Utilization of palm shells fly ash as filler on the mixture of Asphalt Concrete Wearing Course (AC–WC)

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Abstract. The scarcity of natural component of road construction, such as river sand, gravel and rock; against high market demand causing the increased of material market prices. Therefore, there is a call for innovations of substitutes to reduce the demand of natural resources use. Aceh Barat is boastful of palm plantation supplying the palm oil industry. Palm oil production generates waste including fly ash. This study aims to investigate the physical properties of fly ash to be used as filler in asphalt concrete mixture AC WC. The study also inspects the Marshall characteristics of the mixture of Asphalt Concrete Wearing Course (AC-WC) used palm shells fly ash. Results of the study displays that there are characteristics value of the AC-WC mixture which is compliant with the Specification for Asphalt Concrete Mix by Department of Public Work 2010. KAO 5.51% for palm shells fly ash filler. The stability value of the AC-WC mixture used palm shells fly ash as filler is 1279.54 kg; flow 3.5 mm; MQ 362.18; Density 2.4 gr/cm3; VIM 4.18%; VMA 15.55% dan VFB 74.21%. This research benefits is sought to realize the cooperation of the agricultural industry in the field of road transportation which is environmentally friendly and sustainable.

1. Introduction

The rapid development of infrastructure, particularly the road leading to high demand for natural component of road construction. The material such as river sand, gravel and rock, became scarce. Material scarcity leads to high market prices. Therefore we need an innovation or alternative material in order to reduce the demand of natural resources. Aceh Barat, one of the districts in the Province of Aceh, is a region boastful of palm plantation that yields palm oil whilst produces abundant palm kernel shells and fiber (pulp) as industrial by-products. The extraction process of Crude Palm Oil (CPO) is benefitted from the by-products through using them to fuel the furnace/steam boiler [5]. Palm kernel shells and palm pulp that have been burned at high temperature between 500°F to 700°F will deform into Palm Oil Clinker (POC) that has been widely accepted as disposal waste in the industry. After being burned under high temperature, palm kernel shell and palm pulp will deform into remnants which is considered as boiler waste and it comes in the form of: 1. Ashes; accumulated under the furnace, collected into ashes collecting point and is relatively heavyweight; 2. Clinker; boiler clinkeris derived from palm kernel shell and attached to the boiler wall. [1]

This study aims to examine the physical properties of Palm Shells Fly Ash as an alternative component in asphalt concrete mixture. This research also elaborated the Marshall characteristics of Asphalt Concrete Wearing Course (AC-WC) blend using Palm Shells Fly Ash as filler. The benefits of this research are (1) Gain alternative filler substitutes that can optimize the surrounding natural resources; (2) Strive to realize the cooperation of the agricultural industry in the field of road transportation which is environmentally friendly and sustainable.
transportation which is environmentally friendly and sustainable; (3) Provide an overview of the influence of the use of alternative materials as a form of technology development of pavement materials by utilizing palm shell fly ash waste; (4) Transdisciplinary between civil engineering and agricultural engineering.

2. Literature study

2.1. Aggregate
Aggregate is known as a compact and coarse grained material which constitutes of natural gravel, crushed stones produced by stone crusher, stone dust and sand. Aggregate plays a significant role in the mixture of asphalt concrete, in where it occupies the largest proportion generally ranging between 90% to 95% of the total weight of the mixture; or 75% to 85% of the mixture volume [7]. Quality, durability and load-bearing capacity of pavement is strongly formed by the characteristics of its aggregates. Therefore, prior to be using in the mixture, a laboratory analysis is required to determine the characteristics of the aggregates.

2.2. Filler
Filler works to fill spaces amongst fine and coarse aggregates in order to increase mixture density. Filler is material that passes through a sieve no. 200 (75 micron) and not less than 75% of the total weight of the mixture. Filler consists of limestone dust, cement dust (PC), dust of cement kiln and stone dust. It must be dry and free from clumps and other undesirable material [4]. Described grading in general as the distribution of particles by aggregate size that works to complement one another form an interlocking structure [6].

2.3. Asphalt concrete
Sukirman (2003) explained asphalt concrete layer as continuously graded asphalt which has been commonly used for roads with heavy traffic loads. Asphalt concrete is widely known as AC. The most important characteristics of AC mixture is its stability. The minimum thickness of AC layer ranges between 4cm to 6cm. Type of AC layers by its function can be divided into the followings:
1. AC as wear layer, commonly identified as AC-WC (Asphalt Concrete - Wearing Course); the minimum thickness is 4 cm;
2. AC as binder layer or commonly acknowledged as AC-BC (Asphalt Concrete Binder Course); the minimum thickness is 5 cm;
3. AC as foundation layer or widely identified as AC-base (Asphalt Concrete Base); the minimum thickness is 6 cm;
AC layer consists of a blend of hard asphalt and aggregate with continuous grading; the materials are mixed, spread and compacted at a certain temperature. Components of AC layer consists of coarse aggregate, fine aggregate, filler (if necessary) and hard asphalt.

