Analyze marshall characteristic and cantabro abrasion loss of laston-wc with high-density polyethylene variations

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Abstract. Indonesia needs asphalt mixture with good quality and high resistance against daily heavy traffic. One of the ways is to modified asphalt mixture with High-Density Polyethylene (HDPE). This is also useful for reducing environmental problems due to daily use of plastic. This study investigates the performance of asphalt mixture with High-Density Polyethylene (HDPE) substitution with variants of 0%, 2%, 4% and 6% by asphalt weight in the mixture. In this study, the asphalt mixing process conducted by two methods such as wet and dry method and using the original seeds of High-Density Polyethylene (HDPE) substitution and chopped High-Density Polyethylene (HDPE) substitution. The performance of asphalt mixture with High-Density Polyethylene (HDPE) substitution was analyzed using Marshall test that based on Asphalt Pavement Specification (Bina Marga, 2018) and Cantabro Abrasion Loss (CAL) test in terms of strength, stiffness, and durability characteristics. Laboratory result showed that asphalt mixture substitution by original seeds of High-Density Polyethylene (HDPE) with dry method gives the maximum stability that is 1970.8 kg at 6% High-Density Polyethylene (HDPE) substitution content. But, only in level content of 2-4% High-Density Polyethylene (HDPE) substitution substitution which qualifying the specification such as Stability, Void In Mixture (VIM), Void in Mineral Aggregates (VMA), Void Filled with Asphalt (VFA), and Marshall Quotient (MQ).

Keywords: Concrete asphalt, HDPE, Wet method, Dry method, Marshall Characteristic, Cantabro Abrasion Loss

1 Introduction

To satisfy the traffic movement needs, the most important things to be considered is the pavement of road construction. In Indonesia, road construction is mostly a flexible pavement layer. Indonesia is a country located in the tropics so that the relatively high temperature is one of the causes of damage to the flexible pavement layer that uses asphalt as the binding material. Modified asphalt mixture that has a high performance than conventional asphalt is needed. The asphalt mixture performance is shown by the result of the Marshall Characteristic with parameters such as Stability, Flow, Void in Mixture (VIM), Void in Mineral Aggregates (VMA), Void Filled with Asphalt (VFA), and Marshall Quotient (MQ) based on Asphalt Pavement Specification [1]. The other is shown by the result of Cantabro Abrasion Loss (CAL) test that determines the abrasion loss of asphalt mixtures. One of the ways is to modified asphalt mixture with High-Density Polyethylene (HDPE). The addition of polymers typically
increases the stiffness of the asphalt and improves its temperature susceptibility [2]. This is also useful for reducing environmental problems due to daily use of plastic [3].

Therefore, this research investigates the performance of asphalt mixture with High-Density Polyethylene (HDPE) substitution with variants of 0%, 2%, 4% and 6% by asphalt weight in the mixture. This research is conducted by two methods in mixing the asphalt mixture, such as wet method and dry method. Using two kinds of High-Density Polyethylene (HDPE) which is the original type and waste type of High-Density Polyethylene (HDPE).

2 Experimental Design

2.1 Materials

In this research, there are 3 kinds of material that use in modified asphalt mixture such as asphalt, aggregates, and High-Density Polyethylene (HDPE).

2.1.1 Asphalt

The asphalt material used in this research is Asphalt Shell Penetration 60/70 which is generally used in road construction in Indonesia. All the asphalt qualifies the requirements stated by Standar Nasional Indonesia (SNI).

2.1.2 Aggregates

In this research, there are 2 types of aggregates that use in asphalt mixtures such as coarse aggregate and fine aggregate. Coarse aggregate consists of Hotbin I and Hotbin II that shown by Figure 1 and Figure 2, fine aggregate consists of Hotbin III, Hotbin IV, and Filler that shown by Figure 3 and Figure 4.

2.1.3 High-Density Polyethylene (HDPE)

High-Density Polyethylene is a strong, high density, moderately stiff plastic with highly crystalline structure. It is frequently used as a plastic for milk cartons, laundry detergent, garbage bins, and etc [4]. There are two kinds of High-Density Polyethylene (HDPE) used in this research, such as original seeds of High-Density Polyethylene (HDPE) and chopped waste High-Density Polyethylene (HDPE).

2.2 Sample Construction

The asphalt concrete mixture is were prepared and tested according to SNI 06-2489-1991. The Marshall method uses several trial aggregate-asphalt binder blends (typically 5 blends with 3 samples each for a total of 15 specimens), each with a different asphalt binder content. Then, by evaluating each trial blend’s performance, an optimum asphalt binder content can be selected [5]. In order for this
concept to work, the trial blends must contain a range of asphalt contents both above and below the optimum asphalt content. Therefore, the first step in sample preparation is to estimate an optimum asphalt content. Trial blend asphalt contents are then determined from this estimate that qualifies the Characteristic Marshall according to General Specification of Bina Marga 2018.

