The Effect of Combining Coal Fly Ash and Lokan Shells As Filler Towards The Mixture Of Asphalt Concrete Wearing Course

Chaira and Veranita
Department of Civil Engineering, Teuku Umar University, West Aceh 23615, Indonesia
Corresponding author: chaira@utu.ac.id

Abstract. Sustainable construction is expected to create a quality environment so that environmental sustainability is maintained. The use of coal as fuel for PLTU have a negative impact on the environment, because it produces waste in the form of fly ash and bottom ash. Lokan freshwater is widely used as a food ingredient. This research study a mixture of AC-WC asphalt using coal fly ash and lokan shell ash as a filler. Research is needed to determine the durability and performance of the pavement that uses these waste materials by using asphalt pen 60/70 as a binder. This study uses Marshall Method and using three variations in the percentage of coal fly ash and lokan shell ash to the total filler. The highest stability obtained at V1 with a value of 1,389.158 kg. Marshall test conducted on the AC-WC blend on OAC for the mixture variation of V1, V2, V3, disclosed that Stability, flow, MQ, VMA and VFB values were acquiescent to the required specification. For the value of VIM on V1 and V3 were not acquiescent to the required specification. The coal fly ash and lokan shells as filler recommended for alternative material on a mixture of AC-WC.

Keywords: Coal Fly Ash, Lokan Shells, Filler, Marshall Method, AC-WC.

1. Introduction
The development of science is needed to meet the increasing need for the use of alternative materials in road construction along with the depletion of natural resources due to the continuous use which negatively impacts the environment. Sustainable construction is expected to create a quality environment so that environmental sustainability is maintained. The use of waste as an alternative material is an interesting idea in overcoming the scarcity of road-forming pavement materials. Nagan Raya is one of the districts in Aceh Province that has coal resources. The benefits of coal, among others, are as fuel driving the Steam Power Plant (PLTU). The use of coal as fuel turns out to have a negative impact on the environment, because it produces waste in the form of fly ash and bottom ash. Another waste that is often found in the Nagan Raya and West Aceh areas is Lokan Shells. Lokan freshwater is widely used as a food ingredient that is served by many restaurants. Based on the above problems, the authors try to conduct research on a mixture of AC-WC (Asphalt Concrete Wearing Course) asphalt using coal fly ash and lokan shell ash as a filler. Research is needed to determine the durability and performance of the pavement that uses these waste materials. The study inspect the Marshall characteristics and the performance characteristics of the mixture of Asphalt Concrete Wearing Course (AC-WC) using coal fly ash and lokan shells as filler. The Specification for Asphalt Concrete Mix by Department of Public Work 2010. Comprehensive procedures for evaluating alternative materials in terms of technical performance and sustainability are very significant for making the right decision whether to use them for road construction. The
The purpose of this study was to determine how much influence the percentage of coal fly ash variation and lokan shell ash as a filler in AC-WC concrete asphalt mixture by using asphalt pen 60/70 as a binder.

The benefits of this research are (1) Processing the waste around the environment into alternative materials; (2) Strive to realize the cooperation with the power generation industry and the food industry in the field of road 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 coal fly ash and lokan shell; (4) Transdisciplinary between civil engineering and agro marine industry.

2. Experimental/Methods

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

2.1. Materials

Filler (filler) is a mixture that fills the space between fine and coarse aggregates which will increase density, filler is material that 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 and must be dry and free of lumps and other disturbing materials [2].

Indonesia has many industries that use coal as raw material for combustion, one of which is the PLTU (Steam Power Plant) industry. PLTU waste production in the form of bottom ash (bottom ash) and fly ash (fly ash). Bottom ash is ash particles left behind and removed from the bottom of the furnace, while fly ash is ash particles carried by the exhaust gases. Fly ash itself is technically defined as the result of combustion of coal in the furnace of a steam power plant in the form of fine [3]. Coal fly ash waste is taken from the Nagan Raya power plant and then filtered with sieve number 200 so that it meets the specifications specified for the filler.