2.4. Asphalt Retona Blend
Asphalt Retona Blend 55 is a product introduced by PT. Olah Bumi Mandiri. Retona Blend 55 is a modified bitumen manufactured by mixing petroleum base asphalt of 60 PI with petroleum base asphalt of 80 PI combined with the semi extraction refined Buton asphalt.

2.5. Planning of Asphalt Concrete Mix
Sukirman (2003) concluded that the objective of asphalt mix planning is to achieve an effective mix of graded aggregates and asphalt mixtures. AC mixture as pavement layer should have the following characteristics:
- Stability;
  Stability is the ability of AC pavement to allow traffic load without deteriorating into permanent deformation such as waves, grooves or bleeding. Level of required stability is in accordance with the function of the road and the traffic load it serves.
- Durability;
Durability is the ability of the AC to receive recurrences of traffic loads such as vehicle weight; and friction due to the effects of weather and climate, such as air, water and temperature changes.

- Flexibility;  
  Pliability or flexibility is the ability of AC to adapt to soil or foundation decrease and movement to resist cracks.

- Fatigue resistance;  
  Fatigue resistance is the ability of AC to receive repeated deflection.

- Skid resistance;  
  Surface roughness or resistance to skid is a vital ability of AC surface particularly in wet conditions when it is required to provide friction for vehicles wheels to prevent slip accidents.

- Impermeability;  
  Impermeability or water-resistant is an ability of AC to prevent water or fluid or air to penetrate into its layer.

- Workability;  
  Workability is the ability of the AC mixture to be laid and compacted to achieve the desired density. Sukirman (2003) confirmed that in order to achieve a mixture design to accommodate the specifications of aggregate mixture, it is required to blend more than two fractions of aggregates. Desired mixtures can be obtained through gradually blend the two fractions; nevertheless, it can also be calculated by using below formula:

\[
P = aA + bB + cC,\]

Where:
- \(a\) = Coarse aggregate percentage;
- \(b\) = Fine aggregate percentage; and
- \(c\) = Filler percentage.

Whereas \(a + b + c = 1\)

According to [6], the calculation of bitumen content planning can be obtained by using the following formula:

- Formula to estimate design asphalt percentage:

\[
P_b = 0.035(\%CA) + 0.045(\%FA) + 0.18(\%filler) + \text{Constant} \tag{2}\]

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
- Filler = Aggregate with the minimum of 75% passed through No. 200 sieve;

The calculation uses constant value of approx. 0.5 for low absorption aggregate and approx. 1.0 for high absorption aggregate.

- Specimens used with the estimated level of asphalt were rounded up to 0.5 to two levels

3. Materials and method

Figure 1 shows a framework of the land cover classification study. The details of materials and methodology are explained in the next section.

3.1. Data

In this study data collection is useful for the research process, the data needed are primary data and secondary data. Primary data is obtained from the results of testing the physical properties of the material and the Marshall test results of asphalt concrete mixtures, while secondary data is supporting
data obtained from material production brochures and other literature. The testing method follows the 1990 AASHTO [1] procedure and the Department of Public Works standards or other standards if not in both procedures.

3.2. Processing
The study was conducted in the Laboratory of Transportation of Engineering Faculty of Syiah Kuala University in Banda Aceh. The steps taken in this research are preparing the materials and equipment needed in the research process. The next step is checking the aggregate and asphalt physical properties and sieving analysis. This inspection is very necessary to ascertain whether the material to be used meets the requirements as an asphalt concrete mixture material as the requirements set out in the specifications of asphalt concrete. After the results obtained meet the required specifications, then the planning of making specimens is carried out. Tested specimens were created from AC mixture contains Palm Shells Filler. Prior to blending it with the asphalt mix, PSF was ground and allowed to pass through a sieve analysis. Other materials used in the mixture were crushed stone aggregate, binder Retona Blend 55.

Asphalt concrete material consists of coarse aggregate, fine aggregate, filler and hard asphalt (Retona Blend 55). The material is mixed, stretched and compacted at a certain temperature. Material in the form of palm shell furnace waste obtained from the waste of oil palm processing furnaces at the PT. Mopoli Raya in West Aceh. Then the material must pass the filter No. filter. 200 in accordance with the specifications for fine aggregates issued by The Department of Public Works [2].

