Marshall Characteristic Of Asphalt Concrete Wearing Course Using Crude Palm Oil and Pen 60/70 As A Binder

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Abstract. Asphalt is one of the non-renewable natural resources. It is necessary to conduct various studies regarding alternative materials can be used as a substitute for asphalt. Crude palm oil (CPO) has almost the same texture and properties as asphalt, when it is heated it will melt so it can be substituted as a binding agent in the AC-WC layer. Based on the background, this study aims to analyze the effect of 50% CPO substitution and 50% pen 60/70 on the AC-WC layer. This research is based on the Public Works Department General specifications in 2010 using the marshall method by varying 50% CPO and 50% pen 60/70. Variation of 50% CPO and 50% 60/70 pen get Asphalt Optimum Content (AOC) value of 4.5% from the test results of 15 test specimens and 6 specimens using AOC. The results of the test with a 30-minute immersion (stability) all the characteristics meet the marshall parameters that are implied, namely: a stability value of 842 kg, a Flow of 3.1 mm, a VIM of 4.64%, a VMA of 15.30%, a VFB of 69.67% and the MQ value of 271.51 kg / mm. Marshall testing with a 24-hour immersion (durability) did not meet the specifications required so that this pavement is not durable.

1 Introduction
The highway is one of the means of land transportation used to mobilize goods and services. One of the things that need to be considered in planning highway pavement is the material used. The pavement layer uses several materials, namely aggregate (coarse and fine), asphalt (binder), and filler (filler). The pavement layer arrangement consists of several layers, namely AC-Base, AC-BC, AC-WC. Asphalt Pen 60/70 is a non-renewable natural resource, so it is necessary to carry out various kinds of research in line with the increasing growth of infrastructure, especially roads. Asphalt is the result of the distillation/refining of petroleum. One of the materials that have characteristics such as asphalt is Crude Palm Oil (CPO). According to data from the directorate general of plantations, in 2017, the total area of Indonesian palm oil plantations is 12 million hectares and the total production of CPO is 35.36 million tons/year. Indonesia is one of the largest CPO exporting countries compared to other countries. The depletion of crude oil reserves will have an impact on the depletion of asphalt raw materials so that many countries in the world switch to using CPO as a substitute material that is processed into biodiesel fuel. Based on the above background, research was carried out on the use of CPO as a substitute for Pen 60/70 asphalt as a binder in the AC-WC layer concrete asphalt mixture with a variation of 50% CPO: 60/70. This research uses the Marshall method. The benefits of this research are to obtain alternative materials for highway construction as a form of technology development and establish cooperation between civil engineering and agronomy.
2 Literature Study

2.1 Flexible Pavement or Asphalt pavement

Asphalt pavement generally consists of an asphalt surface layer that is above a granular foundation layer that is spread over the subgrade [1]. The flexible pavement elements consist of the surface course, base course, and subbase course [2]. Asphalt Concrete Wearing Course (AC-WC) is the top layer and directly receives the load of the vehicle wheels which will be spread to the next layer with the distribution of the load angle of 45°, therefore this layer must be following the specifications indicated [3].

2.2 The Properties Of The Flexible Pavement Mixture

According to [4] The design of a flexible pavement mixture must meet the following requirements:

- **Stability:**
  The ability of the pavement layer to serve traffic loads without experiencing permanent deformations such as waves and grooves.

- **Flexibility:**
  The asphalt mixture must be able to accommodate permanent deflection within certain limits without cracking.

- **Durability:**
  The resistance of flexible pavements to disintegration as a result of traffic loads and the effects of weather changes, without the release of asphalt film from the granules.

- **Flexibility:**
  The ability of the asphalt mixture to accommodate permanent deflection to a certain extent without cracking.

- **Fatigue resistance:**
  The resistance of the asphalt mixture in receiving repeated deflection caused by traffic loads without experiencing cracks.

- **Skid resistance:**
  The surface roughness is high enough to create road user safety, especially when the road is wet.

- **Impermeability:**
  The mixture of asphalt against the entry of water and air.

- **Workability:**
  The asphalt mixture must be easily carried out in the implementation of the fields for its overlay and compacting.