The lokan shells are the shells of many molluscs that live in estuary and coastal waters. This lokan shell contains calcium carbonate (CaCO$_3$) which when heated will turn into CaO and release CO$_2$ into the air, so that only CaO (lime tohor) and Si (Silica) remain where the content is a cement-forming component in addition to Fe$_2$O$_3$ and Al [4]. For lokan shell waste, it is taken at the noodle shop around West Aceh district. Lokan shell that is taken is cleaned first from dirt. Prepare a combustion tool for lokan shells in the form of a furnace made of bricks, firewood and iron wire. The lokan shell is burned on an iron wire after the flame is burning above 110$^\circ$C. The lokan shell is removed from the fireplace after it becomes soft and easily destroyed, this can be seen from the shell's skin which turns white. Burning time ± 5 minutes. Before it is crushed, the shell is cleaned again from the burnt dirt using dishwashing foam and then ground until it becomes smooth. After collision, the shells are filtered with sieve number 200.

Table 1. Chemical properties of coal fly ash.

| No | Test parameters | Bituminus | Subbituminus | Lignit |
|----|----------------|-----------|--------------|--------|
| 1. | SiO$_2$        | 20-60     | 40-60        | 15-45  |
| 2. | Al$_2$O$_3$    | 5-35      | 20-30        | 20-25  |
| 3. | Fe$_2$O$_3$    | 10-40     | 4-10         | 4-15   |
| 4. | CaO            | 1-12      | 5-30         | 15-40  |
| 5. | MgO            | 0-5       | 1-6          | 3-10   |
| 6. | SO$_3$         | 0-4       | 0-2          | 0-10   |
| 7. | Na$_2$O        | 0-4       | 0-2          | 0-6    |
| 8. | K$_2$O         | 0-3       | 0-4          | 0-4    |
Table 2. Chemical properties of Lokan Shell.

| Chemical properties | Level of chemical compounds |
|---------------------|-----------------------------|
| CaO                 | 67.072                      |
| SiO₂                | 8.252                       |
| Fe₂O₃               | 0.402                       |
| MgO                 | 22.652                      |
| Al₂O₃               | 1.622                       |

Figure 1. Coal fly ash.  
Figure 2. Lokan shells.

Aggregate is a road pavement layer containing 90-95% aggregate based on percentage weight or 75-85% aggregate based on volume percentage as the main component. With this the carrying capacity, durability and quality of road pavement are also determined by the nature of the aggregate and the results of the aggregate mixture with other material [1].

The nature and quality of the aggregate determine the ability of pavement in carrying the burden of traffic. Aggregate with good quality and properties is needed for surface layers which directly bear the burden of traffic and spread it to the layers below.

Coarse and fine aggregates are taken from PT. Wiratako Mitra Mulia, Nagan Raya Regency. Examination of coarse aggregate (gravel) and fine aggregate (sand) as concrete asphalt forming material needs to be done to get good quality material. Examination of physical properties of aggregates covers specific gravity and aggregate requirements, aggregate content weight, aggregate wear, weathering (soundness), flaky and oval index, and viscosity of asphalt [1].

Table 3. Physical properties of aggregate.

| No.   | Physical properties of aggregate | unit   | result | Specification |
|-------|----------------------------------|--------|--------|---------------|
| 1.    | Spesivic gravity                 | gr/cm³ | 2.88   | Min. 2.5      |
| 2.    | Absorption                       | %      | 1.179  | Maks. 3       |
| 3.    | bulk density                     | kg/dm³ | 1.313  | Min.1         |
| 4.    | Impact value                     | %      | 2.78   | Maks.30       |
| 5.    | Aggregate wear                   | %      | 19.39  | Maks. 40      |
| 6.    | Flat Indeks                      | %      | 41.71  | Maks. 10      |
| 7.    | Elongated Indeks                 | %      | 9.11   | Maks. 10      |
| 8.    | Aggregate attachment to bitumen  | %      | 95     | Min. 95       |

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.

