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Evaluation of Resilient Modulus Performance of Warm Mix Polymer Modified Asphalt Using Natural Zeolite Additives

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Abstract

The performance structure of the hot mix asphalt are usually measured by parameters such as Marshall, but in the recent developments, the requirement of the hot mix asphalt specifications should meet the other parameters such as considering the result of modulus of elasticity test. The demands simulated in a performance of road pavement structure, should be strong and durable. Polymer asphalt binder became more popular in many researches and practices today due to its potential to improve durable at low temperature on asphalt mixtures. Polymer modified asphalt (PMA) also can be developed by means of warm mix technology by mixing the mixtures with synthetic or natural additives. This mixture can improve pavement durable with lower temperature in its mixing and compaction process. This research proposed a development of warm PMA mixture with natural zeolit, i.e. natural additive from Bayat (Central Java) and the performance of the mixture, in the terms of volumetric and mechanical properties, and modulus of elasticity test, was evaluated using Marshall method and UMATTA test, respectively. The results showed that warm PMA mixture with 1% Bayat natural zeolite had lower 30oC temperature of mixing and compaction temperature than asphalt 60/70 mixture. The results showed that PMA with 1% natural zeolite had greater Marshall stability than that without natural zeolite. Under UMATTA test at temperature of 25oC and 35oC, PMA with 1% natural zeolite showed better performance than that with asphalt 60/70 mixture, as indicated by temperature of 25oC of 2521 MPa and 2464 MPa and temperature of 35oC of 938 MPa and 842,67 MPa (for PMA with 1% natural zeolit and mixture with aphalt 60/70, respectively).

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Keywords: Resilient Modulus, Polymer Modified Asphalt, Warm Mix Asphalt, Natural Zeolite

1. Introduction

1.1. Background

Layers of asphalt concrete is a cover layer of pavement construction which has a structural value and in contact with the vehicle wheel load, where the intended use suitable to serve heavy traffic. Asphalt concrete must have high performance in mixing such is the durability. Among the modified asphalt material to improve the strength of the mixture, polymer is a material often used in road construction as asphalt modifier [9]. Polymer asphalt binder is becoming more popular in many research and practice today because of its potential to improve the strength and durability at low temperature in the asphalt mixture. By using a polymer modified asphalt is expected this mixture can increase service life.

1.2. Research purposes

Generally, this research aims to identify and evaluate the effect of temperature on the warm asphalt mixture using bitumen modification of polymers and additives natural zeolite Bayat.

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In detail the objectives of this research are:

1. Getting the temperature of mixing and compaction minimum temperatures on the warm asphalt mixture using bitumen binder polymer with additives of natural zeolite.

2. Compare and analyze the performance of resilient modulus of warm asphalt mixture polymers and additives of natural zeolite with a mixture without zeolite using the tool Universal Material Testing Apparatus (UMATTA).

2. Literature review

2.1. Warm mix asphalt

Warm mix asphalt as a technology , which produced at lower temperatures of mixing and compaction, the vulnerability of moisture is a concern that will occur due to the use of aggregates in the mix may not dry as it is used in a mixture of Warm Asphalt Mixture. Warm Asphalt Mixture refers to technologies that allow a significant reduction of the temperature of mixing and compaction temperatures asphalt mixture, by decreasing the viscosity of bitumen by adding additives [5].

Various Warm Asphalt mixture research with the use of additives has been done. Types of additives which are already widely used and developed for the WMA include the use of synthetic zeolite with various trademarks such as Aspha-min®, Sasobit® and Advera®. The use of warm asphalt mixture in the asphalt mixture technology resulted in the use of mixing temperature / solidification temperature that is lower in the mixture, making considerable energy savings and emission mitigation[13].

2.2. Polymer Modified Asphalt

Polymer modified asphalt is used to increase the durability of asphalt to temperature changes with increasing stiffness binder / binder at elevated temperatures and reduced stiffness at low temperatures at the same time [3]. Polymer as an material added (modifier) in asphalt concrete mixtures modification is to increase the stiffness at high temperatures, to reduce rutting and at the same time reducing the stiffness at low temperatures to reduce brittleness and cracking. Classification of polymers [5] [see Table.1].