![Figure 1. Palm shells filler.](image)

Specimen consists of:
- 15 specimens of AC mixture with varied content of Retona Blend 55 (4.5; 5; 5.5; 6; 6.5); these specimens did not contain POC (plain). Marshall Evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC).
- Specimens with variation content of Palm Shells Fly Ash as Filler blended with the mixture of AC-WC on OAC. Specimens were water-bathed for 30 minutes in normal stability; while other 12 specimens were soaked for 24-hour under 60°C of temperature.

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.
Figure 2. Research flow chart.
4. Result and discussion

4.1. Physical properties aggregate
The majority of the products were in compliant with the required specification, except for the flakiness index that did not meet the maximum value of 10%; however, it was considered to be acceptable to use in the mixture of AC-WC.

Table 1. Examination on physical properties of aggregate.

| No.  | Physical properties of aggregate | Unit       | Result  | Specification |
|------|---------------------------------|------------|---------|---------------|
| 1.   | Specific gravity                | gr/cm³     | 2.688   | Min 2.5       |
| 2.   | Absorption                      | %          | 1.187   | Max 3         |
| 3.   | Bulk density                    | Kg/dm³     | 1.349   | Min 1         |
| 4.   | Impact value                    | %          | 3.09    | Max 30        |
| 5.   | Keausan                         | %          | 19.376  | Max 40        |
| 6.   | Flat Index                      | %          | 41.71   | Max 10        |
| 7.   | Elongated Index                 | %          | 9.11    | Max 10        |
| 8.   | Aggregate attach to bitumen     | %          | 95      | Min 95        |

4.2. Chemical properties of palm shell fly ash
The exam is required to the specification

Table 2. Examination on chemical properties of palm shell fly ash.

| No.  | Test parameters | Unit       | Test method | Result |
|------|-----------------|------------|-------------|--------|
| 1.   | Specific gravity| gr/ml      | Gravimetri  | 2.22   |
| 2.   | Alkali (Na)     | %          | AAS         | 0.06   |
| 3.   | Water content   | %          | Gravimetri  | 0.07   |
| 4.   | Dust content    | %          | Gravimetri  | 98.73  |
| 5.   | MgO             | %          | Titrimetri  | 7.55   |
| 6.   | P2O5            | %          | Spektrofotometri | 1.20 |
| 7.   | SiO2            | %          | Gravimetri  | 24.50  |

4.3. Physical properties of palm shell fly ash
The exam is required to the specification

Table 3. Examination on physical properties of palm shell fly ash.

| No.  | Physical properties of palm shell fly ash | Unit       | Result  | Specification |
|------|------------------------------------------|------------|---------|---------------|
| 1.   | Specific Gravity                         | gr/cm³     | 2.22    | Min 2.5       |
| 2.   | Aggregate wear                           | %          | 37      | Max 40        |

4.4. Physical properties of Retona Blend 55
The results obtained from this test indicate that Retona Blend 55 required to the specification

Table 4. Examination on physical properties of Retona Blend 55 Asphalt.

| No.  | Physical properties | Unit       | Result  | Specification |
|------|---------------------|------------|---------|---------------|
| 1.   | Specific Gravity    | gr/cm³     | 1.1     | >1            |
| 2.   | Penetration         | (0.1 mm)   | 59      | Min 40        |
| 3.   | Daktility           | Cm          | 85      | Min 50        |
| 4.   | Softening point     | °C          | 55.75   | Min 55        |
4.5. Recapitulation of Marshall test in the Mixture of AC WC with Retona Blend 55 content variation using palm shells fly ash (its acquiescent to the required specification).

Table 5 shows that specimens of AC WC mixture with varied content of Retona Blend 55 (4.5; 5.0; 5.5; 6; 6.5); these specimens did contain Palm Shells Fly Ash. Marshall evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC). The OAC obtained is 5.51% we got 5.51% for Optimum asphalt content.

