ISSN 0853-2982 eISSN 2549-2659

JURNAL TEKNIK SIPIL

Jurnal Teoretis dan Terapan Bidang Rekayasa Sipil

Optimizing the Use of Rediset®LQ as an Additive in Warm Mix Asphalt Technology

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Abstract

The application of warm mix asphalt technology to reduce mixing and compaction temperatures has a weakness in decreasing the performance of mixture and is more sensitive to high temperatures. This is influenced by the type of additives and the warm mix asphalt technology used. The purpose of this study is to determine the optimum percentage of Rediset®LQ used and the amount of temperature drop in the type of Pen 60/70 asphalt mixture. Determination of the percentage of optimum use of the Rediset®LQ was carried out by using mixed workability analysis. The results of the warm mix asphalt test are then compared with the control HMA, the volumetric value that is close to the control HMA is considered to have equivalent workability. The variation of the use of the Rediset®LQ is 0.25% to 0.75% with a variation of the mixture temperature reduction of 15 ºC, 30 ºC, and 45 ºC. The results showed that the optimum percentage of using Rediset®LQ on asphalt pen 60/70 was 0.5% with a large reduction in mixing temperature and optimum compaction of 30 ºC. Evaluation of the resilient modulus value of the WMA mixture is equivalent to the HMA mixture at low, medium, and high temperatures. Based on the analysis, the Warm Mix Asphalt Concrete Binder Course with Rediset®LQ additive, also lower mixing and compaction temperature, is suitable for use on pavement layers.

Keywords: Warm mix asphalt, Rediset®LQ, resilient modulus.

Abstrak

Aplikasi teknologi campuran beraspal hangat untuk menurunkan temperatur pencampuran dan pemadatan, memiliki kelemahan pada performa campuran yang menurun dan lebih sensitif terhadap temperatur tinggi, hal ini dipengaruhi oleh jenis aditif dan teknologi campuran beraspal hangat yang digunakan. Tujuan penelitian ini adalah untuk mengetahui persentase optimum penggunaan Rediset®LQ dan besar penurunan temperatur pada jenis campuran asphalt concrete binder course menggunakan aspal pen 60/70. Penentuan persentase penggunaan Rediset®LQ optimum dilakukan dengan analisis workability campuran. Hasil pengujian warm mix asphalt kemudian dibandingkan dengan HMA kontrol, nilai volumetrik yang mendekati HMA kontrol dianggap memiliki workability yang setara. Variasi penggunaan Rediset®LQadalah 0,25%, 0,5% dan 0,75% dengan variasi penurunan suhu campuran 15 ºC, 30 ºC, dan 45 ºC. Hasil penelitian menunjukkan bahwa persentase optimum penggunaan Rediset®LQ pada aspal pen 60/70 sebesar 0,5% dengan besar penurunan temperatur pencampuran dan pemadatan optimum sebesar 30 ºC. Evaluasi nilai modulus resilien campuran campuran beraspal hangat setara dengan campuran HMA baik pada temperatur rendah, sedang dan tinggi. Berdasarkan analisis maka campuran beraspal hangat additif Rediset®LQ dengan suhu pencampuran dan pemadatan yang lebih rendah layak untuk digunakan pada lapis perkerasan jalan.

Kata Kunci: Campuran beraspal hangat, Rediset®LQ, modulus resilien.

1. Introduction

Warm mix asphalt is a mixture of asphalt which is produced at a lower temperature than hot mix asphalt, based on the temperature of the mixture, the asphalt mixture can be classified into four categories, namely, hot mix asphalt (HMA) with a mixing temperature range of 190 ºC – 15 ºC, Warm mix asphalt or (WMA)

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with a mixing temperature range of 100 ºC - 140 ºC, half-hot mix asphalt or (HWMA) with a mixing temperature range of 60 ºC - 100 ºC and cold mix asphalt or CMA (Cold Mix Asphalt with a range of mixing temperature 0 ºC - 40 ºC (Vaitkus et al., 2016) (Zaumanis, 2014)

Warm mix asphalt technology aims to reduce the viscosity of the asphalt, the implementation (workability), namely with a lower spread temperature and a decrease, namely by decreasing the mixing temperature, several techniques can be used to achieve the above objectives, namely by using organic additives, chemical additives and techniques. water-base or the foaming process (Mohd Hasan et al., 2015) (Oliveira et al., 2013)

Rediset®LQ is a chemical additive without using water (water free) produced by AkzoNobel from the Netherlands, Sweden, and America, introduced in America in 2007, to improve the performance of warm mix asphalt additives. Rediset has two types in the form of solid with the name Rediset WMX and the newest type of liquid with the name Rediset®LQ (AkzoNobel, n.d.)

