose fiber, these values were 1100 µm, 45 µm and less than 1.0 respectively. As the results, the OAC of coconut and cellulose fiber were found to be 6 % and 5.8 %, respectively. Other result from draindown test showing that the draindown percentage of coconut fiber was 60% lower than that of cellulose fiber. Adding that, the have summed up that the

SMA mixing with coconut fiber was economical when compared to SMA mixing with cellulose fiber because of its cheaper and also abundantly available.

Kiran Kumar and Ravitheja [3] also studied on characteristics of SMA by using natural fibers (coir, sisal and banana fibers). In their study, they have chosen AC60/70 with the concentration of 5.5 – 7.5 % (0.5% increment) as the asphalt contents of the mixtures. First they have determine the OAC (6.42%) of the SMA mixing without addictive and that OAC was used in preparing all the stabilized mixes to maintain consistency throughout the study. The fiber contents for all fibers (equal to 6 mm long) in this research were varied between 0.1%, 0.2%, 0.3% and 0.4% by weight of the mixtures. As the result, the optimum fiber content of coir, sisal, and banana fiber was 0.3%. The coir fiber have showed the best performances among other fibers in term of stability (10% greater than that of sisal and banana fiber).

Hassan et al. [10] investigated the effects of 0.4% of cellulose fibers (0.6 mm long), SBR-modified binder (4% SBR), and a combination of fibers and SBR compared with a control with no additives. The study have shown that, fibers reduced drain-down more than polymer alone.

According to the literature review, it can be concluded that (1) polymer modified asphalt can be used without using any fibers, (2) unmodified asphalt must need fiber to prevent draindown of the mixtures, (3) sisal, banana, and coconut fiber can be used to substitute cellulose fiber, (4) 0.3 % of cellulose fiber and 0.3 – 0.5% of coconut fiber are sufficient for draindown prevention, (5) coconut fiber shall be used because it has higher stability and be able to fulfill other requirement as well, (6) among fibers, coconut fiber is said to be more economical because of its availability (mostly abundance).

2. REQUIRED MATERIALS

2.1 Aggregate Gradation

The aggregates using in this study were adopted from Roi Et province, the northeastern provinces of Thailand. To produce the aggregate gradation of 12.5 nominal maximum aggregate size (NMAS), the combination of 12.5mm, 9.5mm, dust rock, and Portland cement was made as shown in Figure 2.1 below. Portland cement which passed 0.075mm (No.200) sieve of more than 90% was added into the mixtures and its specific gravity testing in laboratory was 2.97.

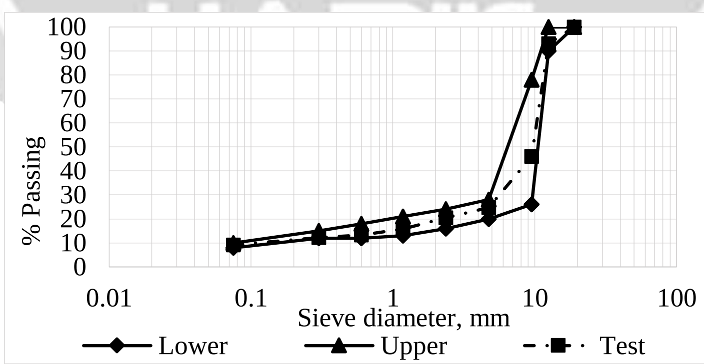


Figure-2.1: Gradation curve of the blended aggregate selecting in the study

2.2 Fiber

In this study, coconut fiber was selected to prevent draindown and also used to compare the stability values of SMA mixtures. This fiber was adopted from Sichon district located in the northern part of Si Thammarat province of Thailand. The length of this fiber was up to 250mm long. After carefully selected, it was leaned and cut into the designated length (5 – 20mm and 20 – 40mm). To ensure that this fiber can be used and prepared for SMA mixtures at mixing temperature, flash and fire point test were performed. The average result of flash and fire point were greater than 200^{o}C which indicated that coconut fiber can be used to prepare SMA mixtures.