Table. 1 Classification of Polymers

Polymer Type	Common name	Needs for commpation
SBS (Styrene Butadiene Styrene)	Thermoplastik Rubber	Hot Mix, filling Cracks
EVA (Ethylene Vinyl Acetate)	Thermoplastic	Durability of flows, Seal, Crack
Polyethylene, Polypropylene	Thermoplastic	Durability against Flow
SBR (Styrene Butadiene Rubber)	Synthetic Rubber / Elastomer	Durability against cracks, grooves
Natural Rubber	Rubber	Durability against cracks, grooves

2.3. Natural Zeolite

Zeolite is a mineral composed of hydrated crystalline alumino silicate containing alkali or alkaline earth cations in a three-dimensional framework. Zeolites have a high capacity as an absorber [13]. There are two kinds of zeolite i.e. natural zeolites and synthetic zeolites. To be used as absorbents and catalysts with high activity then the natural zeolite must be purified of impurities amorpus (quartz) and other rocks. Zeolite management is intended to maximize the size of the pores of the natural zeolite with activation method [9].

2.4. Resilient Modulus Mixtures

Modulus of rigidity is one of the parameters that are used for planning and evaluating the performance of asphalt mixture. Due to the asphalt mixture is a material that is not perfectly elastic hence the terminology elastic modulus (E) is not suitable for use and instead use the term Resilient Modulus (MR), ie modulus of elasticity based on reverse deformation (recoverable strains)[1]. So that the resilient modulus is defined as :

$$M_R = \frac{\sigma_d}{\varepsilon_r} \quad (1)$$

By σd as deviator voltage, ie axial voltage given while εr is a reversible deformation (recoverable strains). This method uses nomograph solution introduced by Van Der Poel (Shell Bitumen, 1990) to calculate the resilient modulus of bituminous mixtures based on properties of bitumen and aggregate volume concentration. While the Resilient Modulus Tests conducted in the laboratory by using the tool "Universal Material Testing Apparatus (UMATTA)" where the specimen or a mixture of the Refusal optimum bitumen content (KAO Ref). In general, the greater the value of the resilient modulus asphalt mixture will be stiff

3. Materials and Methods of Research

3.1. Materials

Aggregate derived from Subang, West Java, Polymer modified bitumen which is used is the E-55, Natural zeolites are from Bayat, Central Java, powder sieve no. 400. HCl liquid used to dissolve the compound impurities contained in natural zeolite before the activation process. Aqua D'Minerals is a liquid to clean the natural zeolite of compound impurities, which is used in conjunction with HCI liquid, before the activation process.

3.2. Research Methods

To be able to use natural zeolite as an additive in warm asphalt mixture, then the natural zeolite activated beforehand using chemical activation method to obtain water levels approached the synthetic zeolites. Testing was based on standard specification of Warm Asphalt Mixture, published by the [3] and if the test procedure is not contained in the SNI (Indonesian national standard) then refer to the ASTM (American Society for Testing and Materials). AASHTO (American Association of State Highway and Transportation Officials). Laboratory testing of resilient modulus performance using a Universal Material Testing Apparatus (UMATTA) on condition Optimum Asphalt Content (KAO). Testing refers to the ASTM D 4123-82 (1987), which is used in the testing temperature is 25ºC and 35ºC.

4. Results and Discussion

4.1. Aggregat

Aggregate Tests performed on coarse aggregate, fine aggregate and gradation, the results can be seen in Table 2, Table 3, Table 4 and Figure 1.

Table 2. Results of Coarse Aggregate Quality Testing

No	Testing Type	Testing Methods	Result	Specification	Unit
1.	Abrasion	SNI 03-2417-2008	17,5	≤ 40	%
2.	Weight Type				
	Bulk	SNI 03-1969-2008	2,647	> 2,5	-
	SSD	&	2,688	2,5	-
	Apparent	SNI 03-1970-2008	2,760	< 3	-
3.	Absorption	SNI 03-1969 -2008	1,543	≤ 3	%
4.	Angularitas Coarse Aggregate	ASTM D 4791-2005	99.9/99.6	≥ 95/90	%
5.	Particles Flat and Oval	ASTM D 4791-2005	1,0	≤ 10	%
6.	Weathering	SNI 03-3407-1994	0,3	≤ 12	%
7.	Sieve Qualify No. 200	SNI 03-4142-1996	0,47	≤ 1	

