Immersion index HRS -WC Halp-Gap gradation with oil palm waste filler substitution

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Abstract. The purpose of this study was to analyze the effect of adding ash from palm oil waste as a substitute for filler material from cement on the immersion index of the HRS-WC mixture using semi-gap gradations. The bitumen content used was 5.9%; 6.4%; 6.9%; 7.4% and 7.9%. Meanwhile, the proportion of oil palm ash waste to cement is 0%: 100%, 25%: 75%, 50%: 50%, 75%: 25% and 100%: 0%. The test results show the effect of adding CPO filler content on asphalt content, the higher the percentage of addition of asphalt content, the number of cavities in the mixture, the smaller the cavities in the aggregate and the more cavities filled with asphalt, up to the addition of 50% CPO content, then 50% CPO increase up to 100% reduced asphalt tar voids. The Marshall Immersion test obtained the immersion index for the Lataston HRS-WC mixture with a semi-gap gradation using CPO Waste Ash as a cement substitute material, it is susceptible to water, this is because even though the mixed cavity is filled with CPO Waste Ash, but effective asphalt which also functions to waterproof the mixture will have reduced. So that if you use CPO waste ash as a substitute for cement filler, the use of asphalt content must also be large (added). The semi-gap gradation in the Lataston HRS-WC mixture also affects the level of water tightness, where the semi-gap gradation will form a denser mixture so that it becomes more waterproof.

1. Introduction

The development of the palm oil processing industry in Indonesia is currently growing rapidly from year to year. The development of this industry will have an impact on the accumulation of solid waste generated from processing fresh fruit bunches from oil palm. The resulting waste is in the form of empty shells, coir and bunches. In the processing industry, fiber and coir are used as boiler fuel for mechanical energy and heat. The problem that arises is that the residue from the boiler combustion is in the form of ash from the combustion that will accumulate in industrial locations. Oil palm shell ash contains a large amount of silica, so the ash from the oil palm shell is very dangerous to human health when inhaled through breathing [1].

In this study, the shell ash will be used as a substitute for filler material which has been using rock ash or cement which is quite expensive. Filler is a hot mixture of asphalt. Although the filler is already present in coarse aggregate and fine aggregate, the filler content is very small so it is necessary to add filler [2] - [3]. Filler is a material that has an important role in the HRS-WC mixture besides aggregate and asphalt. This is because the filler functions as a filler for cavities in the asphalt mixture so that the air cavity becomes smaller and results in high friction resistance and interlocking between aggregates. The quality of the filler in the mixture will affect stability due to reduction of air void spaces and make
the asphalt more sticky, thereby increasing its strength [4]. The amount of filler used in the mixture is limited because a lot of filler will cause the mixture to be stiffer and crack more easily. Conversely, a small amount of filler makes the mixture more pliable and easy to deform.

To improve the performance of the mixture, it can be done by modifying the physical properties of the asphalt, especially its penetration and softening point, by using additives so that it is expected to reduce the sensitivity of the bitumen to temperature and its elasticity. The use of palm oil waste ash, namely fibers and shells, as a filler aggregate in the Hot Rolled Sheet (HRS) mixture is possible to obtain a mixture with more stable characteristics. One of the characteristics of the asphalt concrete mixture is durability. This property is related to the resistance of a mixture from destruction (disintegration) due to the influence of weather, water or traffic loads. The nature of durability (durability or durability) on the surface layer is needed to be able to withstand the wear and tear that occurs due to the influence of weather, water and changes in temperature or wear caused by vehicle wheel friction.

One of the factors that can affect the decreased durability of a mixture (asphalt layer) is water. If an asphalt layer is always submerged by water, the durability of the mixture will decrease. Another factor that can affect the durability of the mixture (asphalt) is compaction. To see the potential for durability caused by these two factors, it can be measured through a durability index. Durability is the ability of a bituminous mixture to continuously resist the effects of water and temperature. HRS (Hot Rolled Sheet) or Lataston is a non-structural surface layer that has an aggregate of gaps and half-gaps [5]. HRS has high flexibility properties and is resistant to melting and serves as a cover layer to prevent water from entering the surface into the pavement construction so as to maintain the strength of the construction to a certain degree.