2.2 Mix Design, Sample and test

2.2.1 Mix design The general objective of designing hot asphalt mixes is to determine the combination of asphalt and aggregate that will provide long-term pavement performance for each part of the pavement structure [6]. AC mixture as pavement layer should have the following characteristics:

- Stability; the ability of asphalt mixes against plastic deformation or permanent deformation due to traffic loads.
- Durability; Durability of a pavement layer against disintegration due to traffic loads and the effects of weather changes, without experiencing the removal of asphalt films from aggregate granules.
- Flexibility; Pliability or flexibility is the asphalt mixture must be able to accommodate permanent deflection within certain limits without experiencing cracks.
- Fatigue resistance; Fatigue resistance is the resistance of asphalt mixes in resisting deflection loads caused by repetitive traffic loads so that the mixture does not experience cracks.
- Skid resistance; Surface roughness or resistance to skid is surface layer must have a high enough roughness, so as to ensure the safety of road users, especially when in wet conditions.
- Impermeability; Impermeability or water-resistant is an ability of asphalt mixture to the entry of water and air.
- Workability; Workability is the asphalt mixture must be easily carried out in the implementation of the fields for its overlay and compacting.

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 [6]. Desired mixtures can be obtained through gradually blend the two fractions; nevertheless, it can also be calculated by using below formula:

\[ P = aA + bB + cC \] (1)

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

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

Formula to estimate design asphalt percentage:

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

Where:
- \( Pb \) = Mid level of asphalt content/ideal percentage against the weight of 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;
- 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].
From the calculation, the plan Pb asphalt content is obtained with two variations of asphalt content above Pb and two variations of asphalt content below Pb (\(-1.0\%; -0.5\%; P; + 0.5\%; + 1\%)).

\[
Pb = 0.035(50\%)+0.045(43\%)+0.18(7\%) + 0.73 = 6\%
\]

| Aggregate | Aggregate weight restrained | Variation of Asphalt content (gr) |
|-----------|-----------------------------|----------------------------------|
| Sieve size | Specification | % pass | % restrained | % restrained cum. | 5.0% | 5.5% | 6.0% | 6.5% | 7.0% |
| 1 1/2" (37.5 mm) | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1" (25mm) | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CA | 3/4" (19,0 mm) | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/2" (12,5 mm) | 90-100 | 90.0 | 10.0 | 10.0 | 114 | 113.4 | 112.8 | 112.2 | 111.6 |
| 3/8" (9,5 mm) | 77-90 | 78 | 12.0 | 22.0 | 136.8 | 136.08 | 135.36 | 134.64 | 133.92 |
| NO 4 (4,75 mm) | 53-69 | 65.00 | 13.00 | 35.0 | 148.2 | 147.42 | 146.64 | 145.86 | 145.08 |
| NO.8 (2,36 mm) | 33-53 | 50.00 | 15.00 | 50.0 | 171 | 170.1 | 169.2 | 168.3 | 167.4 |
| FA | No.16 (1.18 mm) | 21-40 | 40.00 | 10.00 | 60.0 | 114 | 113.4 | 112.8 | 112.2 | 111.6 |
| No.30 (0.6 mm) | 14-30 | 30.00 | 10.00 | 70.0 | 114 | 113.4 | 112.8 | 112.2 | 111.6 |
| No.50 (0.3 mm) | 9-22 | 19.00 | 11 | 81.0 | 125.4 | 124.74 | 124.08 | 123.42 | 122.76 |
| No.100 (0.15 mm) | 6-15 | 11.00 | 8.00 | 89.0 | 91.2 | 90.72 | 90.24 | 89.76 | 89.28 |
| No.200 (0.75 mm) | 4-9 | 7.00 | 4 | 93.0 | 45.6 | 45.36 | 45.12 | 44.88 | 44.64 |
| Total Percent restrained aggregate | 93 | 1,060.2 | 1,054.62 | 1,049 | 1,043.46 | 1,037.88 |
| Filler (coal fly ash/lokan shells) | 7 | 7 | 79.8 | 79.38 | 78.96 | 78.54 | 78.12 |
| Aggregate weight (gr) | 100 | 1140.0 | 1,134.0 | 1,128.0 | 1,122.0 | 1,116.0 |
| Asphalt weight (gr) | 60 | 66 | 72 | 78 | 84 |
| Mixed weight (gr) | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 |