Table 3. Results of Fine Aggregate Quality Testing

No	Testing Type	Testing Methods	Result	Specification	Unit
1.	Sand Equivalent	SNI 03-4428-1997	61,0	≥ 60	%
2.	Weight Type				
	Bulk	SNI 03-1969-2008	2,658	> 2,5	-
	SSD	&	2,691	2,5	-
	Apparent	SNI 03-1970-2008	2,748	< 3	-
3.	Absorption	SNI 03-1969 -2008	1,235	≤ 3	%
4.	FineAggregate Angularitas	SNI 03-6877-2002	48,50	≥ 45	%
5.	Weathering	SNI 03-3407-1994	1,8	≤ 12	%
6.	Clumps of clay	SNI 03-4141-1996	0,40	≤ 1	%

Table 4. Results of Combined Gradation Asphalt Concrete Mixed

Size Sieve		Spesification		Combined Gradation	Unit
		Min	Max		
3/4"	(19,1 mm)	100	100	100,0	%
1/2"	(12,7 mm)	90	100	92,5	%
3/8"	(9,52 mm)	72	90	80,0	%
No. 4	(4,75 mm)	54	69	60,0	%
No. 8	(2,36 mm)	39,1	53	46,0	%
No. 16	(1,18 mm)	31,6	40	35,0	%
No. 30	(0,60 mm)	23,1	30	26,0	%
No. 50	(0,30 mm)	15,5	22	18,0	%
N0.100	(0,150 mm)	9	15	11,5	%
No. 200	(0,075 mm)	4	10	6,5	%

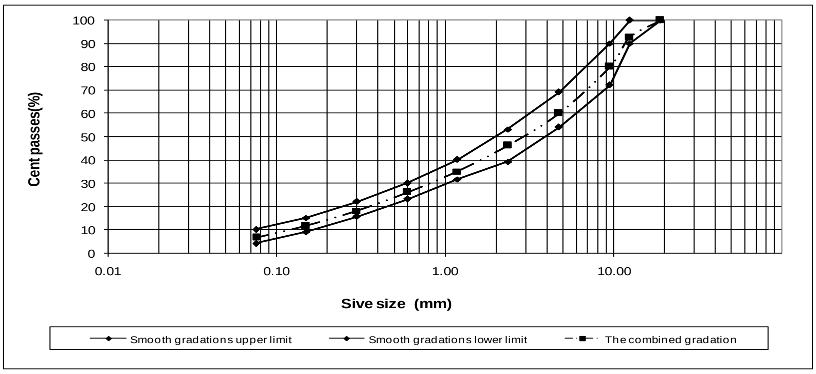


Fig. 1. Gradation Combined Mixed Graph

See Table 2 to Table 4 and Figure 1 obtained aggregate characteristics of both the aggregate coarse, medium and fine and gradation meet the specifications of [4], so that the aggregate can be used as research material.

4.2. Polimer Modified Asphalt

Elastomeric polymer bitumen testing results can be seen Table 5. Based on test results elastomeric polymer bitumen asphalt meets the specifications [3].

Table 5. Results of Testing Quality Polymer Modified Asphalt

No.	Testing Type	Methods Type	Result	Specification
1.	Penetration at 25 ° C, 100 g, 5 seconds	SNI 2456 : 2011	61	50 – 70
2.	Viscosity at 135 ºC	SNI 06-6441-2000	818	≤2000
3.	Softening point (ºC)	SNI 2434 : 2011	53,5	-
4.	Ductility at 25 ° C, 5 cm / min (cm)	SNI 2432 : 2011	> 140	≥100
5.	Flash point (COC) (ºC)	SNI 2433 : 2011	332	≥232
6.	Solubility in C2HCl3 (%)	SNI 06-2438-1991	99,8663	Min. 99
7.	Density	SNI 2441 : 2011	1,036	≥1,0
8.	Losing weight (TFOT)	SNI 06-2440-1991	0,0145	≤2,2
9.	The difference in softening point (ºC)	ASTM D 5976 part. 6.1	0,2	≤0,8
10.	Penetration after TFOT (%)	SNI 2456 : 2011	85,2	≥54
11.	Ductility after TFOT (cm)	SNI 2432 : 2011	> 140	≥50
12.	Mixing temperature (ºC)	ASSHTO-72-1990	173 – 179	
13.	Solidification temperature (ºC)	ASSHTO-72-1990	159 - 165	≥45

Based on Table 5. Obtained the test results of the characteristics of Polymer Modified Asphalt (PMA). The results of the PMA characteristics, it can be concluded that the overall quality of the PMA Asphalt meet the specifications of the Department of Public Works (2010), so the PMA can be used as a binder mixture of Asphalt Concrete-Wearing Course modification comparison. In this research, the mixing temperature is set based on the diameter of the solidification temperature of 176ºC and 162ºC.