Rediset®LQ can simplify the compaction process even though it is done at a lower temperature, this product is also easier to use because it is in the form of a liquid with a relatively small dosage of only 0.4% - 0.6% of the weight of asphalt for WMA additives, besides Rediset®LQ contains active adhesion which allows the coating of aggregates that do not dry out, prevents stripping and increases moisture resistance (AkzoNobel, n.d.) (Hamzah et al., 2014). The active adhesion content in Rediset®LQ allows better coating even at higher moisture levels resulting from the lower mixing temperature of warm mix asphalt porous. Rediset®LQ can remove residual water from the surface of the aggregate, and creates a strong chemical bond between the aggregate and asphalt, and is more resistant to water (AkzoNobel, n.d.). The percentage of use of Rediset®LQ varies, depending on the type and level of hardness of asphalt, asphalt PG, and the percentage of RAP used (AkzoNobel, n.d.)

This study aims to determine the percentage of optimum Rediset®LQ use and the amount of drop in the mixing temperature on Warm Mixture Asphalt (WMA).

2. Materials and Method

2.1 Aggregat

The aggregate used comes from Karawang Regency, West Java Province, Indonesia. The test result is shown in **Table 1**.

Gradation design refers to General Specifications Bina Marga, for Asphalt Concrete - Binder Course (AC-BC). The gradation design used the middle boundary in the Fuller curve, as in **Figure 1**.

Table 1. Aggregate properties

Test	Test Method	Aggregate	
		Course	Fine
Specific Gravity	ASTM C127-84	2,619	2,656
Water Absorption (%)	ASTM C127-84	1,763	0,732
Los Angles Abrasion (%)	ASTM C131-76	5,12	-
Flakiness and Elongation (%)	ASTM D-4791	7,2	-

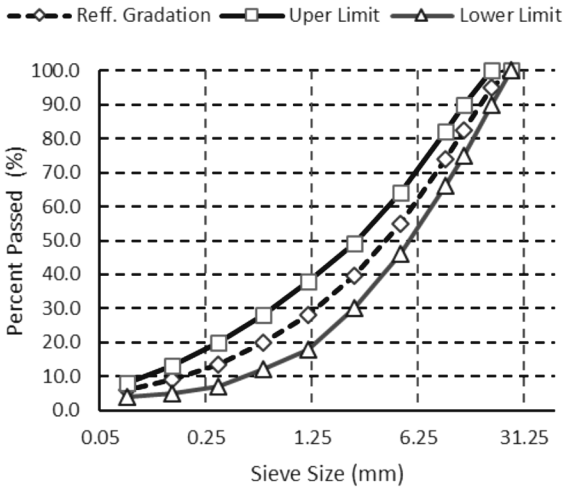

Figure1. Gradation curve (Bina Marga)

2.2 Rediset®LQ

The type of Rediset®LQ 1106 used is a liquid with an Amine value content of 540-640 mgKOH / g and 1% water. (AkzoNobel, 2015), Rediset®LQ can be seen in **Figure 2**.

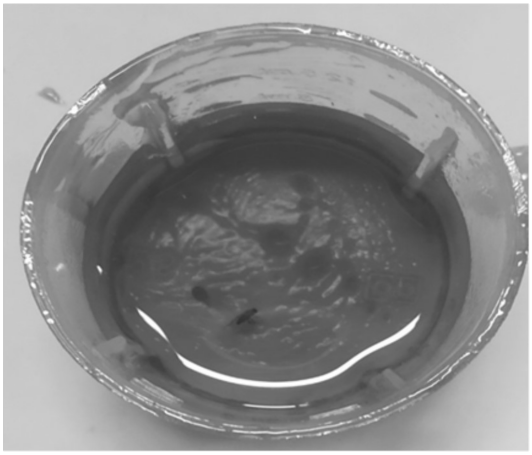

Figure 2. Rediset®LQ 1106

2.3 Asphalt Pen 60/70

The original asphalt used in this research is the type of asphalt pen 60/70 produced by PT. Pertamina, this type of asphalt is commonly used as a road pavement material in Indonesia. The asphalt specifications used are following the General Specifications of Bina Marga (2018). Result test is shown in **Table 2**.

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Table 2. Basic Properties of asphalt Pen 60/70

Properties	Value	Specifications
Penetration @ 25 8C (0,1 mm)	63.2	60-70
Softening Point (8C)	49.65	/ 48
Ductility @ 25 8C (cm)	/ 100	/ 100
Flash Point (8C)	248	/ 232
Spesific Grafity	1.04	/1,0
Weight Loss TFOT(%)	0.003	[0,8
Penetration TFOT (%)	80.4	/ 54
Ductility TFOT (cm)	/ 100	/ 50

2.4 Preparation of binder modification

Asphalt modification is carried out on a laboratory scale at the Bandung Institute of Technology, mixing asphalt with Rediset®LQ material directly, and with the wet mix method (Leng, et al., 2017); (Bressi, et al., 2019). The mixing asphalt pen 60/70 and additive Rediset®LQ, by heating the asphalt in a temperature range of 120 ºC to 145 ºC, the Rediset®LQ is slowly poured into hot asphalt and using a 500 rpm low-speed mixer for 5 minutes (Leng, et al., 2014).

