Performance of Polymer Modified Asphalt Mixture Using Gypsum Filler

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Abstract. Road infrastructure is a means of transportation that is quite important in developing the economy in a region, so it is necessary to increase the quality and quantity of materials used and to add or modify the material used in the asphalt mixture by using gypsum powder waste and polymer asphalt. This study was aimed to determine the performance of the polymer-modified asphalt mixture using gypsum powder filler on the Laston AC-WC layer. The method used in this study was a laboratory experiment with Marshall testing with variations in the content of gypsum powder fillers, namely 0%, 1%, 2%, and 3%. The results showed that the addition of gypsum powder filler can increase the value of the void in the mixture and the void in mineral aggregates, but it can reduce the value void filled with asphalt, stability, and flow values. This affected the density and reduced durability of the asphalt mixture, but it provided the benefit of being able to accelerate the stiffening of the asphalt and make the asphalt mixture more resulting in resistance to deformation damage.

Keywords: polymer asphalt, gypsum, Laston AC-WC.

1 Introduction

Road infrastructure plays a very important role in the development of activities in a region in supporting economic, social, and cultural growth [1], [2]. This activity will develop if it has good transportation infrastructure and facilities, therefore it is necessary to increase the quality and quantity of road infrastructure to meet the needs of the community. Flexible hardening, one of the road constructions used in various countries, consists of four main materials, namely coarse aggregate, fine aggregate, filler, and bitumen [3]. The use of fillers has an effective role in determining the properties and behavior of asphalt mixtures [4], [5], rock ash, and Portland Cement (PC). They are usually used as fillers that are the result of limited production quantities and are quite expensive so that alternative materials are needed.

The use of waste in the construction industry is important because the high amount of waste produced has a significant impact on the environment [6], [7], several waste materials used as fillers in asphalt mixtures have been developed, including lime recycled waste [8], coal fly ash [9], slag [10], gypsum powder [11] and other non-plastic mineral materials. In this study, a filler of gypsum powder containing a mineral with calcium sulfate (CaSO42H2O) was used which is often used as an adhesive, flame retardant, and easy to repair. This makes gypsum waste good for use as a filler besides being able to bind asphalt better it also does not cause environmental pollution [11], [12].

One type of asphalt pavement is concrete asphalt layer (LASTON) where the pavement structure that is directly in contact with air and vehicle loads is the AC-WC (Asphalt concrete -Wearing Course) surface layer and the watertight layer so that in addition to the selection of aggregates, it is also influenced by the quality and the quantity of the asphalt binder [13],[14]. Asphalt material can be developed and modified to improve its performance, this is because asphalt is a viscoelastic material so that when the stiffness is high, cracks occur and if it is too flexible, deformation will occur so that appropriate modification to performance is required. Polymer is one of the modifications of asphalt which is used as an effective modifier to improve the performance of the mixture and increase the strength so that the design life is longer [15], besides that, polymer modifier can also overcome various damages that occur on the pavement such as permanent deformation, temperature changes, cracking and raveling [16],[17]. This can be achieved if it is by the characteristics of the location, traffic loading, and the environment [18].

Increased material requirements, decreased road performance and environmental problems can be overcome by the use of appropriate materials, where filler and asphalt have an important role in the mixture, so based on this it is necessary to carry out further studies to determine the performance of polymer modified asphalt mixtures using powder fillers gypsum

2 Materials And Methods

2.1 Aggregate

The aggregate material used was from Bojonegaro, Serang Regency, Banten Province. There are 2 types of aggregate sizes used, namely coarse aggregate split 1-2 and screening, then fine aggregate (rock ash). The test results for coarse and fine aggregates can be seen in Table 1, where the characteristics showed that the aggregate meets the general specifications of Bina Marga in 2018 division 6 [19].

Table 1. Characteristics of Coarse Aggregates

No	Testing	Result	Test Specification	
			Minimum	Maximum
Coarse Aggregates				
1	Bulk Specific Gravity	2,72	2,5	-
2	Apparent Specific Gravity	2,82	2,5	-
3	SSD Specific Gravity	2,76	2,5	-
4	Absorption (%)	1,21	-	3
Fine Aggregates				

1	Bulk Specific Gravity	2,61	2,5	-
2	Apparent Specific Gravity	2,76	2,5	-
3	SSD Specific Gravity	2,67	2,5	-
4	Absorption (%)	2,04	-	3

2.2 Asphalt

The asphalt used in this study was asphalt modified polymer type elastomer (E-55) equal to the value of PG-76 and entered into type II modified asphalt, which was then tested for physical properties which can be seen in Table 2. Based on the test results, it was obtained that the asphalt met the General Specifications of Bina Marga 2018 division 6.

