The Physical and Mechanical Properties of Ethylene Vinyl Acetate Modified Binder

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Abstract. During its service life, road pavement can easily crack, perforated or deformed. These damages happen as a result of low quality asphalt which indicated by its penetration index and stiffness value. 60/70 penetration asphalt modified by EVA polymer is expected to increase penetration index and stiffness value. Some experiments in the laboratory were carried out based on specified requirements and SNI-2011 asphalt testing procedures. The solid EVA was mixed with the liquid asphalt pen 60/70 at a medium to high temperature until it reaches 250 \(\degree\)C. During the mixing, this mixture was stirred for approximately \(\pm 15\) minutes until homogeneous. These experiments consist of ductility test, penetration test, softening point test, flash point test, fire point test, specific gravity test, lose on heating test and asphalt stickiness to aggregate test. From the experiment, it can be concluded that the addition of 3.5\% EVA in the asphalt pen 60/70 is generally acceptable based on the ductility value of SNI-2011 qualification. The addition of 3.5\% give the ductility value of 130 cm, flash point of 300 \(\degree\)C, fire point of 310 \(\degree\)C, softening point of 54 \(\degree\)C, specific gravity of 1.020 gr/cc, asphalt stickiness to aggregate of 100\% covered, and lose on heating of 0.037\%. Nevertheless the experiment results in penetration value of 37.27 which doesn’t conform the qualification of asphalt pen 60/70. This penetration value resulting in penetration index value of -0.9. This shows that the asphalt resist to the temperature changing. Theoretical predictions of asphalt characteristics using BANDS 2.0 showed that the addition of EVA can increase the penetration index and the stiffness of the bitumen.

1. Introduction
The highway is a land transportation infrastructure that is very important to facilitate community activities in economic movements and other social activities. In general, one of the highway pavement binders that are often used is an asphalt mixture because asphalt is a viscoelastic material. However, during its service life the asphalt in the mixture was easily damaged due to weather changes, overloading and heavy traffic volume. With the consideration of the resistance to load and weather it can determine the pavement design. If the road design uses flexible pavement design, the planned quality and thickness must be good so that the pavement is not easily damaged due to the load of vehicles passing through it. A method is needed to improve the ability of asphalt in the mixture to maintain or improve the properties of asphalt by modifying asphalt with added ingredients of elastomeric polymer. The type of elastomeric polymer used in this study is Ethylene Vinyl Acetate (EVA) [1]. Asphalt modification with EVA is expected to increase the stiffness of the asphalt, because of its good stiffness in holding the load and can reduce the penetration value so that the asphalt...
becomes harder and can increase the softening point value so as to produce a good Penetration Index value so that the asphalt is more resistant to change weather [2,3].

2. Experimental

The method used in this study is the experimental method, namely research in the Highway Laboratory of the Civil Engineering Study Program of the Faculty of Engineering, University of Sebelas Maret, Surakarta based on SNI-2011 terms and conditions. The results of this study will illustrate the effect of adding EVA polymer on 60/70 penetration bitumen. The resulting value can be used as a basis for the analysis of EVA modified asphalt characteristics so that a conclusion can be drawn.

2.1 Sample Production

Before the manufacture of specimens, asphalt mixing was carried out this was added with EVA with variations in the addition of 0% to 4% at 0.5% intervals of asphalt weight. Making test specimens is done after obtaining one of the best mixture methods or mixtures which do not clump from the three methods carried out, and then the modified EVA asphalt is poured in the medium of the test object for each test. The specimens to be made in this study can be clarified using Table 1.

| Percentage of EVA (%) | Penetration | Softening Point | Flash Point/Burning Point | Ductility | Specific Gravity | Lost Weight | Afinity | The number of sample (Unit) |
|-----------------------|-------------|-----------------|---------------------------|-----------|-----------------|-------------|---------|---------------------------|
| 0                     | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 0.5                   | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 1                     | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 1.5                   | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 2                     | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 2.5                   | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 3                     | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 3.5                   | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |
| 4                     | 3           | 4               | 2                         | 3         | 3               | 3           | 2       | 20                        |

