Investigation of the immersion resistance of the HRS-WC mixtures with applying static loading

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Abstract. The inclusion of rainwater often compounds the damage to the road before reaching the plan life through the surface and shoulders of roads. This can lead to the release of aggregates and exfoliation of asphalt on the surface layer. The study aims to determine the level of road durability against the Marshall, volumetric, and durability properties of the HRS-WC mixture. The study used various static loading 100 Kpa, 150 Kpa, and 200 KPa with immersion. In the immersion method, there are two differences, namely, immersion with and immersion without loading. The test objects’ loading using a simple and economical test tool utilizes the beams and iron cylinders obtained from the laboratory, testing using Marshall Test. The results of the analysis obtained the durability of unloading soaked value higher than the load. The analysis results showed that the durability of the mixture was soaked seven days with a load of 100 KPa was 77.40%, for 150 Kpa amounted to 52.02%, and for 200 KPa, which is 47.67%. Analysis results showed a 7-day immersion value with a cumulative load of 68.38%, while analysis results showed a seven day immersion value with periodic loading of 75.43%.

1. Introduction

One type of asphalt mixture is Hot Rolled Sheet (HRS). This mixture is divided into HRS-WC (Wearing Course) and HRS-Base. Road pavement must be designed with the most accurate method to consider the influence of traffic conditions [1], temperature, the materials used [2, 3], and immersion methods [4]. Because HRS-WC is in direct contact with the vehicle’s wheels, it is designed to withstand shear forces, weather changes, and vehicle wheel pressure. The effect of wheel loads can cause increased fatigue, damage to the pavement layer, and permanent deformation [5]. Flexible pavement deformations were often found in parking areas, storage space at piers, and aprons at airports. If the pavement layer is adequately compacted, the pavement service life will be longer [6]. Besides, this mixture functions as a waterproof layer so that water does not soak into the pavement layer [7]. The soaking water in the mix can weaken the bond between the asphalt and aggregate. The continuous loading of vehicles will cause fatigue in the pavement layer.

Some of the things that cause road construction damage include excessive vehicle traffic loads, temperature, water (either infiltration or inundation), and road pavement construction that did not meet technical requirements [8]. Water is one of the causes that reduce the durability of asphalt pavement construction [9, 10, 11]. Durability is the compacted asphalt mixture’s ability to maintain its structural integrity throughout the expected service life [12]. The best way to check the durability of asphalt is from pavement failure [13]. According to references [14, 15],...
standing water on the road surface can reduce the mixture’s stiffness and strength. This caused a lot of peeling asphalt layers on the road surface. One of the factors influencing the asphalt mixture’s durability is a void in the mix (VIM). The small VIM causes the waterproof layer and air not to enter the combination to have good durability. Aging asphalt mixture has an immense void due to the oxidation process. The large percentage of the void caused a decrease in water resistance. When soaked, water will quickly enter and fill the cavity, thereby reducing the mixture’s durability. The more extended immersion of the specimen can cause lower durability [16].

This study aims to analyze the HRS-WC mixture’s resistance immersed in water with a temperature of 25°C, without and with a load. Durability is also analyzed using load variations, namely: cumulative and periodic loads. This is done to determine the effect of load variations in destroying the mixture until it reaches a fatigue condition.

2. Research methods

This research was conducted at the Laboratory of Civil Engineering Study Program, Universitas Muhammadiyah Surakarta. The specimens were made with a load variation of 100, 150, and 200 KPa, and immersion time of 1, 4, and 7 days. There are two methods for loading variation, namely cumulative and periodic. The difference between the two loading process methods can be seen in Figures 1 and 2. The Marshall test was performed to obtain Marshall Properties consists of stability, flow, Marshall Quotient (MQ), and density. Another parameter reviewed is volumetric values, including Void In the Mix (VIM), Void in Mineral Aggregate (VMA), and Void Filled With Asphalt (VFWA). The load used in this study was 150 KPa with static loading according to reference [17]. This is done taking into account practicality and convenience in the laboratory. Specimens were weighed in saturated surface dry (SSD) conditions and inside a 25°C of water, and then immersed in a 60°C water bath for 30 minutes.

The parameters used to see the durability of the asphalt mixture are the Residual Strength Index (RSI) and the Durability Index (DI). RSI is a parameter used by Bina Marga [18] to compare the stability value of 24-hour immersion at 60°C with standard stability. DI is a single parameter developed by Craus et al. [19] by performing a more extended immersion. Craus et al. [19] stated that the one-day immersion criterion does not always reflect the mixture’s long-lasting properties after a period of immersion. The RSI value (%) can be calculated with Equation 1.

\[ RSI = \frac{S_2}{S_1} \times 100\% \] (1)
With, $S_1$: Standard Marshall stability with 30 minutes immersion at a temperature of $\pm 60^\circ$ C (kg), $S_2$: Marshall stability after 24 hours immersion at $\pm 60^\circ$ C (kg).

The bigger the RSI, the more durable the asphalt mixture. The minimum RSI value required by Bina Marga is 90%, so if the RSI value is above 90% the asphalt mixture is considered sufficiently resistant to damage due to the influence of water and temperature.

3. Result and discussion

3.1. The effect of immersion time and load on durability

As mentioned earlier, the asphalt mixture's durability can be seen from the Marshall properties, the volumetric, and the Residual Strength Index. This study's results compared with the appropriate secondary data can be seen in Figures 3 until 5.