Pavement with Lataston HRS is aimed at considerations of unstable road foundations and economic considerations for light traffic loads with load repetitions ≤ 1 million ESA [6]. The mixture of Lataston (HRS) which is non-structural in nature and as a wear and watertight layer with the aggregate arrangement is graded gap and semi-gaps in almost the same mixing, the difference is that the aggregate grading size is incomplete or there is no aggregate fraction in the gaps gradation which is aimed at considering aggregate limitations. Smooth. So that the performance of the mixture of Lataston HRS graded gaps and semi gaps can only be distinguished on the characteristics of the marshall characteristics, namely Stability, Flow, Marshall Quotint, VMA, VFB and VIM [7].

Pavement with HRS is suitable to be applied in Indonesia because it has high flexibility and is resistant to melting considering that Indonesia is a tropical country with quite high hot temperatures [8]. As a non-structural layer containing more fine aggregate and asphalt, the structural strength of the HRS-WC mixture is prone to plastic deformation with the appearance of grooves on the asphalt surface. Therefore, the quality of HRS-WC needs to be improved through new specifications and the type of material used must have good physical and mechanical properties.

Research on the use of waste as a substitute for road pavement includes The Effect of Additional Sugar Palm Fibers on the Durability of Mixed Laston AC-WC [9]. Study of Laston BC Durability and Permeability Using Coconut Shell Addition Materials [10]. Study of HRS-WC Mixture Performance Using the Waste of Crude Palm Oil Ash as Filler [11]. The Effect of Rattan Fiber Use on Stability and Durability for Lataston Additive [12]. Characteristics of HRS - BASE Mixture Using Dolomite Powder As Filler [13]. Study of the Use Bagasse Ash as a Filler Replacement to Characteristics Asphalt Concrete [14]. Effect of Collision Variation towards the Index Retained Strength of Mixed Asphalt Concrete Wearing Course [15].

The purpose of this study was to analyze the effect of adding ash from palm oil waste as a substitute for filler material from cement on the immersion index of the HRS-WC mixture using semi-gap gradations. The bitumen content used was 5.9%; 6.4%; 6.9%; 7.4% and 7.9%. Meanwhile, the proportion of oil palm ash waste to cement is 0%: 100%, 25%: 75%, 50%: 50%, 75%: 25% and 100%: 0%.

2. Methodology
The methodology used in this research is that the stages of the research are divided into four main parts, namely preparation and testing of materials, preparation of a semi-graded Lataston HRS-WC mix design, manufacturing and checking the characteristics of the mixture and analyzing the results of mixed testing.

2.1 Location of material
Taking material in this study for coarse aggregate material, fine aggregate using the Bili-bili aggregate of the Jeneberang river, Gowa Regency and ex Pertamina asphalt with Pen 60/70 and the filler used is the production of Semen Tonasa. Palm Oil Waste (CPO) uses palm oil processing waste from Bone-bone District, East Luwu Regency.

2.2 Testing Standards
Examination of material characteristics is the characteristics of coarse aggregate, fine aggregate characteristics, filler and asphalt. Examination of characteristics and limitations using SNI stipulated in the specifications of Bina Marga 2018 Division 6 Revision 1 [7]. Examination of the characteristics of coarse and fine aggregates is the Abrasion Inspection with a Los Angeles machine with SNI 2417: 2008, adhesiveness of aggregates to asphalt with SNI 2439: 2011, Broken Grains on Coarse Aggregates with SNI 7619: 2012, Flat and Oval Particles with ASTM D4791-10 Comparison of 1: 5, Material passing No.200 sieve with SNI ASTM C117: 2012, Sand Equivalent Value with SNI 03-4428-1997, Clumps of Clay and Crumbling Grains in Aggregate with SNI 03-4141-1996, Aggregate Passing Sieve No.200 SNI ASTM C117: 2012. Inspection of asphalt characteristics of asphalt penetration at 25OC (0.1 mm) with SNI 2456: 2011, Ductility at 25OC, (cm) with SNI 2432: 2011, Flash Point (OC) with SNI 2433: 2011, Specific Gravity with SNI 2441: 2011, Weight Loss (%) with SNI 06-2441-1991, Penetration at 25OC (% originally) with SNI 2456: 2011, Ductility at 25OC (cm) with SNI 2432: 2011

