The Effect of Using PVC as A Mixed Additive Material Asphalt Concrete Wearing Course

Veranita and Bambang Tripoli
Department of Civil Engineering, Teuku Umar University, Indonesia
Corresponding author: veranita@utu.ac.id

Abstract. The quality of pavement is influenced by good quality materials. Alternative materials can be used to increase the adhesion and viscosity of asphalt, including the using of latex and waste materials. The using of waste materials from polyvinyl chloride (PVC) in addition to reducing environmental pollution problems is also expected to be an added material to improve the performance of asphalt. The purpose of this study is to determine the effect of using PVC on the asphalt mixture. The specification refers to the Bina Marga 2018 method, by making the specimen of three variations of PVC. The variations of PVC are 3%, 4% and 6%. The results of the Marshall test showed that the optimum asphalt content was 6.5%; 5.8% and 6%. The result of 30 minutes immersion Marshall test at 3% variation is 1,367.91 kg, at 4% variation is 1,283.84 kg and 6% variation are 1,225.81 kg. The durability value for three variation is 94.75%, 92.54% and 93.85%. The using of PVC as an additive indicated that the addition of PVC to the asphalt mixture can provide better durability but the higher the PVC as a additive can reduce stability because the void in mixture is low.

1. Introduction
The rapid development of economy in Indonesia raises many problems for the pavement in this country. The unpredictable weather causes the existing road pavement is getting worse. The ability of the road pavement has to a sufficient thickness to accommodate the stresses of loading on the surface, in order to protecting the subgrade from damage. Therefore, the design of the asphalt mix is very important in ensuring an effective asphalt mixture that can overcome the possible damage effect of loads. In fact, there are many areas in Indonesia that have not received road infrastructure facilities, especially in Aceh. Materials are increasingly scarce so that prices are increasing, construction equipment and the range of procurement are obstacles in realizing the need for proper road construction. meet the quality standards by the Technical Specifications of Bina Marga 2018. Innovation is needed to find alternative materials that can be used to increase the effectiveness of cost. Some research and scientists have previously conducted research with utilization of used PVC, besides overcoming the problem of environmental pollution is also expected to be an alternative material for asphalt concrete mixture. In this case it allows of additional materials (additives) and substitute materials in hot asphalt mixture which is expected to provide more strength for a road surface layer.

One of the used materials that are widely found in nature is plastic waste, there are many types of plastic in the market including polyvinyl chloride (PVC). PVC plastic is widely used, especially in the construction sector, such as pipes, wallpapers, floors, windows, etc., which is one of the used items used in the asphalt mixture. The addition of PVC plastic to the asphalt mixture is expected to improve the quality of the mixture. Referring to the description above, the purpose of this study is to determine
the effect of the use of PVC on the marshall parameters of the asphalt concrete wearing course (AC-WC) mixture.

The greater percent of PVC in asphalt mixing, it will be higher the Marshall quotient (MQ) value. The range of MQ values from 223.65 kg / mm to 394.74 kg / mm. The presence of plastic in the AC-BC asphalt mixture can improve the road construction's ability to accept loads, but the construction is still flexible [1]. Polyvinyl chloride (PVC) is made by polymerizing an emulsion or suspension in the form of a porous powder [2]. The types of plastics that are widely used include Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polypropylene (PP), and Polyvinyl Chloride (PVC) [3]. PVC is included in the thermoplastic polymer type, which is a substance that loses its shape when heated and becomes rigid again when cooled [4]. PVC is in the form of white powder or colored granules, resistant to climate change and humidity.

Visually, the colour of rice husk ash is grey with a smooth, dense, and round grain shape [5]. Based on its chemical composition, rice husk ash can be used as a filler in concrete Asphalt mixture because the chemical composition of rice husk ash is the same as silica fume [6]. The chemical composition of rice husk ash can be seen in Table 1.

| No | Chemical Compound | Percentage (%) |
|----|-------------------|----------------|
| 1  | SiO₂              | 92.99          |
| 2  | AL₂O₃             | 0.18           |
| 3  | Fe₂O₃             | 0.43           |
| 4  | CaO               | 1.03           |
| 5  | K₂O               | 0.72           |
| 6  | Na₂O              | 0.02           |
| 7  | MgO               | 0.35           |

2. Research method
The stages of this research are the preparation stage, the making of specimen and the testing stage. This research was conducted at the Highway Materials Laboratory, Faculty of Engineering, Syiah Kuala University, Banda Aceh. The materials for making specimen are aggregate, asphalt Pen 60/70, polyvinyl chloride (PVC) and filler from rice husk ash which passed sieve no.200. This research refers to the specifications of Bina marga 2018, with using of PVC as a material additive mixture with asphalt which is into three variations, the variations are 3%, 4% and 6% and each variation consists of 3 specimens.