The total number of sample 180

2.2 Sample Testing

The Testing of the specimens is to examine the properties of 60/70 penetration asphalt which has been modified with EVA. The test results used are the average value of the test results of the test object. If there is a deviation from the test results then it must be retested. The tests carried out are Ductility (SNI 2432: 2011), Penetration (SNI 2456: 2011), Softening Point (SNI 2434: 2011), Flash Point and Burn Point (SNI 2433: 2011), Specific Weight (SNI 2441: 2011), Asphalt attachment on aggregates (SNI 2439: 2011), and weight loss (SNI 2440: 2011). Based on the results of penetration testing and asphalt softening point, it can predict modified stiffness modulus and penetration index with BANDS 2.0 computer program.

3. Results and Discussion

3.1 The Physical properties of EVA modified bitumen

The mixing method used in this study is a hot-cold method. Mixing is done using medium heat until it reaches a temperature of 250°C and is stirred until the mixture does not clot. The way to find out the homogeneous mixture or not is done visually by looking at the mixture of asphalt and EVA mixed
perfectly and there is no clumping of EVA in the asphalt mixture. The results of testing the basic characteristics of EVA modified asphalt can be seen in Table 2.

| The Test                              | Unit     | The Condition of 60/70 pen | Percentage of EVA (%) |
|---------------------------------------|----------|---------------------------|-----------------------|
| Penetration (25°C, 100gr, 5 sec)      | 0.01 mm  | 50 - 70                   | 62.13 44.20 41.60 39.67 38.53 37.67 37.47 37.27 36.53 |
| Softening Point (ring and ball) Flash | °C       | Min. 50                   | 51.0 51.5 51.9 51.9 52.0 52.1 53.0 54.0 56.5 |
| Point (Cleveland open cup) Burning    | °C       | Min. 200                  | 295 315 325 307.5 305 320 315 290 290 |
| Ductility 25°C                        | Cm       | Min. 100                  | 150 150 150 150 150 150 150 130.0 68.0 |
| Specific Gravity                      | 1        | Min. 1                    | 1.049 1.046 1.029 1.028 1.024 1.022 1.021 1.020 1.011 |
| Weight Loss                           | %        | ≤ 0.8                     | 0.005 0.01 0.013 0.017 0.020 0.023 0.033 0.037 0.037 |
| Adhesion                              | %        | ≥ 97                      | 100 100 100 100 100 100 100 100 100 |

3.2 The Prediction of the Mechanical Properties.

The results of the research on EVA modified asphalt in the laboratory were obtained Penetration values and Softening Points which were used as input data in the BANDS 2.0 Program. Then the assumption data are vehicle speed with a value of 0.02 (± 30 km / h), asphalt temperature of 20-60 °C (condition of road surface temperature in Indonesia) and the temperature at Penetration testing is 25 °C. The prediction results of penetration index and bitumen stiffness using the BANDS 2.0 program can be seen in Table 3.

| Prediction of Asphalt Modification EVA with BANDS 2.0 Program | Penetration Index | Bitumen Stiffness (MPa) |
|---------------------------------------------------------------|-------------------|-------------------------|
| Kadar EVA                                                     | Penetration       | Softening Point         | 20°C 30°C 40°C 50°C 60°C |
| 0%                                                            | 62.13             | 51.0                   | -0.4 21.6 3.97 0.664 0.146 0.0344 |
| 0.5%                                                          | 44.20             | 51.5                   | -1.1 45.6 7.44 0.974 0.173 0.038 |
| 1%                                                            | 41.60             | 51.9                   | -1.1 50.9 8.34 1.07 0.185 0.0404 |
| 1.5%                                                          | 39.67             | 51.9                   | -1.2 56.9 9.12 1.13 0.189 0.0404 |
| 2%                                                            | 38.53             | 52.0                   | -1.3 60.4 9.63 1.17 0.193 0.0411 |
| 2.5%                                                          | 37.67             | 52.1                   | -1.3 63.2 10 1.21 0.197 0.0417 |
| 3%                                                            | 37.47             | 53.0                   | -1.1 59 10.1 1.32 0.221 0.048 |
| 3.5%                                                          | 37.27             | 54.0                   | -0.9 53.9 10.2 1.44 0.252 0.0552 |
| 4%                                                            | 36.53             | 56.5                   | -0.4 47.3 10.5 1.76 0.331 0.0774 |

