Study of HRS-WC mixture performance using the waste of crude palm oil ash as filler

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Abstract. Filler has an important role in the HRS-WC mixture besides aggregates and asphalt due to its functions to fill the void in the asphalt mixture so that it could produce more friction resistance and high interlocking aggregate. The use of filler in the mixture is limited in number because too much filler will lead to the stiffer and easily cracked mixture. On the contrary, the lower values could lead to the easily deformed and too flexible mixture. Previous researchers have studied the use of the waste of crude palm oil (CPO) ash as a filler. This research aims to study the performance of the HRS-WC mixture using CPO ash as a filler. The asphalt content used was 5.9%; 6.33%; 6.75%; 7.18%; and 7.6%, while the proportion of CPO ash waste is 0%, 25%, 50%, 75%, and 100%. The mixture gradation is made using a gap-graded and half gap-graded mixture. The results showed that the stability is higher when 25% of CPO ash proportion is used, but it is decreased again when the proportion is larger than 25%. The use of a small asphalt content will increase the value of VIM. The flow value decreases when 32% of CPO ash proportion is used and increases again over the use of 32%. The use of a large amount of CPO ash filler in the mixture will increase VMA. While the VFB will decrease if the larger amount of CPO ash is used. The immersion index of the mixture can still be maintained even when the use of CPO ash is increased. The use of CPO ash as a substitute for filler in the HRS mixture - WC must be balanced with the increasing of asphalt mixture.

1. Introduction
Hot Rolled Sheet (HRS) is one of the road pavement layers consisting of a mixture of hard asphalt, aggregates with variable gradations, and fillers. These fillers are mixed, spread, and compacted at certain temperatures and conditions with a thickness between 2.5 to 3 cm [1]. The relatively high asphalt content in the mixture aims to increase the flexibility, durability, and resistance for creating a mixture that is not easily cracked. The using of HRS in the pavement is suitable to be applied in Indonesia because it has high flexibility. It is also melting-resistance, considering that Indonesia is a tropical climate country [2]. As a non-structural layer containing more fine aggregate and asphalt content, the strength of the HRS-WC mixture is easily subjected to plastic deformation affecting the appearance of grooves on the asphalt surface [3]. Therefore, its quality needs to be improved. The type of material used should also have good physical and mechanical properties. Filler has an important role in the HRS-WC mixture besides aggregates and asphalt due to its functions to fill the void in the asphalt mixture so that it could produce more friction resistance and high interlocking aggregate. The quality of the filler in the mixture would affect the stability due to the void reduction [4]. The void
reduction will lead to the denser mixture and finally increasing its strength. The use of filler in the mixture is limited in number because too much filler will lead to the stiffer and easily cracked mixture. While the lower values could lead to the easily deformed and too flexible mixture [5].

Nuswantoro 2003 [6] investigated the use of crude palm shell (CPS)-ash as an additional filler in HRS. The optimum mixture composition is split stone 33%, fly-ash 26.5%, sand 36%, and CPS-ash 4.5%, with the optimum asphalt content around 7.59%. The effect of the use of CPS-ash as filler material on the characteristics of Marshall in AC-WC mixtures [7]. It shows that both the Portland cement (PC) and CPS-ash filler properties have different characteristics. The use of PC filler has a stability value of 2025.2 kg with Optimum Asphalt Content (OAC) 6%, while the use of CPS-ash filler has a stability value of 1844 kg with the same OAC 6%. The effect of CPS-ash filler in the AC-WC mixture [8]. The Marshall and Wheel Tracking Test results showed that the OAC value is 5.5% and the optimum filler content value is around 3%. The stability value with 7% PC filler is 959,057 kg, while it is around 1017,693 kg with a 7% CPS-ash filler by immersing the specimens for 30 minutes at 60°C [8]. The dynamic stability value is 2739.1 trajectory/mm for PC filler and 2520.0 trajectories/mm for CPS-ash filler.

This study aims to know the performance of the HRS-WC mixture using crude oil palm (CPO) ash as a filler. The asphalt content used was 5.9%; 6.33%; 6.75%; 7.18% and 7.6%, while the proportion of CPO ash is 0%, 25%, 50%, 75% and 100%. The mixture gradation is made using a gap-graded and half gap-graded mixture.

2. Methodology

2.1. Location

The coarse and fine aggregate is taken from the Bili-Bili quarry, Jeneberang River, Sungguminasa. The asphalt material is Pertamina asphalt with penetration 60/70 from the Road and Bridge Material Testing Laboratory of the Department of Highways Baddoka, South Sulawesi. The cement filler was taken from a local building material store and the CPO ash from palm oil processing in Bone-bone subdistrict, East Luwu, South Sulawesi.