2.1. Material preparation and test equipment
The materials used in this research are coarse aggregate, fine aggregate, asphalt pen 60/70, polyvinyl chloride (PVC), and rice husk ash filler. The equipment for making test objects for Marshall testing are filters, scales, ovens, molds, frying pans, frying spoons, spatulas, gas stoves, gas trays, gloves, aggregate containers, temperature gauges (thermometer), a compactor (marshall automatic compactor), a hydraulic jack (extruder), a ruler, a rag, a waterbath, and a set of marshal testing tools.

2.2. Implementation procedure
The primary data obtained from testing conducted by researchers, while secondary data can be obtained from literature, both from books and journals. The mixed design in this research used the Marshall method, because the Marshall method is easier to apply. The design steps for Marshall method are: (1) studying the desired mixed aggregate gradation specification from the Specifications of Bina Marga 2018, (2) design the aggregate proportion, this proportion is determined analytically where the aggregate proportion is selected from the gradations in accordance with the Bina Marga 2018.
The principle of this method is to determine the selected aggregate gradation and then count the number of grains that escape and are retained according to the predetermined specifications in order to obtain the composition of coarse aggregate, fine aggregate and filler. The estimated design asphalt content can be obtained from the Equation 1.

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

where \( Pb \) is middle/ideal asphalt content, percent of the weight of the mixture; \( CA \) is coarse aggregate held by sieve no. 4; \( FA \) is fine aggregate passes sieve no. 4 and stuck with filter no. 200; \( \text{Filler} \) is Filler an aggregate of at least 75% that passes through filter no. 200. The constant value is about 0.5 for low aggregate absorption and 1.0 for high aggregate absorption.

Total aggregate weight of 1200 grams for one specimen. Weight of asphalt is obtained from the percentage of asphalt content x 1200 grams (total weight of aggregate). The draft weight of the asphalt obtained is then substituted with PVC as a variation of the binder.

The design of the variations of PVC and pen asphalt 60/70 in the AC-WC mixture is made of three variations, namely the variation of 3%, 4% and 6%. Test specimens were made using variations of asphalt (5% 5.5% 6% 6.5% 7%) then varying the asphalt content. Each plan was made 3 (three) specimens in accordance with the spacing of Table 2.

### Table 2. Specification of aggregate of dense graded [7]

| Sieve No. | Gradation plane Article I | Accumulation (%) |
|-----------|---------------------------|------------------|
| ASTM (mm) | WC | % passing | % retained | |
| 3/4" | 19 | 100 | 100 | 0 | 39 |
| 1/2" | 12.5 | 90-100 | 95 | 5 | |
| 3/8" | 9.5 | 77-90 | 83.5 | 11.5 | |
| No. 4 | 4.75 | 53-69 | 61 | 22.5 | |
| No. 8 | 2.36 | 33 - 53 | 43 | 18 | |
| No. 16 | 1.18 | 21 - 40 | 30.5 | 12.5 | |
| No. 30 | 0.6 | 14 - 30 | 22 | 8.5 | |
| No. 50 | 0.3 | 9-22 | 15.5 | 6.5 | |
| No. 100 | 0.15 | 6-15 | 10.5 | 5 | |
| No. 200 | 0.075 | 4-9 | 6.5 | 4 | |
| Filler | | | | 6.5 | 6.5 |

2.3. Making and testing of specimens

After all aggregate meet the specifications, the next step is to carry out a mix design to get the aggregate composition and asphalt content. The materials used in the mixture of specimens are coarse aggregate, fine aggregate, and filler. The aggregate and filler are weighed according to their size based on the desired gradation. The total weight of the mixed aggregate is the weight of the aggregate which can produce a solid specimen as high as 6.35 cm with a diameter of 10.2 cm. Generally, the weight of the mixed aggregate is ± 1200 grams.

The optimum asphalt content is the middle value of the range that meets all specifications. The optimum asphalt content is good asphalt content that meets all the desired properties of the mixture in the optimum asphalt content range of ± 0.5% [8].

Test specimens to find KAO. The value of KAO can be found with 30 test specimens, tested by Marshall. This can be seen in Table 3.