2.3 Marshall Test Parameters

Testing with the Marshall method and tools was first introduced by Bruce Marshall, Miss Mississippi State Highway Department in 1948, and was subsequently developed by the U.S Corps of Engineer. The marshall device is a press device equipped with a proving ring with a 22.2 KN (5000 lb) capacity and a flowmeter. The proving ring is used to measure the stability value and the flowmeter to measure plastic melt or flow. The marshall specimen is a cylinder with a diameter of 4 inches (10.16 cm) and a height of 2.5 inches (6.35 cm)[3]. Marshall parameters consist of stability, flow, density, marshall quotient, voids in the mix, voids in mineral aggregate, and voids filled by bitumen.
Table 1. Asphalt concrete wearing course specification.

| No | Mixed Traits                  | AC-WC Specification |
|----|--------------------------------|---------------------|
| 1  | Density                       | Min 2 gr/cm³        |
| 2  | Voids in Mix                  | 3.5-5.5 %           |
| 3  | Voids in Mineral Agregat       | Min 15 %            |
| 4  | Voids Filled By Bitumen        | Min 65 %            |
| 5  | Stability                      | Min 800 kg          |
| 6  | Flow                           | Min 3-5 mm          |
| 7  | Marshall Quotient              | Min 250 kg/mm       |
| 8  | Durability                     | Min 90%             |
| 9  | The number of collisions per field | 75 kali             |

Source: General Specification of Bina Marga (2010)

3 Experimental Methods

The entire study was conducted at the Transportation Laboratory of the Faculty of Engineering, Syiah Kuala University, Banda Aceh.

3.1 Materials

Aggregate is the main component in the pavement layer so that the quality and bearing capacity of the pavement is determined by the physical properties of the aggregate, both coarse aggregate, and fine aggregate. Besides, the aggregate gradation also determines the quality of the pavement. According to [3] the physical properties of aggregates that need to be checked are the cleanliness of the aggregates (cleanliness), the hardness of the aggregates, the resistance of the aggregates, the flakiness and the shape of the aggregates, the ability of the aggregates to absorb water, the specific gravity, and the adhesiveness of the aggregates to the asphalt. Aggregate is a material consisting of solid minerals, in the form of large masses, and in the form of fragments [3]. A good aggregate surface is a rough surface, because it can provide good interlocking power to other materials and bonding power to the asphalt. The aggregate for the pavement layer mixture is classified into coarse aggregate, fine aggregate, and filler. Coarse aggregate is held in sieve no. 8 (2.33 mm) and fine aggregate passes through sieve no.8 (2.38 mm) and is held by sieve no. 200 (0.075mm). In this study, split stone was used.

The filler is a mixture that fills the space between fine and coarse aggregates which will increase density, filler passes through sieve no. 200 (75 microns), and not less than 75% by weight. Fillers consist of limestone dust, fly ash, cement (PC), cement kiln ash, and rock ash. The filler must be dry and free of lumps and other disturbing materials. Filler cement was used in this study.

Asphalt is a thermoplastic material that will become harder or thicker if the temperature decreases and will be softer or more liquid if the temperature increases [1]. Asphalt is used as binder in concrete asphalt mixtures. Asphalt based on its type can be divided into: emulsion asphalt, liquid asphalt, and cement asphalt SNI No. 1737-1989 [2]. Asphalt cement (hard asphalt) of many types, is determined by the penetration value such as 40-50 penetration asphalt, 60-70 penetration asphalt, 80-100 penetration asphalt, 120-150 penetration asphalt, and 200-300 penetration asphalt. In this study, the binder used was 60-70 penetration asphalt.

Crude Palm Oil (CPO) is vegetable oil from the mesocarp (fruit fibers) of palm oil. Mesocarp contains 56% oil, while the core (kernel) contains 44% oil. Crude palm oil is obtained from the
extraction or pressing process of the palm head and has not been refined[5]. The CPO used comes from one of the palm oil mills in Nagan Raya Regency.

3.2 Mix Design and Sample

3.2.1 Mix design

After checking the physical properties of the aggregate and asphalt, it is followed by a mixed gradation planning taking into account the amount of material used (in the percentage of weight) to the total weight of the mixture (job mix design). After planning the aggregate mixture gradation, the mean value of the asphalt content is calculated using the formula:

\[ P_b = 0.035(\%CA) + 0.045(\%FA) + 0.18(\%filler) + \text{Constant} \]  

Where:
- \( P_b \) = Mid-level of asphalt content/ideal percentage against the weight of the mixture;
- \( CA \) = Coarse aggregate greater than No. 8 sieve;
- \( FA \) = Fine aggregate passed through No. 8 sieve but greater than No. 200 sieve; and
- \( \text{Filler} \) = Aggregate with a minimum of 75% passing through No. 200 sieve;

➢ Constant values are around 0.5 for low aggregate absorption and 1.0 for high aggregate absorption.
➢ The specimen used with asphalt content according to the estimation is rounded to 0.5 with two asphalt levels above and two asphalt levels below the initial estimated asphalt level that has been rounded up to 0.5% [2].