After validating the optimum asphalt content, the mixtures were prepared to substitute the optimum asphalt content as much 2%, 4% and 6% by asphalt weight with two kinds of High-Density Polyethylene (HDPE); original seeds and chopped. All the asphalt mixture with substitution High-Density Polyethylene (HDPE) are made to analyze the Characteristic Marshall and Cantabro Abratation Test. There were 93 samples prepared for this research.

In this research used a 2 method of asphalt mixing [6], namely:
- Wet Method: a method of mixing where plastic put into hot asphalt then stirred until homogeneous;
- Dry Method: a method of mixing where plastic put into aggregates which are heated at mixed temperatures, then hot asphalt is added. This method can be cheaper than the wet method, it's easier just to put the plastic into hot aggregate.

2.3 Laboratory Test
2.3.1 Marshall Characteristic Test

The Marshall Characteristic test provides the performance prediction measure for the asphalt mixture with substitution of HDPE. There are Stability, Flow, Void in Mixture (VIM), Void in Mineral Aggregate (VMA), Void Filled with Asphalt (VFA), and Marshall Quotient (MQ) [7].

The stability portion of the test measures the maximum load supported by the test specimen. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen’s plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. Void in Mixture (VIM), Void in Mineral Aggregate (VMA), Void Filled with Asphalt (VFA) are kind of volumetric analyze of asphalt mixture using pycnometer and digital scales and MQ is used to analyze the stiffness of the mixture.

2.3.2 Cantabro Abrasion Loss test

The Cantabro test was carried out to measure the effect of modified bitumen in the bituminous mixture on resistance to disintegration between aggregate and bitumen. This test uses an approach in accordance with Standard of Tex-245-F [8], in which the initial weight of each test specimen was recorded before placing it in a Los Angeles machine without the steel balls. The Cantabro loss (CL) is the percentage of CL after 300 rotations of the Los Angeles machine.

3 Result and Discussion

3.1 Optimum Asphalt Content results

Optimum asphalt content is the recommended percent asphalt taken as the percent asphalt that will produce the maximum density under a fixed compacted effort, and the compacted specimens must satisfy the standard. By Figure 5, the optimum asphalt content is 6% that satisfy all the standard.
3.2 Marshall Characteristic results

3.2.1 Asphalt Mixture with Substitution of High-Density Polyethylene (DHPE) Original Seeds, Wet Process

According to the result that shown by Figure 6, stability value has an increase of 26.81% compared to asphalt without the substitution of High-Density Polyethylene (HDPE) with the maximum value occurs at 6% High-Density Polyethylene (HDPE) content that valued 1687.86 kg. The value of flow decreased by 7.31% as the use of High-Density Polyethylene (HDPE) increased. The highest flow value occurs at 2% High-Density Polyethylene (HDPE) content that valued 4.83 mm. The Void in Mixture (VIM) value has an increase of 42.75% along with the increase in the use of High-Density Polyethylene (HDPE) which is valued 7.04% that occurs at 6% High-Density Polyethylene (HDPE) content. The Void in Mineral Aggregates (VMA) value has an increase of 25.75% as the use of High-Density Polyethylene (HDPE) that valued 20.31% which occurs at 6% High-Density Polyethylene (HDPE) content. The Void Filled with Asphalt (VFA) value has a decrease of 12.18% as the use of High-Density Polyethylene (HDPE) increased valued 65.34% that occurs at 6% High-Density
Polyethylene (HDPE) content. The maximum Marshall Quotient (MQ) occurs at 6% High-Density Polyethylene (HDPE) content valued 533.07 kg / mm.

![Graphs showing stability, flow, VIM, VMA, VFA, and MQ vs HDPE content.](image)

**Figure 6.** Marshall Result of High-Density Polyethylene (HDPE) Original Seeds Substitution by Wet Process

### 3.2.2 Asphalt Mixture with Substitution of High-Density Polyethylene (HDPE) Original Seeds, Dry Process

According to the result that shown by Figure 7, Stability value has an increase of 59.54% compared to asphalt without the substitution of High-Density Polyethylene (HDPE) with the maximum value occurs at 6% High-Density Polyethylene (HDPE) content that valued 1970.8 kg. The value of flow decreased by 19.88% as the use of High-Density Polyethylene (HDPE) increased. The highest flow value occurs at 2% High-Density Polyethylene (HDPE) content that valued 3.5 mm. The Void in Mixture (VIM) value has an increase of 93.55% along with the increase in the use of High-Density Polyethylene (HDPE) content. The Void in Mineral Aggregates (VMA) value has an increase of 27.81% as the use of HDPE that valued 20.89% which occurs at 6% HDPE content. The VFA value has a decrease of 14.49% as the use of High-Density Polyethylene (HDPE) increased valued 62.68% that occurs at 6% High-Density Polyethylene (HDPE) content. The maximum Marshall Quotient (MQ) occurs at 6% High-Density Polyethylene (HDPE) content valued 718.95 kg / mm.
3.2.3 Asphalt Mixture with Substitution of Chopped High-Density Polyethylene (HDPE).