Table 2. Characteristics of Asphalt

No	Testing	Result	Test Specification	
			Minimum	Maximum
1	Penetration 250C; 100gr, 5 sec, 0,1 mm	56,3	40	-
2	Lost Weight (%)	0,06	-	0,8
3	Density	1,042	1,0	-

2.3 Gypsum

The minerals contained in gypsum are sulfates, which are sedimentary rocks with the composition of calcium sulfate dihydrate ($CaSO_4$, $2H_2O$). Gypsum has physical properties in the form of crystals that have gradations of white, gray, yellow, orange, or black, with water content in the structure with the content of approximately 23.3% for lime (Ca) and sulfur (S) of 18.5%. The following is in Table 3 the chemical composition contained in gypsum [20].

Table 3. Gypsum Powder Chemical Composition

No	Material	Content
1	Calsium (Ca)	23,82
2	Hydrogen (H)	2,34
3	Calsium Oxide (CaO)	32,57
4	Water (H_2O)	20,93
5	Sulphur (S)	18,62

There are various types of gypsum, the most commonly found is calcium sulfate hydrate with the formula $CaSO_4$, $2H_2O$ (Calcium Sulfate Dihydrate). Evaporated minerals such as carbonate, borate, nitrate, and sulfate can form gypsum by depositing these 25 minerals in oceans, lakes, caves, and salt layers [11]

2.4 Method

The study on the performance of asphalt mixtures using modified elastomeric polymer asphalt and gypsum filler used laboratory experimental methods, where the study stages consisted of preliminary literature studies, material characteristics testing, making asphalt mix designs, testing Marshall mixes with the Marshall method, and determining the optimum asphalt content in each mixture.

The mixing method used was asphalt mixed first with gypsum powder and then mixed with aggregate. There were 4 variations of the mixture which are differentiated based on the gypsum filler content, namely 0, 1, 2, and 3% % with the proportion of weight calculation to the total filler. The following in Fig.1 describes the methodology in this study.

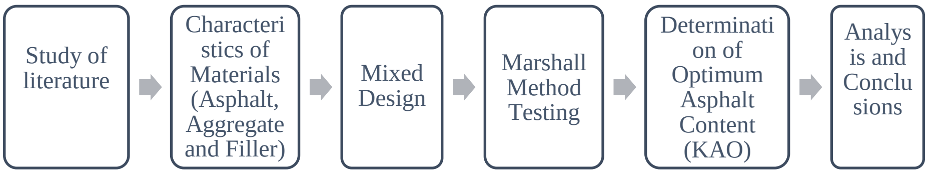

Fig. 1. The Methodology of Study

3 Analysis

3.1 AC-WC Layer Mixed Design

In the mixed design, the first stage was the determination of the proportion of the aggregate in the mixture by testing the sieve analysis to get the percentage passing of each fraction used in the mixture. Based on the gradation calculation, the mix design value with the composition used for split aggregates 1-2 is 15%, fraction 24%, and 61% screening for rock ash aggregate. The mixed grade used was by Fig. 2, where the design can be said to be a good proportion because the mixed aggregate was graded close to the middle gradation of General Bina Marga 2018 specification range division 6 with the Laston layer type (AC-WC).

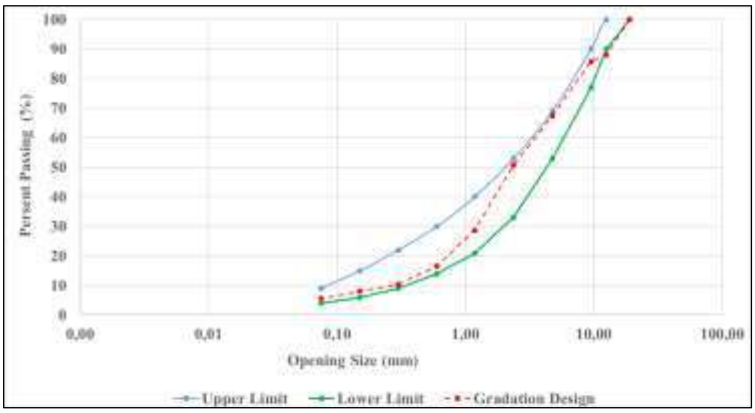

Fig. 2. Graduation Design

3.2 Characteristic of Mix Asphalt

The use of the gypsum grade variation determined the volumetric parameters in the mixture, where the variation is one of the factors that influence the properties of the asphalt mixture. Analysis of the volumetric characteristics and the Marshall test are as follows.