This AC-WC layer is for heavy traffic so that each specimen will be crushed by 2 x 75 collisions according to the requirements of [6]. The number of test objects planned to determine the middle asphalt content is 15 specimens to produce the Optimal Asphalt Content (OAC). The results of the evaluation of the relationship between Marshall parameters (stability, flow, density, VMA, VFB, VIM and Marshall Quation) with variations in asphalt content will get the mean value plotted through the graphs. OAC is the asphalt grade representing all Marshall parameters that meet the requirements set forth by the Department of Public Works specifications.

3.2.2 Samples

The specimen is made to find the optimum asphalt content (OAC)

Making test objects for stability and durability testing to find Optimum Asphalt Content (OAC) and using OACare the same working steps. Mixing is carried out following the Binamarga 2010 Spesification [6] technical guidelines with the following steps:
Weighing the aggregate, and the filler according to the planned aggregate percentage of the mixture, then the material is put into the open at a temperature of 105-110°C for 30 minutes;

- Weigh the asphalt and CPO according to the planned weight then heat it until the asphalt and CPO melt;
- Remove the aggregate and filler from the open, then mix with asphalt and which has been liquid and stirred until all the aggregate is covered with asphalt at a temperature of 160°C;
- Take a mold that has been smeared with lubricant first then give a piece of paper
- Pour the asphalt mixture into the mold and compaction at a temperature of 140 °C using a hammer test for 2 x 75 times collisions
- After the compaction process is complete, the test object is removed from the mold using an ejector and is coded type x and left to stand for 24 hours
- After settling, the height of the test object is measured on the three sides of the test object and the weight of the test object is weighed in water
- The test object is surface dried and then the weight of the dry surface is weighed
- Furthermore, the specimen is immersed in a water bath at a temperature of 60°C ± 1 °C for 30 minutes for stability test and 24 hours immersion for durability test specimens;
- Remove the test object from the water bath then place it on the ring marshall for testing

Tested specimens were created from the AC mixture contains asphalt (pen 60/70) and CPO as a binder. The test specimen is made using filler variations following the mixed design plan contained. The specimen consists of:

- 15 specimens of AC mixture with varied content of 50% pen 60/70 and 50% CPO; Marshall evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC).
- 3Specimens with the same variation of binder on OAC. Specimens were water-bathed for 30 minutes in normal stability.

3.3 Marshall test
The criteria for mixed asphalt concrete can be examined using Marshall test equipment in the laboratory. This examination is intended to determine the resistance (stability) to the plastic melt (flow) of the asphalt mixture and is guided by the AASHTO T-245-74 provisions [3]. The result obtained based on testing will be compared with the requirements issued by Binamarga 2010 specification.

4 Result and Discussion
4.1 Result
Recapitulation of Marshall test in the Mixture of AC WC with pen 60/70 and CPO binder variation.
Table 2 shows that specimens of AC WC mixture with varied content of pen 60/70 and CPO (50%:50% variation) 4.5; 5; 5.5; 6; 6.5: Marshall evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC).
Table 2. Recapitulation of marshall test in the mixture of AC WC with pen 60/70 and CPO as a binder with variation 50%: 50% to find OAC.

| No. | Mixture Characteristic | Asphalt Content( % ) | Dept PU Specification |
|-----|------------------------|-----------------------|----------------------|
| 1.  | Stability(kg)          | 801.058               | >800 kg              |
| 2.  | Flow Plastic (mm)      | 2.7                   | min 3 mm             |
| 3.  | VIM (%)                | 4.96                  | >250                 |
| 4.  | VMA (%)                | 15.02                 | 3.5-5.5 %            |
| 5.  | VFB (%)                | 66.95                 | > 15 %               |
| 6.  | MQ (Kg)                | 293.186               | > 65 %               |

Based on picture 3 the asphalt content of 4.5% fulfills all the required parameter values. Asphalt Optimum Content for 50%/50% is 4.5%. This AOC value is used to make further test objects, namely the test object to find the value of stability (30 minutes immersion) and durability (24 hour immersion).