The optimum asphalt content obtained will be used in the next stage of mixing test objects for stability and durability testing of 18 specimens, namely for stability test is 6 and the durability test is 6 specimens, more details can be seen in Table 4.
Table 3. Composition and number of specimens

| No | Asphalt content | Amount of specimens | Amount |
|----|-----------------|---------------------|--------|
|    |                 | 3%                  | 4%     | 6%     |        |
| 1  | KAO-1%          | 3                   | 3      | 3      | 9      |
| 2  | Pb-0.5%         | 3                   | 3      | 3      | 9      |
| 3  | Pb-0%           | 3                   | 3      | 3      | 9      |
| 4  | Pb+0.5%         | 3                   | 3      | 3      | 9      |
| 5  | Pb+1%           | 3                   | 3      | 3      | 9      |
|    | Total           |                     |        |        | 45     |

Table 4. Number of specimens for durability test

| No | Asphalt content | Amount of specimens | Amount |
|----|-----------------|---------------------|--------|
|    |                 | 3%                  | 4%     | 6%     |        |
| 1  | Durability      | 3                   | 3      | 3      | 9      |
| 2  | Stability       | 3                   | 3      | 3      | 9      |
|    | Total           |                     |        |        | 18     |

Marshall test is carried out to determine the resistance (stability) to plastic fatigue (flow) of the asphalt mixture. This test was conducted at the Transportation Laboratory of the Faculty of Engineering, Syiah Kuala University, Banda Aceh. The equipment used is a complete marshall test, dial stability and flow, water bath, thermometer, callipers and scales.

3. Results and Discussions

This chapter describes data processing and test results and is proposed with a discussion based on the results of research in the laboratory using the methods described in Chapters II and III. The research results presented in tables of results.

3.1. Research results recapitulation

The data generated from the Marshall test are stability, density, flow, VIM, VMA, VFA, and MQ values. The KAO value was obtained by making 30 specimens for middle asphalt content and carrying out the marshall test. Comparison of PVC and pen asphalt 60/70 in each specimen for 3 different variations: 3%, 4% and 6% of PVC variation in the AC-WC mixture. The recapitulation of the parametric test for KAO value with a PVC variation of 3%, 4%, and 6% can be seen in Table 5, Table 6, and Table 7 and presented in graphical form as in Figure 1, Figure 2, and Figure 3. Recapitulation of the value of optimum asphalt content in Marshall testing can be seen on Table 8.

Table 5. Recapitulation of Marshall test for 3% variation

| Characteristic | Characteristic | 5 | 5.5 | 6 | 6.5 | 7 | Specification |
|----------------|---------------|---|-----|---|-----|---|---------------|
| Stability      |               | 889.44 | 989.61 | 1132.03 | 1171.01 | 1240.32 | Min. 800 kg  |
| Flow           |               | 5.13   | 4.37  | 4.13  | 3.70  | 3.4  | 2 – 4 mm     |
| VIM            |               | 3.39   | 3.80  | 4.31  | 5.14  | 6.97 | 3.5 – 5.5 % |
| VMA            |               | 13.26  | 14.55 | 15.91 | 17.53 | 20.13 | Min. 15 %   |
| Density        |               | 2.41   | 2.37  | 2.36  | 2.33  | 2.27 | Min. 2 gr/cm³ |
| VFB            |               | 74.47  | 73.90 | 72.92 | 70.71 | 65.13 | Min 65 %    |
| MQ             |               | 174.02 | 230.25 | 274.49 | 318.43 | 365.90 | Min 250 kg/mm |
### Table 6. Recapitulation of Marshall test for 4% variation

| Characteristic | Specification |
|----------------|---------------|
| Stability      | Min. 800 kg   |
| Flow           | 2 – 4 mm      |
| VIM            | 3.5 – 5.5 %   |
| VMA            | Min. 15 %     |
| Density        | Min. 2 gr/cm³ |
| VFB            | Min 65 %      |
| MQ             | Min 250 kg/mm |

### Table 7. Recapitulation of Marshall test for 6% variation

| Characteristic | Specification |
|----------------|---------------|
| Stability      | Min. 800 kg   |
| Flow           | 2 – 4 mm      |
| VIM            | 3.5 – 5.5 %   |
| VMA            | Min. 15 %     |
| Density        | Min. 2 gr/cm³ |
| VFB            | Min 65 %      |
| MQ             | Min 250 kg/mm |

### Table 8. Recapitulation of optimum asphalt content

| No  | Variation of PVC | Optimum Asphalt Content (KAO) |
|-----|------------------|-------------------------------|
| 1   | 3 %              | 6.5 %                         |
| 2   | 4 %              | 5.8 %                         |
| 3   | 6 %              | 6 %                           |

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**Figure 1.** Graph of optimum asphalt content of 3% variation
To analyze the relationship between asphalt content and Marshall parameters, regression analysis was used. Regression analysis used in accordance with the form of data distribution or scatter diagrams that form a curved or straight line (linear). In this case, non-linear (polynomial) regression is considered the most suitable for data distribution in this research. The second order polynomial equation is the result of calculating the relationship between variations of PVC and Asphalt Pen 60/70 can be seen in Table 9 and Table 10.