2.3 Mixed Composition
The composition of the gaps in the mixture design for HRS-WC is divided into three fractions, namely: coarse aggregate fraction, fine aggregate fraction and filler fraction, where the size of the total aggregate weight fraction used in the mixture is 1200 grams with the composition can be seen in table 1.

| Material            | 5.9  | 6.4  | 6.9  | 7.4  | 7.9  |
|---------------------|------|------|------|------|------|
| Coarse Aggregate (gr)| 321.77 | 320.01 | 318.33 | 316.49 | 314.74 |

Figure 1. Palm shell ash
2.4 Mixed Characteristics
This examination is performed to determine the resistance and strength (stability) to the plastic melt (flow) of the asphalt mixture. Resistance and strength (stability) is the ability of an asphalt mixture to accept loads until plastic melt occurs which is expressed in kilograms or pounds. Plastic melt (flow) is a state change in the form of an originating mixture that occurs due to a load up to the time limit expressed in mm or 0.01 " . The performance of the LATASTON mixture can be checked using a Marshall test kit following the standard procedure for testing Lataston's properties in the 2018 Highways specification [7].

2.5 Determination of the Optimum Asphalt Content
Determination of the optimum asphalt content is based on the results of the conventional Marshall test, then averaged the asphalt content values that meet the requirements. After the Optimum Asphalt Level was determined, a mixture design and test specimens were made using variations in the proportion of Oil Palm Waste Ash (CPO) filler as a substitute for cement filler as much as 0%, 25%, 50%, 75%, and 100% of the filler content at mixture with the Optimum Asphalt Content. The Lataston mixture using CPO ash filler as a cement filler substitution, then tested to get the characteristic value using the Marshall tool, then analyzed the characteristics of the mixture according to the specifications contained in the specifications used. Based on the analysis of the mixture, the optimum CPO waste ash filler content was determined as a cement filler substitute.

2.6 Immersion Index
After determining the optimum asphalt content, the next step is to make a test difference based on the optimum bitumen content, then soak it for ± 24 hours at a temperature of ± 60˚C. To get the immersion index value / residual strength index of the mixture. The immersion index was obtained from the percentage comparison between Marshall Immersion and conventional Marshall.

3. Result and Discussion
3.1 Asphalt content 5.9%
At 5.9% asphalt content with oil palm waste (CPO) ash filler content (CPO) 0%, 25%, 50%, 75% and 100% as in table 2, it shows the results, for VIM all values of filler content meet the requirements high water resistance reduces the water resistance, thus accelerating the aging of the asphalt and reducing its durability. Conversely, if the air cavity in the mixture is low, the pavement will experience bleeding. Furthermore, the VMA value that meets the requirements is the substitution of 75% filler content with a value of 18.06%. This may occur because the more filler content can fill the voids between the aggregates, so that the voids in the mineral aggregates are small. Furthermore, the VFB values of all filler substitutions meet the requirements as well as the stability and MQ values all of which meet the requirements. From table 2, it can be seen that the use of asphalt content of 5.9% in the AC_WC mixture can only use a substitution of the ash filler content of oil palm waste by 75%. Because the VMA value shows the smaller the VMA the higher the level of durability, but the value of the analysis results shows, below the allowable value, this happens because of the low asphalt content.

Table 2. The results of the analysis on the asphalt content of 5.9%
Mixed characteristics

| CPO filler content (%) | 0.00 | 25.00 | 50.00 | 75.00 | 100.00 |
|------------------------|------|-------|-------|-------|--------|
| VIM (%)                | 4.96 | 5.34  | 5.65  | 5.79  | 5.59   |
| VMA (%)                | 17.29| 17.57 | 17.89 | 18.06 | 17.94  |
| VFB (%)                | 71.29| 69.62 | 68.41 | 67.92 | 68.85  |
| Stabilities (kg)       | 2,219.46| 2,588.75| 2,400.41| 2,138.21| 1,676.59 |
| M Q (kg/mm)            | 687.25| 756.91| 740.91| 644.18| 490.37 |