4.3. Natural Zeolite

Test results using the method of activation of natural zeolite chemistry and physics can be seen in Figure [see Fig. 2]. Referring to the results of activation, chemical activation results obtained provide the water content of the natural zeolite was 18.99% greater than the result of activation of physics that just gives the water content of the natural zeolite was 9.64%. So, which is used as an additive in this study were processed using natural zeolite chemical activation.

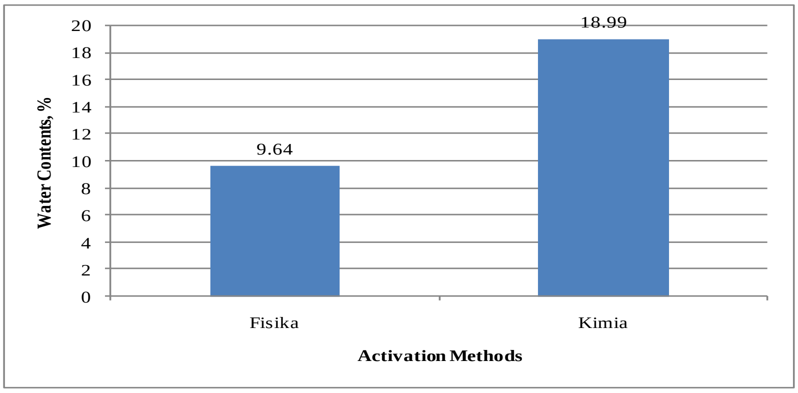


Fig. 2. Effect of Activation Method Against Moisture Absorption In Zeolites

Based on Fig. 2, gives the average value of the moisture content using smaller physical activation method than the chemical activation method. Overall, by looking at the zeolite processing, using chemical activation, obtained water content, which is approaching the synthetic zeolite water content ranges from 15-20%

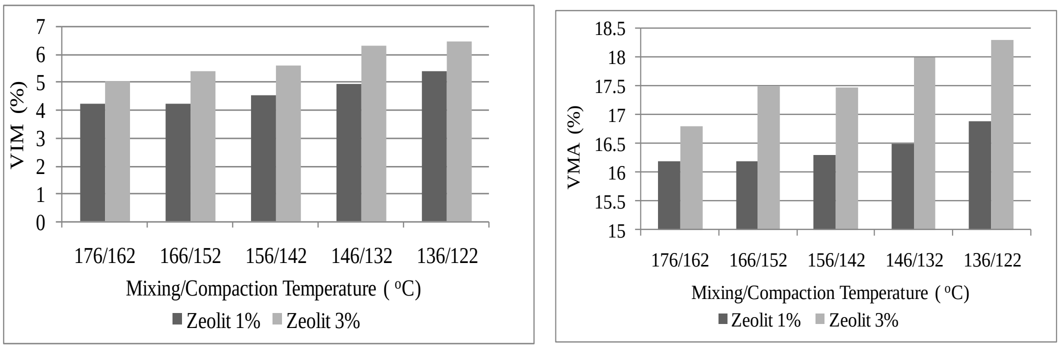
4.4. Marshall Calculation

The test results are divided into three namely Marshall testing to obtain optimum bitumen content, Marshall testing to obtain optimum levels of natural zeolite that can be used as an additive mixture of polymer modified asphalt concrete [see Table. 5] and Marshall test to obtain the temperature of the mixing / compaction temperature in a mixture of polymer modified asphalt concrete additives with natural zeolite using Warm Mix Asphalt method [see Fig. 3]. In this study, the effect of the use of natural zeolite in the mixture of polymer modified asphalt concrete with hot mix asphalt method is analyzed based on the results of the Marshall test. Hot Mix Asphalt mixture using polymer modified asphalt with 0% natural zeolite, is a comparison mixture processed using temperature mixing and compaction temperatures based on viscosity test at 176^{o}C and 162^{o}C

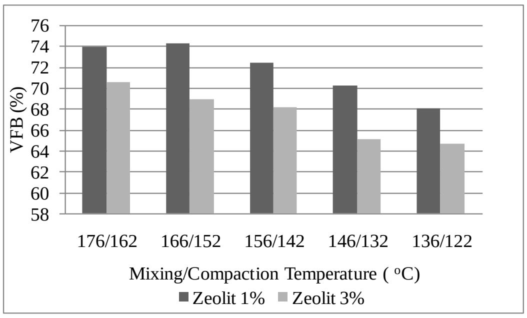
Table. 6 Results of Natural Zeolite on Asphalt Modified Polymer Mixture