2.2. Experimental program

The material to be used in the HRS-WC mixture for gap-graded and half gap-graded should be tested to determine its characteristics. The testing method is based on the Indonesian National Standard (SNI) and American Standard for Testing Material (ASTM). Examination of aggregate characteristics include sieve analysis (SNI 03-1968-1990), bulk density and water absorption for both coarse aggregate (SNI 1969-2008) and fine aggregate (SNI 1970-2008), sand equivalent test value (SNI 03-4428-1997), abrasion with Los Angeles machines (SNI 2417: 2008), the flat and elongated particle test (ASTM D-479), aggregate adhesion to asphalt (SNI 2439: 2011), sieve No.200 test (SNI 03-4142 -1996). The test of asphalt characteristics includes the tests for penetration at 25°C (SNI 06-2456-1991), burn point (SNI 2433-2011), softening point (SNI 2434-2011), specific gravity (SNI 2441-2011), ductility at 25°C (SNI 2432 -2011), Weight Loss Test (SNI-06-2441-1991), filler specific gravity testing (SNI 03-4142-1996). Conventional Marshall Testing includes Stability, VIM (Void in Mix), Flow/flexibility, VMA (Void in Mineral Aggregate), VFB (Void Field with Bitumen).

The asphalt content used was 5.9%; 6.33%; 6.75%; 7.18% and 7.6%, while the proportion of CPO ash waste is 0%, 25%, 50%, 75% and 100%. The specimens used in Marshall Test for gap-graded and half-gap grading are 66 specimens, consisting of 30 specimens for conventional Marshall Test, 30 for optimum asphalt content, six specimens for the Marshall Immersion Test. The gradation mixture uses the specifications from General Specifications of Bina Marga, 3rd Revised Edition, Division 6. The composition design of the HRS-WC mixture is shown in table 1.

**Table 1.** Design of the HRS-WC mixture for gap-graded and half gap-graded mixture.

| Sieve number | % Weight Slip to Total Aggregates in the Mixture |
3. Results and Discussions

3.1. Aggregate characteristics

The results of aggregate wear test using the Los Angeles Abrasion Tool from Fraction A, B, C, and D is respectively 27.64%, 21.18%, 18.32%, and 21.32%, while the General Specifications Standard is a maximum of 40%. The testing results of coarse aggregate indicates that the density and absorption are 2.75% for bulk density, SSD specific gravity 2.77%, apparent density 2.81%, and water absorption 0.80%. The General Specifications (2010) for bulk density, SSD specific gravity, and apparent density are at least 2.5%, and the maximum water absorption is 3%. The testing results of fine aggregate indicates that the density and absorption is 2.64% for bulk density value, SSD specific gravity 2.70%, apparent density 2.81%, and water absorption 2.27%. While the General Specification Standard for bulk density is at least 2.5% and SSD specific gravity is at least 2.5%, apparent density is at least 2.5%, and maximum water absorption is 3%. From the results of the sieve test for sieve No. 200, it is obtained a value of 0.2 while the Bina Marga Standard specifies a maximum value of 8%. It means that the aggregate is clean from clay and silt. The results of sludge testing using 2 (two) samples have an average value of Sand Equivalent (SE) 98.28% and sludge content 1.72%, whereas the specifications are a minimum of 60% for Sand Equivalent and a maximum of 5% for sludge content. The flat and elongated particle test shows that the flat particle index is 9.80%, 5.90%, 6.50%, and 7.60%. The elongated particle index is 8.40%, 5.00%, 7.40% and 9.70%. Both of these values have fulfilled the standards specification from Bina Marga which has a maximum value of 10%.

3.2. Marshall characterisitic

Testing of HRS-WC performance for both gap-graded and half gap-graded mixture is carried out. Figure 1 illustrates that the stability of both gap-graded and half gap-graded mixture with a filler content of CPO ash 0% to 100%. All the Stability values have fulfilled the minimum requirements of 800 kg.

It can also be seen that CPO ash filler could increase the strength/stability of the mixture at 25% of the cement filler substitution while the stability will decrease due to the reduced bonding between aggregates for the mixture of 50% -100% filler CPO ash. It is because the finer CPO ash will make the density of the mixture increase so that stability also increases. Based on the type of mixture shows that half-gap graded mixture will provide greater stability than a gap-graded one. The VIM testing results are shown in figure 2. It has also been fulfilled the requirements. The use of a CPO ash filler will reduce the use of cement filler. Figure 2 also shows that the VIM value is greater in gap-graded mixture compared to half-gap-graded one. It is because half-gap-graded mixture still uses the sieve No. 50 so that the mixture gradation is denser and has fewer void in the mixture.
Flow Test results for gap-graded and half gap-graded mixture can be seen in figure 3. The values of flow are strongly influenced by the amount of asphalt content in the mixture. The flow will be higher as the increasing of the use of CPO ash because the reduced aggregate bond will increase the flexibility. Flow values in the two mixtures have fulfilled the specifications of at least 3 mm. HRS-WC gap-graded mixture has greater flexibility than half gap-graded one due to the effect of lower density.