**Table 9. Polynomial equations in the relationship of PVC and Asphalt in 30 Minute**

| Parameters | Polynomial equation 2nd ord | R²   |
|------------|-----------------------------|------|
| Stability  | \( y = -6.2968x^2 + 80.849x + 1105.5 \) | R² = 0.92 |
| Flow       | \( y = -0.0214x^2 - 0.15x + 4.7 \) | R² = 0.99 |
| VIM        | \( y = 0.0686x^2 + 0.0645x + 3.4332 \) | R² = 0.90 |
| VMA        | \( y = 0.0308x^2 - 0.0167x + 16.245 \) | R² = 0.98 |
| Density    | \( y = -0.0009x^2 - 0.0028x + 2.3679 \) | R² = 0.94 |
| VFB        | \( y = -0.1292x^2 - 1.6991x + 80.152 \) | R² = 0.92 |
| MQ         | \( y = 4.5493x^2 + 6.2408x + 254.53 \) | R² = 0.92 |
Based on the results obtained from data processing and test results in the form of a mixture of PVC and asphalt, it can be seen the comparison of each mixture. This discussion is about how the effect of using PVC as an additive in the asphalt concrete wearing course characteristics. The results of the calculation and the overall characteristic value of the Marshall parameter in terms of the optimum asphalt content and each variation in graphical form.

Based on the optimum asphalt content of each treatment with 3 variations were made, durability is obtained from the comparison between normal stability and immersion stability for 24 hours. The recapitulation results of the durability value can be seen in Table 11.

### Table 11. Recapitulation of durability value

| No | Composition | Asphalt content (%) | Immersion stability 30 minutes | Immersion stability 24 hour | Durability (%) |
|----|-------------|---------------------|--------------------------------|-----------------------------|---------------|
| A  | B           | C                   | D                              | E                           | F = E/D       |
| 1  | 3 %         | 6.5                 | 1,367.91                       | 1,296.06                    | 94.75         |
| 2  | 4%          | 5.8                 | 1,283.84                       | 1,881.10                    | 92.54         |
| 3  | 6%          | 6.0                 | 1,225.81                       | 1,150.38                    | 93.85         |

3.2. Review of the value of stability
The stability value is needed to determine how much the ability of the pavement to accept traffic loads. All stability values for the three variations meet the required specifications of Bina Marga 2018, namely > 800 kg. At the immersion 30 minutes the highest stability value was produced by a variation of 3% with a value of 1,367.9%. For 24 hours immersion, the highest value was obtained at 3% variation with a value of 1296.06 kg. This shows that the addition of PVC to the asphalt mixture can provide better resistance to high temperatures and traffic loads.

3.3. Review of the value of flow
Flow is the amount of change of the specimens that occurs from the load time until the stability conditions are met. Flow shows the plastic melt rate and flexibility of a mixture. A high flow value indicates that the mixture is plastic, so it is better able to follow changes that occur due to load. The flow value is also obtained from direct reading on the Marshall dial during the test. Flow values in all variations do not meet specifications. The flow value at 3% variation is higher and does not meet specifications. Meanwhile, the variations of 4% and 6% still meet specifications. This is probably caused by increasing levels of PVC which will result in decreased flow values.

3.4. Review of the value of VIM
VIM is the number of porous between the aggregate grains covered with asphalt or a cavity contained in the total mixture. VIM is needed to determine the percentage of porous volume that remains after the asphalt mixture is solidified. The higher VIM value indicates that the cavity on the specimen is large and the lack of water tightness. The VIM value at the 3% variation produces the lowest value. This results in a low PVC value in the mixture which results in a reduced VIM value. The VIM value
at a higher level of 6% may be caused by high levels of PVC in a mixture resulting in a high cavity value because it is added by the presence of mixed rice husk ash filler resulting in a high cavity value.

3.5. Review of the value of VIM
The VMA value is the number of porous between the aggregate in the asphalt concrete which is filled with asphalt. The VMA value shows the pore percentage between the aggregate grains. VMA will increase if the asphalt blanket in the mixture is thicker. The VMA values for the three variations for the 30-minute immersion and the 24 hour immersion meet the Bina Marga 2018 specifications. The increase in the percentage of PVC in the mixture results in the VMA value increasing, because more asphalt is added with the addition of PVC additives covering the aggregate grains, thus forming an aggregate grain blanket thick one. This results in the cavity between the aggregates of the test objects getting bigger.