Characteristics of Mixture	Test Result			Specification Mixture*)	Unit
	PMA 0% zeolit	PMA 1% zeolit	PMA 3% zeolit		
Levels of Asphalt	5,8	5,86	5,95		%
Density	2,383	2,372	2,329	-	ton/m^3
VMA	15,5	15,7	16,9	min. 15	%
VFB	79,87	76,73	69,24	min. 65	%
VIM Marshall	3,1	3,7	4,9	3,0 - 5,0	%
Stability	1551,2	1555,3	1507,7	min. 1000	kg
Flow	4,74	5,20	5,04	min. 3	mm
Results for Marshall	331,2	298,9	303,5	min. 300	kg/mm
Levels of Effective Asphalt	5,37	5,37	5,37	min. 4,3	%

Warm mix asphalt using the polymer modified asphalt as a binder and 1% natural zeolite can improve stability of the value of 1555.3 kg. VIM value decreased by 3.7%, but it meets the specifications Marshall.Selected mixture which can degreade temperature of mixing and compaction are pilymer modified asphalt mixtures with 1% natural zeolite as shown in Table 6



(a) (b)



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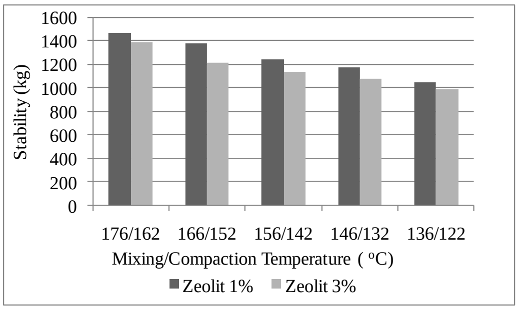

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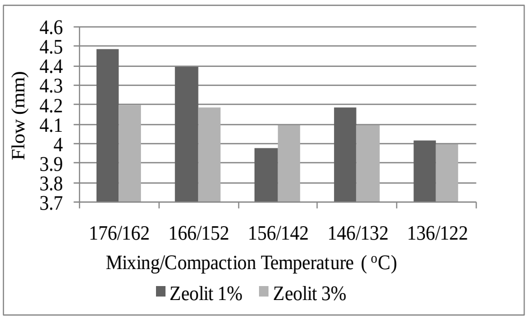

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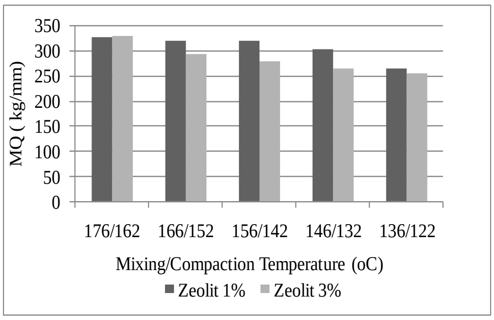

(f)

Fig. 3. Effect of Natural Zeolite Levels 1% and 3% Against Concrete Modified Asphalt Polimers Mixture Characteristics at Various Mixing/Compaction Temperatures

Visible effect of natural zeolite levels 1% and 3% as an additive in asphalt concrete mixtures modified polymers that are processed using Warm Mix Asphalt [see Fig.3]. Relationship between the density of the mixing and compaction temperatures, reflecting the declining trend line density increased levels of zeolite and decreasing temperature. This is evident from the nature of the density of the mixture with the added ingredient of natural zeolite which is almost equal to the density of the mixture without the added ingredient of natural zeolite. Relationship voids in mineral aggregate (VMA), VFB, Flow and Marshall Quotient with temperature [see Fig. 3b, Fig. 3c, Fig.3e, Fig. 3f] showing the temperature range of mixing / compaction temperatures of 166oC / 152oC - 136oC / 142oC for asphalt mixtures containing zeolite content of 1% and 3% can meet the specifications [2]. As for the relationship void in mix (VIM) with temperature [see Fig. 3a], the value of the test results obtained by the VIM can be filled with a mixture of 1% natural zeolite content up to temperatures of 146oC / 132oC.