The VMA test result can be seen in figure 4. The use of asphalt in large quantities will affect the bond between mixtures, also to the void in the mixture and aggregate. It is seen that the increase of asphalt in the mixture can lead to an increase in the void-filled gap in the aggregate. It is due to the large volume of CPO ash filler, so there will be a lot of asphalt attached in the mixture before entering the void. The HRS-WC mixture using a gap-graded mixture has a larger void compared to half gap-graded one.

The VFB test result can be seen in figure 5. The increasing of CPO ash with asphalt content of 5.9% did not fulfill the requirements, while the other composition still exceeded the minimum requirements standard. The VFB value from the result indicates that the half-gap-graded mixture has a higher VFB value than the gap-graded one.

Table 2. Asphalt Characteristics test results.

| Testing Type                        | Values | Bina Marga Specification | Unit |
|-------------------------------------|--------|--------------------------|------|
|                                     |        | Min | Max | (0, 1) mm |
| Penetration Before Weight Loss      | 68.8   | 60  | 79  |           |
| Ductility                           | 148.67 | 100 | -   | cm       |
| Asphalt Softening Point             | 50     | 48  | 58  | °C       |
| Burn Point                          | 300    | 200 | -   | °C       |
| Asphalt Specific Gravity            | 1.073  | 1.0 | -   | gr/cc    |
| Weight Loss                         | 0.142  | -   | 0.8 | %        |
| Penetration After Weight Loss       | 95.78  | 54  | -   | Initial percentage |

Figure 1. Stability test result.
Figure 2. VIM test result

Figure 3. Flow test result

Figure 4. VMA test result
3.3. Immersion index

Immersion index testing was carried out on specimens with asphalt content of 6.33%, 6.75%; 7.18% and 7.6% with the addition of CPO ash 0%, 25%, 50%, 75% and 100%. The gap-graded mixture immersion index with asphalt content of 6.33% using both filler content of 0%, IKS value of 90, and filler content of 25%, IKS value of 91 is still within the standard limits. For asphalt content, 6.75% using 0% CPO filler content is 91, and for CPO filler level 25% is 91. The immersion index value for asphalt content is 7.18% with CPO ash filler content 0% is 92,00, for filler content 25% CPO is 91 while 50% filler content is 90. Immersion index value with 7.6% asphalt content with CPO ash filler content of 0%, 25% and 50% is 93, 92, and 91 respectively.

The immersion index for half gap-graded mixture with asphalt content of 6.33%, filler content of 0%, IKS value of 91, and filler content of 25% with IKS value of 90 is still within the standard limit. For asphalt content 6.75% for 0% CPO filler content is 92, and for 25% CPO filler content is 91. The immersion index value for asphalt content is 7.18% with CPO ash filler content of 0% is 93,00, for filler content CPO 25% is 92 while 50% filler content is 90. Immersion index value with 7.6% asphalt content with CPO ash filler content of 25%, 50% and 75% is 94, 92, and 90 respectively.

Immersion index shows the ability of HRS-WC with the use of CPO ash can withstand the burden of traffic when immersed in water. The use of more asphalt content in the mixture will form a more watertight mixture so that the durability of the mixture will be better. The impermeability is reduced, which results in the mixture being unable to withstand water as the increasing of CPO ash filler. The gap-graded and half-gap graded mixture in the HRS-WC mixture also affect the degree of impermeability to water. The half-gap graded one will form a denser mixture so that it becomes more waterproof.
4. Conclusion
Based on the results of the use of CPO ash as a substitute for cement filler on the characteristics of the gap-graded and half-graded mixture in HRS - WC mixture, it can be concluded as follows:

- The stability value will increase due to the use of 25% CPO ash. Otherwise, it will decrease again after 25%.
- The use of small asphalt content will increase the value of VIM.
- The mixture flow will decrease due to the use of 32% CPO ash. Otherwise, it will increase again after 32%.
- The increasing use of CPO ash filler in the mixture will increase VMA.
- The VFB value will decrease as the increasing CPO ash.
- The immersion index can still be maintained if the use of CPO ash increases.
- The use of CPO ash as a substitute for filler in the HRS mixture - WC must be balanced with the increasing of asphalt mixture.

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