3.6. Review of the value of density
Density is the ratio between the dry weight and the volume of the asphalt concrete mixture. The density values of the three variations meet the specifications of Bina Marga 2018. The combination of a mixture of PVC and rice husk ash as a filler makes the volume of the specimens bigger but easier to compact, while the dry weight does not change.

3.7. Review of the value of VFB
VFB is the percentage volume of solid asphalt concrete which becomes asphalt film or is the percentage of the volume of asphalt that covers the aggregate after undergoing a compaction process. VFB values that are too small because the mixture to be less impermeable to water and air so that the asphalt mixture is easily oxidized which ultimately causes the pavement layer does not last long. Not all of the VFB values of the three variations meet the specifications. The highest VFB value is at a variation of 3% due to the small percentage of addition of PVC additives and the percentage of asphalt is more so that more cavities are filled with asphalt which makes the mixture impermeable to water and air. The lowest VFB value is at 6% variation.

3.8. Review of the value of MQ
The MQ value is an approach to the stiffness and flexibility of a pavement layer or is the flexibility index of a mixture. If the mixture has a high MQ, it means that the mixture is stiffer and has low flexibility. All MQ values in the three variations meet the specifications. The MQ value has increased from various variations of the test specimen, this indicates that the addition of PVC as an additive to the asphalt mixture with a large percentage causes the mixture to become stiffer.

4. Conclusions
The conclusions that can be given from the results of the research on the effect of using PVC as an additive to the mixture of asphalt concrete wearing course are as follows:
1. The results of the marshall characteristic values generated from the Marshall test are the values of stability, density, flow, VIM, VMA, VFA, and MQ. The KAO value was obtained by making 45 specimens for middle asphalt content and carrying out the Marshall test. This research refers to the specifications of Bina Marga 2018.
2. Comparison of PVC and pen asphalt 60/70 in each specimen for 3 different variations, namely 3% PVC variation, 4% and 6% PVC variation. The results of the examination of the 3% PVC variation showed that the KAO value that met the specifications of Bina Marga 2018 was 6.5%, for 4% variation was 5.8% and the 6% PVC variation obtained the KAO value that fulfilled was 6%.
3. Marshall testing of the two variations shows the comparison that the 3% variation, 4% variation and 6% 30 minute immersion PVC meets the requirements, except that the flow value in the 3% variation of PVC is 4.23 mm. This does not meet the 2018 Bina Marga Specifications. The flow
value obtained is quite high, this indicates that the mixture is plastic, so it is better able to follow changes that occur due to load
4. From the results of this study, it can be concluded that the more the addition of PVC shows the stability value is decrease and the value of flow more increase. The durability value of the AC-WC layer, a mixture of PVC and asphalt in the three variations, fulfills the requirements set forth by Bina Marga 2018, namely ≥ 90%.

References
[1] Saifuddin 2015 Pengaruh Plastik PVC Sebagai Subsitosi Aspal Pen. 60/70 Pada Camporan Asphalt Concrete Binder Course (AC-BC) (Banda Aceh: Universitas Syiah Kuala)
[2] Mashuri dan Batti 2011 Pemanfaatan Material Limbah Pada Campuran Beton Aspal Campuran Panas MEKTEK 13(3)
[3] Zulfiani 2012 Studi Karakteristik Campuran Aspal Beton (AC-BC) Terhadap Pengaruh Plastik Sebagai Bahan Subsitusi Aspal (Yogyakarta: Biro Penerbit Teknik Sipil)
[4] Umam 2009 Pengaruh Penambahan Plasticizer Dioctyl Phtalate (DOP) Terhadap Mampu Alir Dan Sifat Mekanik Resin Polivinil Klorida PVC (Jakarta: Universitas Indonesia) 111 – 120
[5] Veranita and Rinaldi 2019 Durabilitas Campuran Aspal Beton Menggunakan Abu Sabut Kelapa dan Abu Sekam Padi Sebagai Pengganti Filler Struktur Material, Manajemen, Rekayasa Konstruksi 1 211 – 219
[6] Akbar S J 2012 Stabilitas Lapis Aspal Beton AC-WC Menggunakan Abu Sekam Padi (Aceh: Universitas Malikussaleh)
[7] Departemen Pekerjaan Umum 2018 Ketentuan Agregat Kasar dan Agregat Halus (Jakarta: Departemen Pekerjaan Umum)
[8] Sukirman S 2003 Beton Campuran Aspal Panas (Bandung: Granit)