2.2.2. Samples and test - Specimens to find the optimum asphalt content (OAC). Tested specimens were created from Asphalt Concrete - Wearing Course (AC-WC) mixture contains coal fly ash and lokan shells as filler. AC-WC 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 and hard asphalt [5]. Marshall Evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC). The characteristics of asphalt concrete mix can be checked using Marshall Equipment. This check is intended to determine the resistance (stability) to the plastic discharge (flow) of the asphalt mixture. Comparison between stability and melt ability is known as Marshall Quotient, which is a picture of stiffness which is a measure of the resistance of a test object to deformation. Performance of solid asphalt concrete is determined through testing of specimens which includes determining the weight of the specimen volume, testing the value...
of stability, testing the melt ability, testing Marshall Quotient, calculating various types of pore volume in solid asphalt concrete (VIM, VMA, and VFA) and thick blanket or asphalt film [5].

Marshall Equipment is a pressure device equipped with a proving ring with a capacity of 22.2 KN (5,000 lbf) and a flow meter. Proving ring is used to measure the value of stability and flow meter to measure plastic discharge or flow. Marshall Specimens are cylindrical with a diameter of 4 inches (= 10.2 cm) and a height of 2.5 inches. Marshall testing procedures follow SNI 06-2489-1991, or AASHTO T 245-90, or ASTM D 1559-76.

![Figure 3. Marshall Test](image1)

![Figure 4. Specimens](image2)

The test specimen is made using filler variations in accordance with the mix design plan contained. The specimen is made into 3 different variations, namely:

a. Addition of coal fly ash filler 100% and lokan shell filler 0% for Variation 1 (15 specimen);
b. Addition of 70% coal fly ash filler and 30% lokan shell filler for Variation 2 (15 specimen);
c. Addition of coal fly ash filler 30% and shellkan filler 70% for Variation 3 (15 specimen).

*Samples on the optimum asphalt content (OAC)*

After getting the OAC value, 9 Specimens with variation content of coal fly ash and lokan shells with the mixture of AC-WC on OAC. Specimens were water-bathed for 30 minutes in normal stability.

3. Result and discussion

3.1. *Marshall Evaluation in the Mixture of AC WC with pen 60/70 content variation using coal fly ash and lokan shells as filler to investigate Optimum Asphalt Content (OAC).*

Table 5, Table 6 and Table 7 shows that specimens of AC WC mixture with varied content of pen 60/70 (5; 5.5; 6; 6.5; 7); these specimens did contain coal fly ash and lokan shells. Marshall Evaluation was carried out on the specimens to investigate their OAC.
Marshall Evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC). We got 6.52% OAC for 0/100% variation of filler; 6% OAC for 70/30% variation of filler; and 6.5 OAC for 30/70% of filler.

3.2 Marshall Evaluation in the Mixture of AC WC with asphalt pen 60/70 on OAC using coal fly ash and lokan shells as filler.

Table 8, 9 and 10 shows that stability value on the AC-WC blend with coal fly ash and lokan shells were acquiescent to the required specification. 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); VIM Value conducted on the AC-WC blend with coal fly ash and lokan shells were not acquiescent to the required specification; Marshall quotient value is acquiescent to the required specification, 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.

**Table 8.** Recapitulation of Marshall test in the Mixture of AC WC with pen 60/70 on OAC using 100/0 % coal fly ash and lokan shells as filler.

| NO | Mixture Characteristic | OAC Coal fly ash and Lokan shells (6.52) | Dept.PU |
|----|------------------------|-----------------------------------------|---------|
| 1. | Stability (kg)         | 1389.158                                | >800 kg |
| 2. | Flow Plastis (mm)      | 5.5                                     | min 3 mm|
| 3. | MQ (Kg)                | 252.574                                 | >250 kg/mm|
| 4. | VIM (%)                | 3.39                                    | 3.5-5.5 %|
| 5. | VMA (%)                | 16.97                                   | > 15 %  |
| 6. | VFB (%)                | 74.04                                   | >65 %    |