While the value of VIM at 3% zeolite content, no VIM value that meets the specifications. This indicates that the polymer asphalt mixture with zeolite content of 1% can be mixed at 30°C lower than normal temperatures. Relationship stability against temperature [see Fig. 3d] shows that the mixture with 1% zeolite can be filled up to 30oC temperature lower than the temperature of mixing and compaction temperatures Hot Mix Asphalt. As for the mixture of 3% zeolite content only met up at a temperature of 156oC / 142oC.

From the flow chart shown that the flow in the mixture of polymer modified asphalt concrete containing levels of 1% and 3% zeolite has a temperature range of mixing and compaction temperatures are the same, which meets the requirements of the minimum melting. The use of natural zeolite materials added Bayat, the type of mineral modernit on the asphalt mixture using elastomeric polymer asphalt binder, when viewed from the decrease in temperature that has been done, can reduce the temperature of mixing / compaction at 30oC, the equivalent of warm mix asphalt binder using conventional synthetic zeolites material added.

Table 7. The Results of Asphalt Mixture Testing With 1% Natural Zeolite Content on the Variation Temperature of Mixing and Compaction

Characteristic of Mixture	Test Result					Mixture Specification	Unit
	PMA with 1% Natural Zeolite						
	176/162	166/152	156/142	146/132	136/122		
Levels of Asphalt	5,85	5,85	5,85	5,85	5,85		%
VMA	16,2	16,2	16,3	16,5	16,9	min. 15	%
VIM Marshall	4,2	4,2	4,5	4,9	5,4	3,0 - 5,0	%
Stability	1460,1	1388,7	1248,5	1185,0	1051,5	min. 1000	kg
Melt	4,49	4,40	3,98	4,19	4,02	min. 3	mm
Results for Marshall	326,7	318,0	319,0	301,0	263,5	min. 300	kg/mm

4.5. Modulus of Resilienct

Table 8. Modulus of Resilient Test Results

Temperature Testing	Mixture Types		
	PMA	PMAz-b4 1%	Asphalt Pen. 60/70
25 ºC	2617	2521	2464
35 ºC	979	938	843
45 ºC	357	403	339

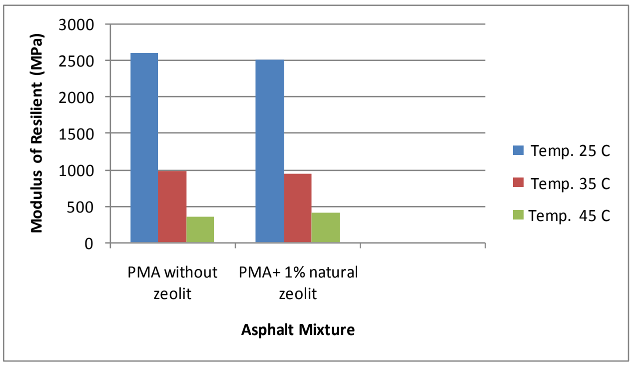

Fig. 4. Results of Modulus Resilient Test

Based on Figure 4 and Table 8, the testing temperature of 25 ° C, appear that PMA mixture without natural zeolite has a resilient modulus values greater than 2521 MPa resilen modulus value at PMA mixture with 1% natural zeolite. This indicates that the PMA mixture with 1% natural zeolite is less flexible, making it more resistant to cracking susceptible occur at low temperatures when compared with PMA mixture without natural zeolite. In the testing temperature 35 ° C, a mixture of PMA with 1% of natural zeolite generally has a smaller 938 Mpa resilient modulus than the modulus of resilience on PMA mixture without natural zeolite of 979 Mpa. The addition of zeolite in the PMA mixture against resilen modulus values, led to a decline in value, this indicates that the PMA mixture with 1% of natural zeolite has a high resistance to permanent deformation, but have fairly low resistance to cracking

5. Conclusion

Activation method can optimize the moisture content contained in the zeolite, of the value of the original moisture content of zeolite Bayat by 3.67% to 18.99%. The added material natural zeolite Bayat sieve no. 400 in a mixture of AC-WC PMA could lead to reduced mixing/compaction temperature 30oC lower than the temperature of mixing / compaction of the asphalt mixture of asphalt binder elastomeric polymers with HMA method, equivalent to the function of synthetic zeolite which can reduce the mixing temperature for 30oC. Mixture with or without zeolite having stiffness properties and spread almost equally. At a temperature of 25oC and 35 oC PMA mixture without natural zeolite is more rigid than the PMA mixture with 1% natural zeolite, making it more resistant to cracking susceptible occur at low temperatures

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