Table 5. Marshall Test of AC WC with Retona Blend 55 content variation using palm shells fly ash.

| No | Mixture Characteristic | Asphalt Content( % ) | Dept PU Spesification |
|----|------------------------|-----------------------|-----------------------|
| 1. | Stability(kg)          | 1589.20               | 1680.48               | 1741.27               | 1682.87               | 1562.33               | >1000 |
| 2. | Flow Plastis (mm)      | 4.3                   | 3.9                   | 3.5                   | 3.6                   | 3.7                   | 3-6 |
| 3. | MQ (kg)                | 366.78                | 434.01                | 496.10                | 478.07                | 431.06                | >300 |
| 4. | Density (gr/cm³)       | 2.38                  | 2.39                  | 2.43                  | 2.43                  | 2.41                  | >2  |
| 5. | VIM (%)                | 6.47                  | 5.22                  | 3.13                  | 2.58                  | 2.43                  | 3.5-5.5 |
| 6. | VMA (%)                | 15.56                 | 15.45                 | 14.62                 | 15.16                 | 16.05                 | >15 |
| 7. | VFB (%)                | 58.47                 | 67.20                 | 78.90                 | 83.67                 | 85.29                 | >65 |

4.6. Recapitulation of Marshall test in the Mixture of AC WC with Retona Blend 55 OAC using palm shells fly ash as filler.

Table 6 shows that stability value on the AC-WC blend with palm shells fly ash as filler were acquiescent to the required specification; Density is the ratio between the dry weight and the volume of the asphalt concrete mixture. Density value were acquiescent to the required specification (2.4 kg/cm³), that is below 2.00 kg/cm³; High flow values have an adverse effect, because if it is traversed by heavy slow moving traffic and also high temperatures resulting in deformation, the asphalt mixture will be damaged before the age of the plan. Flow value were acquiescent to the required specification (3.5); VIM Value conducted on the AC-WC blend with palm shells fly ash as filler were acquiescent to the required specification; The characteristic of asphalt mixture in the mixture of AC-WC coated asphalt concrete with palm shell fly ash as filler Marshall quotient value is 362.18, the Marshall quotient value is influenced by the value of stability and flow in the mixture, where the MQ value is obtained from the division between stability and flow. Marshall quotient is negatively correlated with flow values, decreasing flow values results in an increase in the Marshall quotient. The Marshall quotient for all retona levels meets the limits required by the PU Department, [3] which is greater than 300.

Table 6. Recapitulation of Marshall test in the Mixture of AC WC with Retona Blend 55 OAC using palm shells fly ash as filler.

| No | Mixture Characteristic | OAC Fly Ash (5.51) | Dept.PU |
|----|------------------------|--------------------|---------|
| 1. | Stability (kg)         | 1279.54            | >1000   |
| 2. | Flow Plastis (mm)      | 3.5                | 3-6     |
| 3. | MQ (Kg)                | 362.18             | >300    |
| 4. | Density (gr/cm³)       | 2.4                | >2      |
| 5. | VIM (%)                | 4.18               | 3.5-5.5 |
| 6. | VMA (%)                | 15.55              | >15     |
| 7. | VFB (%)                | 74.21              | >65     |
5. Conclusion

The investigation carried out to examine the physical properties of aggregate that the majority of the products were in compliant with the required specification, except for the flat index that did not meet the maximum value of 10%; the physical properties of palm kernel shells that the majority of the products were in compliant with the required specification, however, it was considered to be acceptable to use in the mixture of AC-WC. Examination on the physical properties of Retona Blend asphalt verified that the bitumen was in compliant with the required specification. Marshall evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC). The OAC obtained is 5.51%; Marshall test conducted on the AC-WC blend for the mixture using palm shells filler were acquiescent to the required specification.

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References
[1] AASTHO 1990 Standard Specification for Transportation Materials and Methods of Sampling and Testing 15th ed AASHTO Washington, DC
[2] Anonim 2006 Pedoman Pengelolaan Limbah Industri Kelapa Sawit Sub Bagian pengelolaan Lingkungan Direktorat Pengolahan Hasil Pertanian, Ditjen PPHP, Departemen Pertanian Jakarta.
[3] Anonim 2008 Buku Petunjuk Praktis Penggunaan Aspal Retona Blend 55 Dalam Campuran Beraspal Panas Direktorat Jenderal Bina Marga Departemen PU Jakarta
[4] Anonim 2010 Seksi 6.3 Spesifikasi Campuran Beraspal Panas Direktorat Jenderal Bina Marga Departemen PU Jakarta p 6-37
[5] Anonim 2013 Cangkang Sawit Sebagai Salah Satu Sumber Energi Alternatif Paling Potensial Pengganti BBM Kompasiana Venusgazer Jakarta
[6] Bukhari 2004 Rekayasa Bahan dan Tebal Perkerasan Jalan Raya Bidang Studi Teknik Transportasi Fakultas Teknik Universitas Syiah Kuala p 18
[7] Sukirman 2003 Beton Aspal Campuran Panas Granit Jakarta p 1 p 109 p 118 p 125.