Recapitulation of Marshall test in the Mixture of AC WC with asphalt pen 60/70 and CPO as a binder on Optimum Asphalt Content
Table 3. Recapitulation of marshall test in the mixture of AC WC with pen 60/70 and CPO as a binder with variation 50%: 50% on OAC (30 minutes on a water bath).

| NO | Mixture Characteristic | OAC 4.5 | Dept.PU |
|----|------------------------|---------|---------|
| 1. | Stability (kg)         | 842     | >800 kg |
| 2. | Flow Plastic (mm)      | 3.1     | min 3 mm |
| 3. | MQ (Kg)                | 271.61  | >250 kg/mm |
| 4. | VIM (%)                | 4.64    | 3.5-5.5 % |
| 5. | VMA (%)                | 15.3    | > 15 %   |
| 6. | VFB (%)                | 69.67   | >65 %    |

Table 4. Recapitulation of marshall test in the mixture of AC WC with pen 60/70 and CPO as a binder with variation 50%: 50% on OAC (24 hours on a water bath).

| NO | Mixture Characteristic | OAC 4.5 | Dept.PU |
|----|------------------------|---------|---------|
| 1. | Stability (kg)         | 675.97  | >800 kg |
| 2. | Flow Plastic (mm)      | 3.0     | min 3 mm |
| 3. | MQ (Kg)                | 225.32  | >250 kg/mm |
| 4. | VIM (%)                | 3.9     | 3.5-5.5 % |
| 5. | VMA (%)                | 14.64   | > 15 %   |
| 6. | VFB (%)                | 73.36   | >65 %    |

Table 5. Durability calculation.

| No. | Composition CPO: Aspal Content | Asphalt | Stability 30 minutes on the water bath | Stability 24 hours on the water bath | Durability Value (%) |
|-----|--------------------------------|---------|----------------------------------------|--------------------------------------|----------------------|
| A   | B                               | C       | D                                      | E                                    | F=(E/D)              |
| 1   | 50% : 50%                       | 4.5     | 842.003                                | 675.974                              | 0.803                |

4.2 Discussion

Stability
The stability value implied by the specification is 800Kg. Meanwhile, the stability value for the 30-minute immersion was 842 Kg. In this variation, the results obtained still meet the required specifications so as not to cause a change in shape to the test object.
**Flow**  
The flow value shows the flexibility level of a mixture, the higher the flow value obtained, the more elastic the mixture is so that the mixture is better able to follow deformation due to traffic wheel loads. The test for flow meets the requirements indicated. This is because the CPO mixes completely when heated.

**Voids In Mix (VIM)**  
VIM is the percentage of cavities present in the volume of the mixture. The VIM value obtained is 4.64% fulfilling the requirements. This is due to the addition of CPO to the mixture, where the nature of the CPO is more liquid which can enter the cavities in the mixture.

**Voids in Mineral Aggregate (VMA)**  
The number of voids in the aggregate that can be filled by asphalt is called VMA. The VMA value will increase if the asphalt cover in the mixture is thicker. The VMA value for this variation meets the required specifications. This is due to the use of CPO so that some of the cavities contained in the test object are not all covered by asphalt but by CPO.

**Voids Filled by Bitumen (VFB)**  
VFB is the percentage volume of asphalt covering the aggregate after undergoing a compaction process. The higher the VFB value, the more cavities in the mixture filled with asphalt so that the mixture becomes more impermeable to water and air. For this parameter, it meets the required requirements. The balanced composition between 60/70 pen asphalt and CPO keeps the mixture impermeable.

**Marshall Quotient**  
The Marshall Quotient (MQ) value is the flexibility index of a mixture in the form of a ratio between stability to flow. The greater the MQ value, the stiffer / brittle the mixture is so that cracks can occur when given loading. MQ that meets the requirements required.

**Durability**  
The value of durability is the ratio between normal stability (30 minutes of immersion) and 24 hours of immersion stability. Durability testing aims to determine how strong the asphalt is in maintaining its properties due to pavement aging. The durability value is not following the required specifications (>90%).

5  **Conclusion**  
Based on the evaluation carried out on the AC-WC mixture using 60/70 pen asphalt and CPO as a binder with a ratio of 50%: 50%,
- All values obtained are following the required specifications.
- Several parameters are close to the minimum required value, namely the value of stability (842kg > 800Kg), flow (3.1 mm > 3 mm), and VMA (15% > 15.3%).
- Durability value is not following the required specifications (>90%).

6  **References**  
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