Penetration index is obtained from the properties of asphalt, namely the softening point and penetration values that describe the sensitivity level of asphalt to changes in temperature [4]. Based on The Shell Bitumen Handbook that a good penetration index value is between -3 to +7. If the
penetration index value is smaller than -3 then it indicates that the material is easily affected by the surrounding temperature, if the penetration index value is greater than +7 then the material is not affected by the surrounding temperature [5]. The prediction results of the Penetration Index with the BANDS 2.0 program can be seen in Figure 1.

![Figure 1. Relationship Graph between EVA Levels and Penetration Index](image1)

The prediction results of Stiffness Bitumen with the BANDS 2.0 program are strongly influenced by the asphalt surface temperature in the field. This can be seen in the results of the prediction of Bitumen stiffness in Table 7. The value of Stiffness Bitumen decreases with increasing temperature. This phenomenon is due to the nature of asphalt which is viscoelastic where asphalt will become liquid when heated and become hard at cold temperatures, so that at high temperatures the asphalt will have a small stiffness and at low temperatures the asphalt has a large stiffness [6].

The reading of the relationship between EVA levels and Stiffness Bitumen at each temperature has increased results in line with the value of EVA levels. The greater the EVA level, the bitumen stiffness increases. For more details the results of the prediction of Stiffness Bitumen can be seen in Figure 2.

![Figure 2. Relationship Graph between EVA Levels on Bitumen Stiffness at 20 °C and 30 °C](image2)

The reading of the graph and the quadratic function on the 20 °C Stiffness Bitumen shows the maximum value is when the addition of EVA is 2.5% with the Stiffness Bitumen value of 63.2 MPa. The reading of the graph and the 30 °C Stiffness Bitumen quadratic function shows the maximum value is when the addition of EVA is 3.094% with a value of Stiffness Bitumen of 10.5 MPa.
The results of predictions of bitumen stiffness at 40 °C and 50 °C show that the value of bitumen stiffness decreases from the result of prediction of 30 °C stiffness bitumen or in other words there is a decrease in bitumen stiffness value with increasing asphalt surface temperature. The addition of EVA is positively correlated with bitumen stiffness value; the greater the percentage of EVA added to the asphalt, the greater the bitumen stiffness value. This shows that with the addition of EVA, it can make asphalt more resistant to resist loads at temperatures of 40 °C and 50 °C.

Asphalt modification of EVA can increase asphalt stiffness at a temperature of 60 °C, although not significant can be seen from asphalt with a level of 0% EVA of 0.0344 MPa to 4% EVA of 0.0774 MPa experiencing an increasing trend of asphalt stiffness so that EVA modified bitumen is used for materials road pavement in Indonesia with an average road pavement temperature of around 60 °C.
4. Conclusion
The best mixing temperature is 250 °C with a hot-cold mixing method that can produce a homogeneous mixture or not clump between asphalt and EVA. Asphalt characteristics with the addition of EVA have better bitumen properties compared to bitumen without using EVA with ductility values, softening points, flash point, burn point, aggregate attachment on asphalt and weight loss testing all meet 60/70 penetration requirements.

Asphalt penetration values do not meet the requirements for 60/70 penetration asphalt. Percentage of optimum EVA levels that still meet the requirements of 60/70 asphalt penetration is at a percentage of 3.5% with ductility values reaching a length of 130.0 cm, flash point 300°C, burn point 310 °C, softening point at 54°C, density of material 1.020 gr/cc, asphalt attachment to aggregate is 100% covered, and loses weight 0.037%.

Penetration value of 3.5% does not meet the requirements of 60/70 penetration asphalt, which are 37.27 with a penetration index of -0.9 so that stronger asphalt against hot weather changes. The theoretical prediction of asphalt characteristics with the BANDS 2.0 program shows that the addition of EVA 3.5% on asphalt can increase the penetration index value and can increase the bitumen stiffness value.

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