2.3 Asphalt Binder

AC60/70 using to prepare the SMA mixtures in this study was provided by Thai Lube Base Public Company Limited located in Sriracha, Chonburi 20230, Thailand. Presently, AC60/70 has been widely used in tropical countries because it is suitable for the tropical climate conditions. There are a few tests used to determine its basic properties as shown in Table 2.1 below.

Table-2.1: Basic properties of AC60/70

Test item	Unit	Test method	Specification	Result
Penetration at 25 Deg.C	-	ASTM D5	60 – 70	67
Ductility at 25 Deg.C	cm	ASTM D113-07	Min 100	> 100
Softening point	Deg.C	ASTM D36	45 – 55	47.5
Flash point	Deg.C	ASTM D92-12b	Min 232	328
Specific gravity at 25 Deg.C	-	ASTM D70-18	1.01 – 1.06	1.056

3. MIXTURE PREPARATION AND TESTING METHODS

3.1 Mixture Preparation

Mixture preparation of this study was followed to Marshall method as outlined in [11]. Mixtures consisting 5 – 20mm were noted as Mix1 while those of 20 – 40mm were noted as Mix2. Mix1 and Mix2 had the same prepared procedures. First of all, the blended aggregate of approximately 1,200g needed to be heated 24hr at mixing temperature (160 – 170^{o}C). Adding that, AC60/70 also needed to be heated at the same temperature of the blended aggregate. After the blended aggregate and AC60/70 were heated already, the mixing procedure could be held. The concentration of coconut fibers added into each mixture were 0.1 – 0.7% (0.2% increment) and AC60/70 were 6 – 7% (0.5% increment).

3.2 Volumetric Properties and Marshall Stability Test

To obtain volumetric properties and Marshall stability results of Mix1 and Mix2, mixtures were prepared as follow. The heated blended aggregate shall be thoroughly mix with each correspondence coconut fiber content before the presentation of AC60/70. After being homogenous, mixtures were poured into preheat mold and then immediately applied 50 blows to each side of the specimen with a standard hammer in order to obtain the sample of 63.5 ∓ 3mm in height and 101 ∓ 0.5mm in diameter (shall keep the specimens to cool to room temperature for 24hr before the extraction).

Volumetric properties of Mix1 and Mix2 including air void (AV), void in mineral aggregate (VMA), voids of coarse aggregate in the compacted mixtures (VCAmix), were obtained from the following formula [11]:

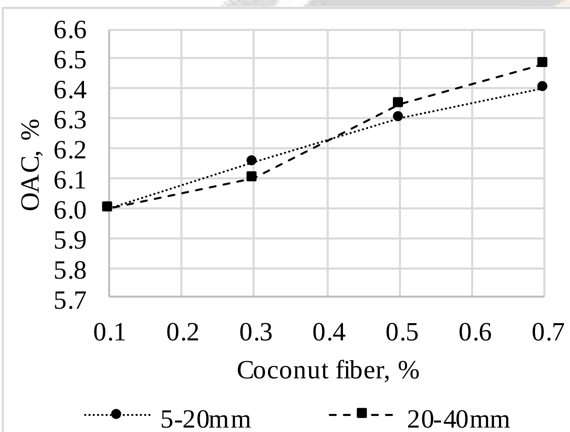
$$AV = 100 \times \left(1 - \frac{G_{mb}}{G_{mm}}\right) \quad (1)$$

$$VMA = 100 - \left(\frac{G_{mb}}{G_{sb}} - P_s \right) \quad (2)$$

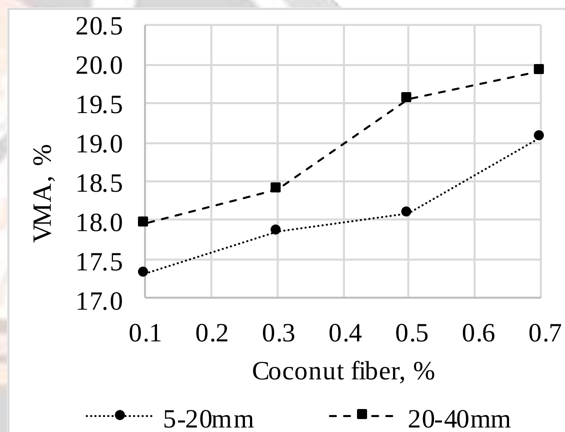
$$VCA_{MIX} = 100 - \left(\frac{G_{mb}}{G_{CA}} \times P_{CA} \right) \quad (3)$$