3.2.1. **Void In Mixture (VIM).** The total volume of air between the aggregates covered after the compaction process was an understanding of the VIM. The magnitude of this VIM value had an effect on the mixture durability, where the VIM value was related to the void in mineral aggregates (VMA) and the void filled with asphalt (VFB). Fig.3 showed the comparison of the VIM value at each asphalt level with the gypsum filler level, where the addition of gypsum filler results in the VIM value that was getting bigger, alkaline was caused by more asphalt dry than filler. This gave results with previous studies where the gypsum content used was 5% - 9% [11]. The VIM values were too high because the mixture easily oxidizes and cracks when traffic loading was applied. If the road was too low bleeding, the VIM value of the AC-WC mixture was limited to a minimum of 3% and a maximum of 5%.

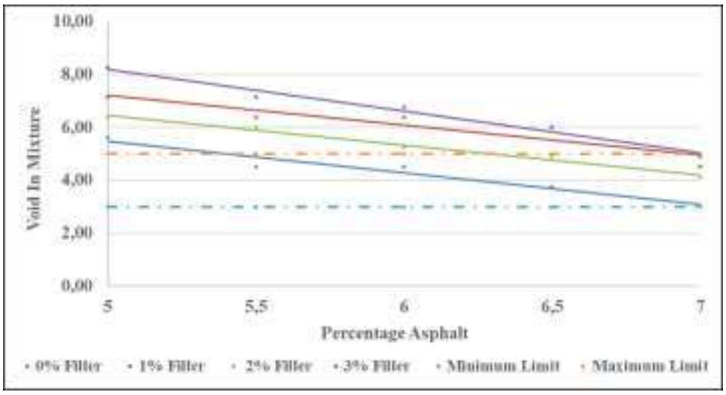

Fig. 3. Relationship between VIM and Asphalt Levels

3.2.2. **Void in Aggregate Minerals (VMA).** The increase in the level of asphalt used in the mixture will decrease up to reaches the minimum point and will increase again with the addition of asphalt content. This was because the asphalt filled the void between the aggregates so that the void could not be filled by asphalt. Based on Fig. 4, the increase in the content of the gypsum filler resulted in the VMA value tending to increase, this indicated that the gypsum filler did not fill the gaps between the aggregate particles, where the asphalt which served as a cover also filling the voids between the aggregate particles. The smaller VMA value indicated that the mixture had more durability because high VMA could cause the mixture to be susceptible to deformation so that 1% gypsum content had better durability than other gypsum levels.

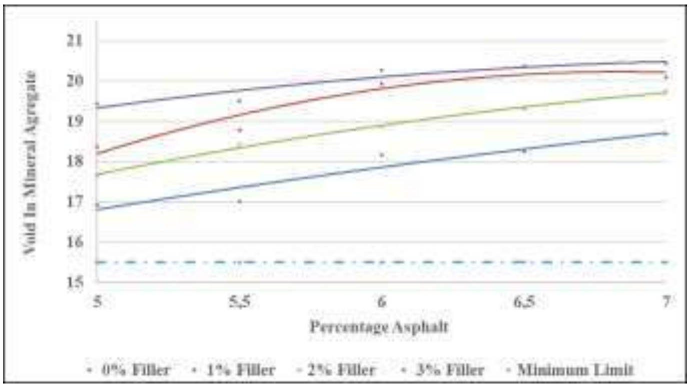

Fig. 4. Relationship between VMA and Asphalt Levels

3.2.3. **Void in Filled Asphalt (VFB).** Asphalt content and the film thickness can be expressed in terms of the volume of mixed asphalt, the relationship between VFB and the increase in asphalt content showed that the VFB value tended to be greater with increasing asphalt content. In Fig. 5, it can be seen that the addition of gypsum filler results in the VFB value was getting smaller meaning that in the 3% gypsum filler mixture the void in the aggregate minerals was filled with less bitumen than the 1% gypsum filler mixture. The mixture with the higher VFB value is 1% gypsum filler which indicates that this mixture can fill the voids in the aggregate larger than the mixture with 3% gypsum filler.