3.2 Asphalt content 6.4%

From table 3 it can be seen that the use of asphalt content of 6.4% with substitution of oil palm ash filler content (CPO) 0%, 25%, 50%, 75% and 100% for the AC-WC mixture all values of the mixture characteristics such as VIM, VMA, VFB, Stability and MQ meet the requirements. From Table 3, it can be seen that the cavity value in the mixture increases with the addition of CPO filler substitution to the addition of CPO by 75%, then the addition of up to 100% CPO content in the cavity decreases again, this also happens to VMA. The addition of CPO filler content into the mixture tends to cause the void value in the mixture to decrease, this is because the existing cavity is filled with more filler. The high air cavity in the mixture causes reduced water resistance, thereby accelerating the aging of the asphalt and reducing its durability.

Conversely, if the air cavity in the low mixture causes the pavement to bleed, this does not happen at the asphalt content of 6.4%. Another case happened in the volume of voids filled with asphalt the increasing content of the CPO filler. The volume of voids filled with asphalt decreased until 75% CPO filler substitution, then VFB increased until the increase in CPO filler content was up to 100%. This may occur because the more filler content can fill the voids between the aggregates, so that the voids in the mineral aggregates are small. The smaller the voids in the mineral aggregate, the higher the level of durability. CPO filler substitution shows the better ability to accept loads without changing shape. This can be seen in Table 3, all the resulting values meet the requirements. Marshall Quotient shows that the mixture is stiffer and less deformable, and shows that the mixture is more resistant to shear or abrasion. This rigidity serves to provide a friction force on the wheels of the vehicle so that it does not slip, especially during wet conditions.

Table 3. The results of the analysis on the asphalt content of 6.4%

| Mixed characteristics | CPO filler content (%) | 0.00 | 25.00 | 50.00 | 75.00 | 100.00 |
|------------------------|-----------------------|------|-------|-------|-------|--------|
| VIM (%)                | 4.64                  | 5.00 | 5.33  | 5.43  | 5.26  |
| VMA (%)                | 18.09                 | 18.35| 18.68 | 18.82 | 18.73 |
| VFB (%)                | 74.34                 | 72.73| 71.48 | 71.14 | 71.96 |
| Stability (kg)         | 2,651.53              | 3,079.91| 2,825.10| 2,444.73| 1,894.48 |
| M Q (kg/mm)            | 786.38                | 942.58| 839.42| 708.25| 537.98 |

3.3 Asphalt content 6.9%

From table 4 it can be seen, the VIM value before substitution of CPO filler content (0%) shows the volume of cavities in the mixture is 4.22%, after adding CPO filler by 25% the cavity in the mixture increases 0.63% and the addition of 50% the content of cavity CPO filler in the mixture increases. 0.19% to 5.04% then the addition of 75% cavity CPO content in the mixture was reduced to 4.99% as well as the addition of 100% CPO waste content, the cavity in the mixture was reduced to 4.62%. The effect of CPO filler substitution on VMA is the same as VIM because the increase in cavities in the mixture also affects the number of voids that cover the asphalt. The cavity in the asphalt mixture in the form of a cavity in the mixture between the aggregate (VIM) and the cavity in the aggregate (VMA)
will be more easily filled with asphalt if more asphalt is used, but if the use of CPO Waste ash filler increases, the cavity will be difficult to fill with asphalt due to the volume of the filler.

Large CPO ash causes a lot of asphalt to be absorbed. This can be seen in table 4 where the Void Field with Bitumen value before the CPO filler substitution with a value of 77.55%, after adding the CPO filler content by 25%, the VFB value decreases to reach a value of 74.82%, the decrease in VFB volume is up to 50% substitution, then the addition of up to with 100% VFB volume will rise again until it reaches 76.28%. The stability value with the addition of filler content of 25% CPO increased, then the addition of 50% to 100% decreased the stability value. CPO ash as filler will help increase the strength/stability of the mixture at 25% cement filler substitution.

Whereas in a mixture of 50% -100% CPO ash filler the stability is reduced due to reduced bonds between aggregates. This is because the finer CPO ash filler will make the density of the mixture increase so that the stability increases, but if the CPO ash filler is more and more, the aggregate bond is reduced due to the need for more asphalt the greater the mix asphalt content with the same proportion of CPO ash filler then stability mix increased. The MQ value shows the same phenomenon as stability. This MQ shows the mixture is more resistant to shear or abrasive.