Where: G_{mb} = bulk specific gravity of the compacted mixture
G_{mm} = theoretical maximum density of mixture
G_{sb} = bulk specific gravity of the total aggregate
P_s = percent of aggregate in mixture
G_{CA} = bulk specific gravity of the coarse aggregate fraction
P_{CA} = percent coarse aggregate in the total mixture

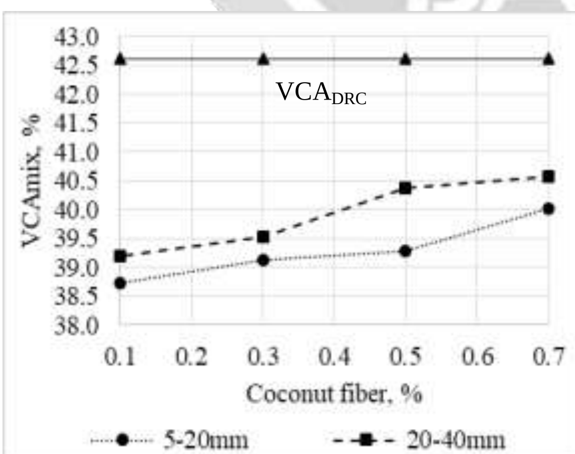
After all these volumetric properties were obtained correctly, Marsahll stability test could be subjected. The samples were kept for about 30mins at 60°C water bath before testing. The peak load which the samples could bear with was recorded as the stability result of the samples. Volumetric properties and Marshall stability results of Mix1 and 2 are shown in Figure 3.1 below.



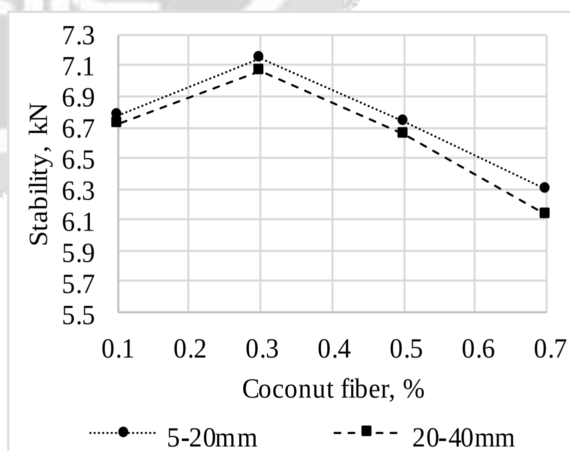
(a).Results of OAC of Mix1 and 2



(b).Results of VMA of Mix1 and 2



(c).Results of VCAmix of Mix1 and 2



(d).Results of stability of Mix1 and 2

Figure -3.1: Volumetric properties and stability results of Mix1 and 2

3.3 Draindown Test

Draindown test in accordance with ASTM D6390 [12] was followed in this study. The samples of this test were prepare similar to samples of Marshall stability but without compaction. After being mix homogenous, sample was poured into 1,000ml glass beaker so that the glass beaker containing the sample could keep in an oven for 60mins at 160 – 170^{o}C. After those 60mins, the specimen was taken out and suddenly poured without shaking. The remained mixture in the glass beaker was recorded so that draindown loss (DDL) can be obtained from the following formula (4). After performance of this test, Figure 3.2 was obtained.

$$DDL = 100 \times \frac{\mathrm{Re}\,mained\ mixture}{Initail\ mixture} \quad (4)$$