Wet Process

According to the result that shown by Figure 8, Stability value has an increase of 18.39% compared to asphalt without the substitution of High-Density Polyethylene (HDPE) with the maximum value occurs at 6% High-Density Polyethylene (HDPE) content that valued 1513.86 kg. The value of flow decreased by 19.88% as the use of HDPE increased. The highest flow value occurs at 2% High-Density Polyethylene (HDPE) content valued 3.97 mm. The Void in Mixture (VIM) value has an increase of 40.57% along with the increase in the use of High-Density Polyethylene (HDPE) which is valued 6.8% that occurs at 6% High-Density Polyethylene (HDPE) content. The Void in Mineral Aggregates (VMA) value has an increase of 28.9% as the use of High-Density Polyethylene (HDPE) that valued 21.21% which occurs at 6% High-Density Polyethylene (HDPE) content. The Void Filled with Asphalt (VFA) value has a decrease of 12.18% as the use of High-Density Polyethylene (HDPE) increased valued 65.34% that occurs at 6% HDPE content. The maximum Marshall Quotient (MQ) occurs at 6% High-Density Polyethylene (HDPE) content valued 438.04 kg / mm.

Figure 7. Marshall Result of High-Density Polyethylene (HDPE) Original Seeds Substitution by Dry Process
3.2.4 Asphalt Mixture with Substitution of Chopped High-Density Polyethylene (HDPE), Substitution by Wet Process

According to the result that shown by Figure 9, Stability value has an increase of 23.05% compared to asphalt without the substitution of High-Density Polyethylene (HDPE) with the maximum value occurs at 6% High-Density Polyethylene (HDPE) content that valued 1605.28 kg. The value of flow decreased by 6.73% as the use of High-Density Polyethylene (HDPE) increased. The highest flow value occurs at 2% High-Density Polyethylene (HDPE) content that valued 3.9 mm. The Void in Mixture (VIM) value has an increase of 45.46% along with the increase in the use of High-Density Polyethylene (HDPE) which is valued 7.39% that occurs at 6% High-Density Polyethylene (HDPE) content. The Void in Mineral Aggregates (VMA) value has an increase of 28.36% as the use of HDPE that valued 21.05% which occurs at 6% High-Density Polyethylene (HDPE) content. The Void Filled with Asphalt (VFA) value has a decrease of 12.94% as the use of High-Density Polyethylene (HDPE) increased valued 64.9% that occurs at 6% HDPE content. The maximum Marshall Quotient (MQ) occurs at 6% HDPE content valued kg / mm.
Figure 9. Marshall Result of Chopped High-Density Polyethylene (HDPE) Substitution by Dry Process

3.3 Cantabro Abrasion Loss results

3.3.1 Asphalt Mixture with Substitution of High-Density Polyethylene (HDPE) Original Seeds

Cantabro Abrasion Loss (CAL) results of Asphalt Mixture with substitution of High-Density Polyethylene (HDPE) Original Seeds 2%, 4%, and 6% through Wet and Dry Mixing Method indicates an increase for abrasion shown by Figure 10. For wet mixing method, Cantabro Abrasion Loss (CAL) value has an increase of 30.82%. For dry mixing method, Cantabro Abrasion Loss (CAL) value has increase of 26.41%.
Cantabro Abrasion Loss (CAL) results of Asphalt Mixture with substitution of Chopped High-Density Polyethylene (HDPE) 2%, 4%, and 6% through Wet and Dry Mixing Method indicates an increase for abrasion shown by Figure 11. For wet mixing method, Cantabro Abrasion Loss (CAL) value has an increase of 14.17%. For dry mixing method, CAL value has increase of 14.54%.

From the results, it can be concluded that the asphalt mixture with High-Density Polyethylene (HDPE) substitution has an increase of stiff and the use of High-Density Polyethylene (HDPE) in the asphalt concrete mixture reduced aggregate-binder adhesiveness [9].

4 Conclusions

Based on the result of this research analysis, it can be concluded that for the used of HDPE (High Density Polyethylene) plastic as a substitution material of asphalt in the Asphalt Concrete Wearing Course can increase the Stability, Void in Mixture (VIM), Void in Mineral Aggregates (VMA), Marshall Quotient (MQ) and Cantabro Abrasion Loss (CAL) values. Whereas Flow and Void Filled with Asphalt (VFA) values will tend to decrease due to the increasing levels of plastic.

The use of High-Density Polyethylene (HDPE) in the asphalt mixture, increasing the properties of resistance to deformation was seen from the increase in Stability value [10] and causes Void the asphalt mixture becomes higher due to reduced asphalt as the binder material substituted by the polymer.

The dry mixing method and the use of High-Density Polyethylene (HDPE) original seeds as substitution material has a better performance of asphalt mixture rather than the wet mixing method and the use of chopped High-Density Polyethylene (HDPE).
The substitution of High-Density Polyethylene (HDPE) level is only within 2-4% that qualify the Specification from Directorate General of Highways.

5 References

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