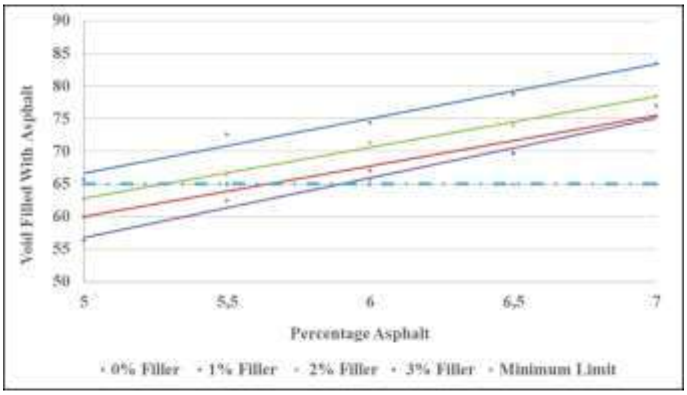

Fig. 5. Relationship between VFB and Asphalt Levels

3.2.4. **Stability**. One of the Marshall empirical values is the stability value, with direct measurement from the test when the test object is loaded with the Marshall test instrument. The stability value is influenced by several factors, including aggregate grading, bitumen content, internal friction of aggregate particles, interlocking, and asphalt adhesion. Fig. 6 shows the stability comparison for each mixture, where the addition of gypsum filler to the asphalt mixture resulted in a decrease in the stability value, due to the gypsum filler which affected the adhesion of the asphalt to the aggregate. The addition of gypsum filler cannot fill the voids in the mixture so that the bonds that occur between the aggregates are reduced.

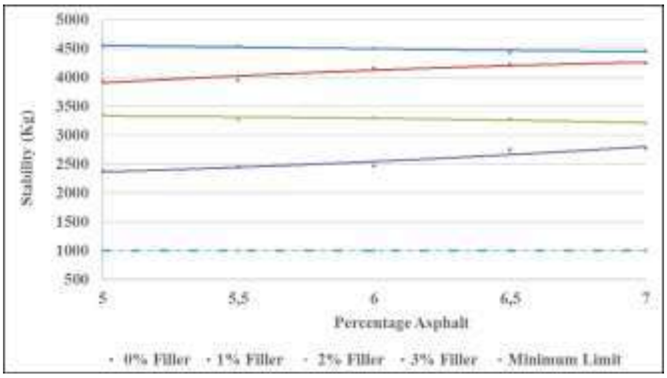

Fig. 6. Relationship between Stability and Asphalt Levels

3.2.5. **Flow**. Flow is a function of the stiffness of the binder and the content of the asphalt mixture, which is one of the empirical parameters that states the change in the plastic shape of the mixture due to loading. The addition of asphalt content will result in the aggregate being covered by asphalt, which results in interlocking between aggregates and causes an increase in melt value. Fig.7 shows that with the increase in the percentage of gypsum, the flow value becomes smaller so that the 1% gypsum mixture has a more flexible behavior than the 3% gypsum content.

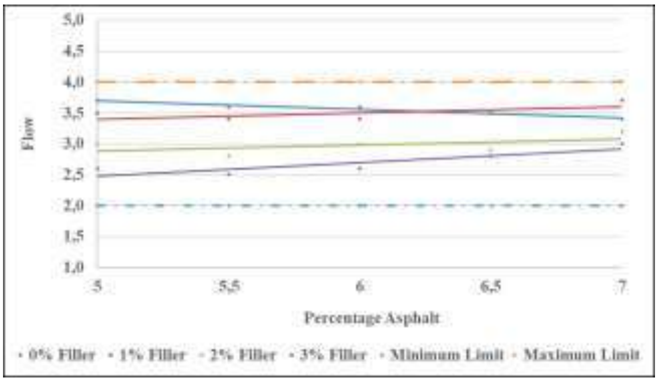

Fig. 7. Relationship between Flow and Asphalt Levels

3.2.6. **Marshall Quotient**. The Marshall Quotient (MQ) value is an approach to the level of stiffness and flexibility of the mixture, where the greater the MQ value of the mixture, the stiffer it is and the other hand the lower it is, the more flexible it is. Based on Fig. 8 the addition of gypsum filler causes the MQ value to be smaller so that the mixture is more flexible, this is because the flow value in the asphalt mixture with 3% gypsum content is the lowest compared to other mixtures.