Figure 3 shows that the immersion time affects decreasing stability. This decrease was
increasingly visible when there was a load of 150 Kpa. The value did not meet the minimum specifications of 800 kg. In the presence of water infiltration in the aggregate, the static load on the immersion results in a change in the mixture’s shape. The cavity gets bigger and the aggregate quickly absorbs the water. Many things affect the decline the stability, one of which is a decrease in the density value. This is because the longer the immersion and the loading, the lower the density of the mixture so that the mixture’s cavity is getting bigger. Figure 3 also shows the trendline flow, which is inversely proportional. At the no-load immersion, the value decreases while with increasing loading. This is because the longer the loading causes the mixture’s cavity gets bigger and increases the flow value. This phenomenon can also be seen in the Marshall Quotient value, which decreases with increasing immersion time.

Figure 4. Characteristic of volumetric

Figure 4 shows that the VIM value increases with the duration of immersion, both without load and with a static load of 150 Kpa. The VIM value is still following the required specifications, namely at least 4% -6%. The existence of loading and the duration of immersion will result in a larger cavity. Changes in the overall shape can be seen in the VMA value, which increases during loading. The difference in the cavity in the mixture causes the asphalt as a binder for the mixture to not work optimally, this can be seen in the decreasing VFWA value.

Figure 5 shows that the loaded specimen has a lower RSI value than without load. This is because immersion destroys and reduces the strength formed due to reduced binding forces between the asphalt and aggregate. This is in line with reference [20], who stated that water reduces the cohesion between asphalt and water, thereby damaging the bond between asphalt and aggregate in the mixture. The load that is carried out causes the bonds between the aggregate particles to weaken and enlarge the mixture’s cavities so that the RSI value decreases.

3.2. The effect of immersion time and loading variation for seven days on durability
As mentioned in sub-section 3.1, indicators for assessing durability are Marshall Properties, mixed volumetric, and Residual Strength Index (RSI). The resulting test of the three things above under loading variation conditions for seven days can be seen in Table 1.

Table 1 shows that the greater the load is given, the durability value will generally decrease. This can be seen from the decreasing value of stability, density, MQ, VFWA, and RSI. Besides, this condition can also be seen in the increase in VIM and VMA values. This decrease is due to the load giving pressure to the asphalt mixture resulting in water bleeding, deformation, and infiltration. The entry of water reduces the aggregate’s binding capacity so that the asphalt mixture can be less durable.
Figure 5. Relationship between Residual Strength Index with soaking duration and loading

| Loading variation for seven days (Kpa) | Stability | Flow | Density | MQ | VIM | VMA | VFWA | RSI |
|--------------------------------------|-----------|------|---------|----|-----|-----|------|-----|
| Without load                         | 1424      | 4.13 | 2.24    | 344| 3.82| 16.57| 76.97| 100 |
| 100                                  | 1101      | 3.85 | 2.23    | 286| 4.58| 16.61| 71.05| 77  |
| 150                                  | 740       | 3.90 | 2.21    | 190| 5.55| 17.49| 67.08| 52  |
| 200                                  | 678       | 4.01 | 2.20    | 169| 5.89| 17.80| 66.15| 48  |

Besides being shown in Table 1, the effect of the variation of loading for seven days can also be shown in the form of the loading method, namely cumulative and periodic loading (see Figures 1 & 2). The results of testing on both ways can be seen in Table 2.

| Loading variation for seven days (Kpa) | Stability | Flow | Density | MQ | VIM | VMA | VFWA | RSI |
|--------------------------------------|-----------|------|---------|----|-----|-----|------|-----|
| Without load                         | 1424      | 4.13 | 2.24    | 344| 3.82| 16.57| 76.97| 100 |
| Cumulative load                      | 974       | 3.50 | 2.23    | 293| 5.02| 17.04| 70.80| 68.38|
| Periodic (200Kpa)                    | 1074      | 3.33 | 2.22    | 307| 4.75| 16.79| 70.99| 75.43|

Based on Table 2, it can be seen that, in general, cumulative loading is more durable than periodic loading. This can be seen from the greater values of stability, flow, MQ, and VFWA. Even so, the RSI value, either cumulative or periodic loading, is less than 90%, which means both conditions are not durable. This condition is caused by water immersion and increasing loads, which continue to exert pressure on the mixture. When water and load simultaneously affect the mix, what happens is the adhesion force between the aggregate and the asphalt decreases. This makes the binding power of the asphalt to the aggregate reduced. The asphalt mixture’s ability to withstand the load above it decreases so that the mixture of constituent particles is shifted.
4. Conclusion
Based on the analysis results, it can be concluded that soaking time without and with static loading on the HRS-WC mixture decreased the RSI value. Soaking time with a variety of static loading resulted in reduced durability of the mix. This can be seen by reducing the value (RSI) of the mixture at a 100 Kpa 77% load, decreasing until the 200 Kpa load reaches 48%. The effect of 7 days of immersion using the cumulative loading method resulted in the HRS-WC asphalt mixture’s performance becoming less durable. It can be seen that the results of immersion with incremental loading, the residual strength index value reaches 68%. The effect of 7 days of immersion using the periodic loading method resulted in the HRS-WC asphalt mixture’s performance becoming less durable. It can be seen that the result of immersion with regular loading, the residual strength index value reaches 75%.

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