**Table 9.** Recapitulation of Marshall test in the Mixture of AC WC with pen 60/70 on OAC using 70/30 % coal fly ash and lokan shells as filler.

| NO | Mixture Characteristic | OAC Coal fly ash and Lokan shells (6) | Dept.PU |
|----|------------------------|---------------------------------------|---------|
| 1. | Stability (kg)         | 889.44                                 | >800 kg |
| 2. | Flow Plastis (mm)      | 3.10                                   | min 3 mm|
| 3. | MQ (Kg)                | 286.92                                 | >250 kg/mm|
| 4. | VIM (%)                | 5.46                                   | 3.5-5.5 %|
| 5. | VMA (%)                | 16.92                                   | > 15 %  |
| 6. | VFB (%)                | 67.74                                   | >65 %    |

**Table 10.** Recapitulation of Marshall test in the Mixture of AC WC with pen 60/70 on OAC using 30/70 % coal fly ash and lokan shells as filler.

| NO | Mixture Characteristic | OAC Coal fly ash and Lokan shells (6.5) | Dept.PU |
|----|------------------------|----------------------------------------|---------|
| 1. | Stability (kg)         | 916.53                                 | >800 kg |
| 2. | Flow Plastis (mm)      | 3.5                                    | min 3 mm|
| 3. | MQ (Kg)                | 261.87                                 | >250 kg/mm|
| 4. | VIM (%)                | 3.03                                   | 3.5-5.5 %|
| 5. | VMA (%)                | 15.70                                   | > 15 %  |
| 6. | VFB (%)                | 80.69                                   | >65 %    |

3.3 Marshall Test conducted on varied composition of mixture within Optimum Asphalt Content (OAC) using coal fly ash and lokan shells as filler.
The stability value that occurs in the AC-WC mixture at all variations in the percentage of filler coal fly ash and lokan shells meets the requirements determined by the Bina Marga Specification, this is ≥ 800 kg. In the 70/30 coal fly ash and lokan shells percentage the stability value was decreased, but in the 30/70 percentage the stability value increased again. It can be seen that variations affect the stability value. The lower the percentage of use of one type of filler does not always reduce the value of stability.

Marshall Quotient value is the quotient between stability and flow which identifies the stiffness and flexibility of an asphalt concrete mixture. Asphalt concrete mixture which has high Marshall Quotient value, shows that the layer is less flexible and stiff and if the value is lower than the asphalt concrete mixture is more flexible and flexible from 250 kg / mm. The Marshall Quotient value is influenced by the stability value and flow value of the mixture. The Marshall Quotient value is negatively correlated with the flow value, the decrease in flow value causes the Marshall Quotient value to increase and if the flow value is higher, the Marshall Quotient will be lower. The highest Marshall Quotient value was obtained for a 70/30 mixture because the flow value was the lowest.

4. Conclusions
1. Marshall evaluation was carried out on the specimens to investigate their Optimum Asphalt Content (OAC). We got 6.52% OAC for V1 variation of filler; 6% OAC for V2 variation of filler; and 6.5 OAC for V3 of filler.
2. The Maximum stability value is obtained from variations in the use of 100% coal fly ash, which is 1,389.158 kg.
3. Marshall test conducted on the AC-WC blend on OAC for the mixture variation of V1, V2, V3, disclosed that Stability, flow, MQ, VMA and VFB values were acquiescent to the required specification.
4. VIM values on variations of V1 and V3 were not acquiescent to the required specification.

5. References
[1] Sukirman 1999 Highway Flexible Pavement Nova Bandung 41 44 60 177 246
[2] Department of Public Work 2010 Section 6.3 Spesifikasi Campuran Beraspal Panas Direktorat Jenderal Bina Marga Departemen PU Jakarta 6 37
Acknowledgments

In this opportunity, I would like to thank my family and my colleagues for their support and encouragement and my gratitude to the very assistive member in this writing paper. This research was funded by research institutions and community service Teuku Umar University West Aceh, beginner lecturer research.