### Table 4. The results of the analysis on the asphalt content of 6.9%

| Mixed characteristics | 0.00 | 25.00 | 50.00 | 75.00 | 100.00 |
|-----------------------|------|-------|-------|-------|--------|
| VIM (%)               | 4.22 | 4.85  | 5.04  | 4.99  | 4.62   |
| VMA (%)               | 18.80| 19.28 | 19.50 | 19.51 | 19.25  |
| VFB (%)               | 77.55| 74.82 | 74.13 | 74.44 | 76.28  |
| Stability (kg)        | 2,020.04 | 2,352.40 | 2,271.16 | 1,850.16 | 1,525.18 |
| MQ (kg/mm)            | 580.17 | 701.82 | 655.70 | 520.00 | 418.34 |

3.4 Asphalt content 7.4%

From table 5, it can be seen that the use of asphalt content of 7.4% with substitution of oil palm ash filler content (CPO) 0%, 25%, 50%, 75% and 100% all values of the characteristics of the mixture such as VIM, VMA, VFB, Stability and MQ meet the requirements. From Table 5, it can be seen that the cavity value in the mixture increases with the addition of CPO filler substitution to the addition of 75% CPO to reach a volume of 4.87%, then the addition of up to 100% CPO content in the cavity in the mixture again decreases to 4.69%, this also happens to VMA. The addition of CPO filler content into the mixture tends to cause the void value in the mixture to decrease, this is because the existing cavity is filled with more filler.

The high air cavity in the mixture causes reduced water resistance, thereby accelerating the aging of the asphalt and reducing its durability. On the other hand, if the air cavity in the low mixture causes the pavement to bleed, this does not happen at 7.4 % asphalt levels. Another case happened in the volume of voids filled with asphalt the increasing content of the CPO filler. The volume of voids filled with asphalt decreased until 75% CPO filler substitution, then VFB increased until the increase in CPO filler content was up to 100%. This may occur because the more filler content can fill the voids between the aggregates, so that the voids in the mineral aggregates are small. The smaller the voids in the mineral aggregate, the higher the level of durability.

CPO filler substitution shows the better ability to accept loads without changing shape. This can be seen in Table 5, all the resulting values meet the requirements. Marshall Quotient shows that the mixture is stiffer and less deformable, and shows that the mixture is more resistant to shear or abrasion. This rigidity serves to provide a friction force on the wheels of the vehicle so that it does not slip, especially during wet conditions.

### Table 5. The results of the analysis on the asphalt content of 7.4%

| Mixed CPO filler content (%) |      |
|-------------------------------|------|
|                               | 0.00 | 25.00 | 50.00 | 75.00 | 100.00 |
| VIM (%)                       | 4.22 | 4.85  | 5.04  | 4.99  | 4.62   |
| VMA (%)                       | 18.80| 19.28 | 19.50 | 19.51 | 19.25  |
| VFB (%)                       | 77.55| 74.82 | 74.13 | 74.44 | 76.28  |
| Stability (kg)                | 2,020.04 | 2,352.40 | 2,271.16 | 1,850.16 | 1,525.18 |
| MQ (kg/mm)                    | 580.17 | 701.82 | 655.70 | 520.00 | 418.34 |
From table 6, it can be seen that the VIM value before substitution of CPO filler content (0%) indicates the volume of cavities in the mixture is 4.22%, after adding CPO filler by 25% the cavity in the mixture increases 0.63% and the addition of 50% the content of cavity CPO filler in the mixture increases. 0.19% to 5.04% then the addition of 75% cavity CPO content in the mixture was reduced to 4.99% as well as the addition of 100% CPO waste content the cavity in the mixture was reduced to 4.62%. The effect of CPO filler substitution on VMA is the same as VIM because the increase in cavities in the mixture also affects the number of voids that cover the asphalt.