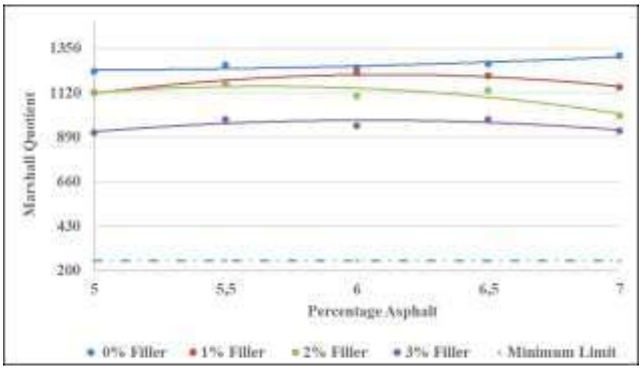

Fig. 8. Relationship between Marshall Quotient and Asphalt Levels

3.2.7. **Optimum Asphalt Content**. Optimum Asphalt Content (KAO) is asphalt content that produces a mixture that fulfills all the elements of the Marshall parameter. Fig. 9 shows that in general, the addition of filler resulted in a decrease in KAO in the gypsum filler 2% then it was added back to the 3% gypsum filler, with the optimum asphalt content obtained in this study was 6.25 % - 7.0 %. Based on the case, it can indicate that using filler gypsum needs more asphalt level with the high VIM value and the lower VFB value so that the thick film asphalt is lower than the mixture without using gypsum filler. It can be seen in picture 10.

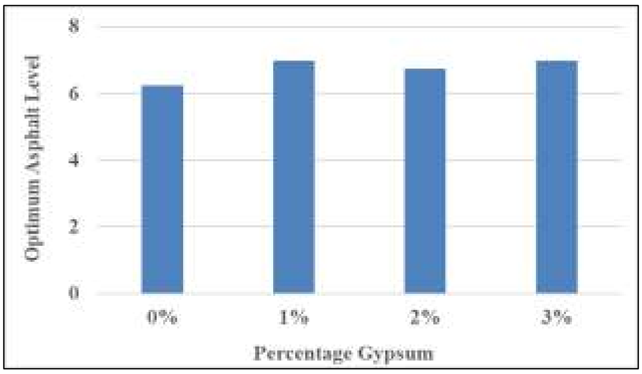

Fig. 9. Optimum Asphalt Levels

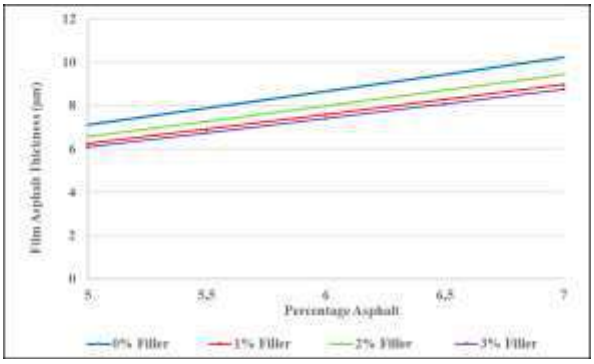

Fig. 10. Relationship between Film Asphalt Thickness and Filler Gypsum

4 Conclusion

From the testing and analysis carried out in this study, the following conclusions are obtained:

1. The characteristics of the material used in this study met the General Bina Margat requirements in 2018 division 6 with the type of Laston layer (AC-WC), where the aggradation used includes the intermediate value of the Laston gradation (AC-WC) with the mix design used for an aggregate of 1-2% for 15%, screening fraction is 24% and rock ash for 61%.
2. The addition of gypsum powder as a filler in the asphalt mixture to the volumetric characteristics can increase the VIM and VMA values, as well as decrease the VFB value. This indicated that the gypsum filler does not remove gypsum among aggregate particles so that it was filled with asphalt resulting in 1% more gypsum mix and gypsum mixture. Meanwhile, empirical testing with Marshall resulted in a decrease in stability and flow values.
3. The use of gypsums powder as a filler in polymer asphalt modification can accelerate the stiffening of the asphalt. It can be seen from a decrease in asphalt temperature then the asphalt is more flexible which is an indicator of resistance to deformation damage. On the other hand, the density of the asphalt mixture decreased because of the greater percentage of slack in the mixture causing its durability to be reduced.

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