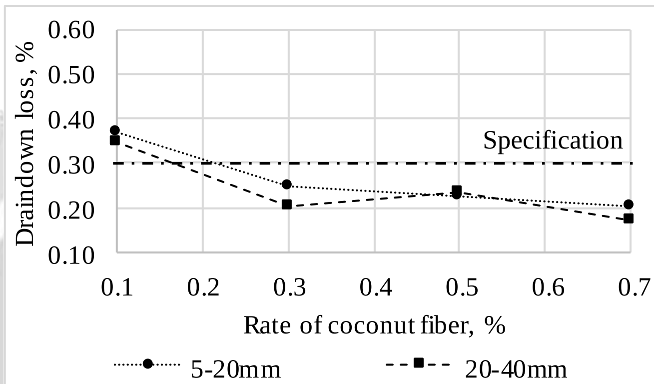


Figure -3.2: Draindown loss results of Mix 1 and 2

4. RESULT AND DISCUSSION

4.1 Volumetric Properties and Stability Characteristic

In this study, the OAC of Mix1 and Mix2 were determined according to NAPA method [13]. To find each OAC of Mix1 and Mix2, 4% of air voids was used as suggested by Brown and Cooley [14]. At this 4% air voids, Marshall stability, VMA, and VCAmix were obtained. The results of Mix1 and Mix2 are discussed as below.

Figure 3.1 (a) is used to present each OAC of Mix1 and Mix2. It is observed that OAC values of each Mix increase when coconut fiber content increases. This is due to the fact that the mixtures need more asphalt to provide sufficient coated area. Additionally, OAC of Mix1 and Mix2 show similar trends.

Figure 3.1 (b) is used to present the VMA results of Mix1 and Mix2. According to Brown and Cooley [11], VMA of any mixtures require to be at least 17%. Therefore the results of VMA of Mix1 and 2 are followed to the prescript specification. Moreover, VCAmix results of any mixtures have to be lower than VCAdrc. According to Figure 3.1 (c), the results of VCAmix of Mix1 and 2 are lower than VCAdrc.

Figure 3.1 (d) is used to present the Marshall stability of Mix1 and 2. It is observed that the stability of Mix1 and 2 start to increase from 0.1% to 0.3% of coconut fiber content and decrease thereafter. This is due to the face that higher additional coconut fiber content could reduce stone to stone contact. It is also observed that Mix1 has higher Marshall stability results than Mix2. This is due to the fact that, longer coconut fiber length could perform to ball shape during mixing procedure (reduce homogeneity).

Additionally, the highest Marshall stability results of Mix 1 and 2 are at 0.3% coconut fiber content. However, Mix1 has the highest Marshall stability result. At this coconut fiber content, the OAC of Mix 1 and Mix 2 are 6.15% and 6.1%, respectively.

4.2 Draindown Characteristics

Figure 3.2 is used to present the draindown loss of Mix1 and Mix2. It is observed that the draindown loss of these two mixes at 0.1% coconut fiber content are out of prescript specification (0.3% Min [11]). However, the draindown loss of Mix1 and 2 at 0.3 – 0.7% coconut fiber content are followed to the prescript specification. This is due to the fact that 0.1% coconut fiber content cannot prevent the drainage of the binder inside the mixtures (AC60/70 is not stiff as polymer modified asphalt). It can be indicated that driandown loss of Mix1 and Mix2 are based on additional coconut fiber content and type of asphalt.

5. CONCLUSIONS

Based on the finding from laboratory in order to investigate the effect of coconut fiber's length on Mix1 and 2, the following conclusions can be drawn out:

- The OAC of Mix1 and Mix2 are quite similar to each other (OAC of Mix1 is 6.15% while Mix2 is 6.10%).
- Coconut fiber length has no significant effect on draindown loss. According to the experiment, it can be observed that draindown loss may be effect by the additional coconut fiber content and the type of asphalt using in mixtures.
- Coconut fiber length do effect to Marshall stability results. It can be indicated by the results that Mix1 (5-20mm) has higher (about 5%) Marshall stability results than Mix2 (20 – 40mm). Therefore this means that shorter length provides more preferable results. Furthermore, this length provides more workability during mixing and compacting time.

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