The cavity in the asphalt mixture in the form of a cavity in the mixture between the aggregate (VIM) and the cavity in the aggregate (VMA) will be more easily filled with asphalt if more asphalt is used, but if the use of CPO Waste ash filler increases, the cavity will be difficult to fill with asphalt due to the volume of the filler. Large CPO ash causes a lot of asphalt to be absorbed. This can be seen in table 6 where the Void Field with Bitumen value before the CPO filler substitution with a value of 77.55%, after adding the CPO filler content by 25%, the VFB value decreases to reach a value of 74.82%, the decrease in VFB volume is up to 50% substitution, then the addition of up to with 100% VFB volume will rise again until it reaches 76.28%.

The stability value with the addition of filler content of 25% CPO increased, then the addition of 50% to 100% decreased the stability value. CPO ash as filler will help increase the strength / stability of the mixture at 25% cement filler substitution. Whereas in a mixture of 50% -100% CPO ash filler the stability is reduced due to reduced bonds between aggregates. This is because the finer CPO ash filler will make the density of the mixture increase so that the stability increases, but if the CPO ash filler is more and more, the aggregate bond is reduced due to the need for more asphalt the greater the mix asphalt content with the same proportion of CPO ash filler then stability, mix increased. The MQ value shows the same phenomenon as stability. This MQ shows the mixture is more resistant to shear or abrasive.

### Table 6. The results of the analysis on the asphalt content of 7.9%

| Mixed characteristics | 0.00 | 25.00 | 50.00 | 75.00 | 100.00 |
|-----------------------|------|-------|-------|-------|--------|
| VIM (%)               | 4.06 | 4.55  | 4.83  | 4.87  | 4.69   |
| VMA (%)               | 19.72| 20.07 | 20.36 | 20.46 | 20.37  |
| VFB (%)               | 79.40| 77.38 | 76.29 | 76.18 | 77.07  |
| Stabilities (kg)      | 1,876.01| 2,263.77| 2,234.23| 1,857.55| 1,251.91|
| M Q (kg/mm)           | 521.76| 649.14| 626.24| 507.84| 335.81 |

### 3.6 Immersion Index
Immersion index analysis was carried out on variations in the asphalt content (AC) of 6.4%, 6.9%, 7.4% and 7.9%, where the asphalt content is considered to meet the characteristics of the mixture. While the asphalt content of 5.9% does not meet the characteristics of the mixture. This test is carried...
out on Soaking Index for Lataston HRS-WC mixture at asphalt content of 6.33% and 6.75% by substituting cement CPO filler using CPO waste ash filler as much as 50% to 100% does not meet specifications, but at asphalt content 7.18% still meets specifications until the use of 50% CPO waste ash and 7.6% asphalt content of the mixture is still watertight to 75% CPO waste ash, which is at least 90%.

Immersion Index shows the ability of the Lataston HRS-WC Mixture to maintain its strength from the load when submerged in water. The use of more bitumen content in the Lataston HRS-WC Mixture will form a more water-resistant mixture so that the mixture's durability will be better. If the use of CPO waste ash as a substitute for cement filler is increasing, then with a large volume it will cause the cavity of the mixture to get bigger so that the tightness decreases which results in the mixture becoming not water-resistant. The semi-gap gradation in the Lataston HRS-WC mixture also affects the level of water tightness, where the semi-gap gradation will form a denser mixture so that it becomes more waterproof.

![Figure 2. Immersion Index For The Addition Of The CPO Filler](image)

4. Conclusion
The effect of adding CPO filler content to asphalt content, the higher the percentage of addition of asphalt content, the number of cavities in the mixture, the smaller the cavities in the aggregate and the more cavities filled with asphalt until the addition of 50% CPO content then the increase in CPO 50% to 100% cavities reduced bitumen dust. Marshall Immersion test results obtained the immersion index of the Lataston HRS-WC mixture with a semi-graded gradation using CPO Waste Ash as a cement substitute material, susceptible to water, this is because even though the cavity of the mixture is filled with CPO Waste Ash, but effective asphalt which also functions to waterproof the mixture will decrease. So that if you use CPO waste ash as a substitute for cement filler, the use of asphalt content must also be large (added). The semi-gap gradation in the Lataston HRS-WC mixture also affects the level of water tightness, where the semi-gap gradation will form a denser mixture so that it becomes more waterproof.

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