2.5 Test method

This research was conducted in 5 stages, the first stage was making the HMA control mixture as a reference for the workability test, the second stage testing the viscosity of modified asphalt using the *Saybolt furol* tool, the third stage of the workability test using the marshal compactor, the fourth stage of the Marshal test to obtain KAO, and the last one was the test. resilient modulus using a UTM device using a gyratory compactor. Gyratory Compactor and the UTM machine can be seen in **Figure 3**.

a. gyratory compactor b. UTM machine

Figure 3. Gyratory compactor and UTM machine

2.6 Marshal tes HMA control

The marshal HMA control test is carried out at the beginning which is useful as a reference for the volumetric analysis of the mixture of WMA and WAR in the workability test, the mixed trial will later refer to the volumetric HMA control. The properties of marshal test HMA can be found in **Table 3**.

Tabel 3. Properties marshal test HMA control

No	Properties	HMA Control
1	OBC (%)	5.5
2	Density (gr/ml)	2.364
3	VIM (%)	3.97
4	VFA (%)	73.59
5	VMA (%)	15.02
6	Stability (Kg)	1401
7	Flow (mm)	3.2

3. Result and Discussion

3.1 Asphalt pen 60/70 additives Rediset®LQ

The Rediset®LQ used in this study is the Rediset®LQ 1106 type, with a percentage of 0.25%, 0.5%, 0.75%, according to the required specifications, namely 0.3% to 1% (AkzoNobel, n.d.), the addition of Rediset®LQ up to 0.75% reduces the penetration value from 63.2 to 60.1 in this condition the asphalt is getting harder, the softening point of asphalt decreases from 49.65 ºC to 48.8 ºC indicating that it is more sensitive to temperature changes, almost the same as research conducted by Vahora & Mishra, (2017b). Increasing Rediset®LQ levels also reduces the PG asphalt, where asphalt becomes softer (Kataware & Singh, 2017). This is following the function of Rediset®LQ which is a chemical additive to warm asphalt mixtures, which is a combination of surfactants and organic additives (Rheology Modifier) (Kheradmand, et al., 2014). The results of this test it can be concluded that the Asphalt pen 60/70 with Rediset®LQ additive meets the General Highway Specifications, 2018. Test results can be seen in **Table 4**.

3.2 Viscosity of Rediset®LQ Additive

Viscosity test using the Saybolt furol tool, the value is shown in Figure 4 and Figure 5. is the viscosity of asphalt at 170 ± 20 cSt, at mixing temperature according to standards General Specifications Bina Marga, 2018.

Figure 4 and **Figure 5**, the effect of the addition of Rediset®LQ on the asphalt pen 60/70 and asphalt modified PVLNR, the higher the percentage of Rediset ®LQ, the lower the viscosity of the asphalt, the more liquid asphalt, thus reducing the mixing temperature and compaction temperature. In asphalt pen 60/70, the increase in the percentage of Rediset®LQ 0.5% decreased the mixing temperature (170 cSt) to 143,5 ºC and the compaction temperature (280 cSt) to 134 ºC. The determination of the amount of temperature reduction from the asphalt viscosity test results has not reached the target, even though it is based on Information on specifications/brochures from distributors using Rediset®LQ 0.5% can reduce mixing and compaction temperatures up to 22 °C to 33°C when compared with conventional HMA (AkzoNobel, 2015), for this reason, a further test is carried out, namely the workability test of the mixture to determine the mixing and compaction temperature from the volumetric

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Table 4. Asphalt Pen 60/70 with Rediset®LQ additives

Properties	Asphalt Pen 60/70 with Rediset LQ additives			Methods	General Highway Specifications
	0,25%	0,50%	0,75%		
Penetration (0,1 mm)	62.5	61	60.1	SNI 2456:2011	55-68
Softening Point (ºC)	49.5	49.2	48.8	SNI 2434:2011	≥ 48
Ductility @ 25 8C (cm)	≥ 100	≥ 100	≥ 100	SNI 2432:2011	≥ 100
Flash Point (8C)	240	233	225	SNI 2433:2011	≥ 232
Solubility in C2HCl3 (%)	99.9	99.91	99.89	AASHTO T44-14	≥ 99
Specific Gratify	1.04	1.04	1.039	SNI 2441:2411	≥1,0
Weight Loss RFTO (%)	0.021	0.025	0.051	SNI 06-2441-1991	≤0,8
Penetration RFTO (%)	79.8	79.4	78.7	SNI 2456:2011	≥ 54
Ductility RFTO (cm)	≥ 100	≥ 100	≥ 100	SNI 2432:2011	≥ 50

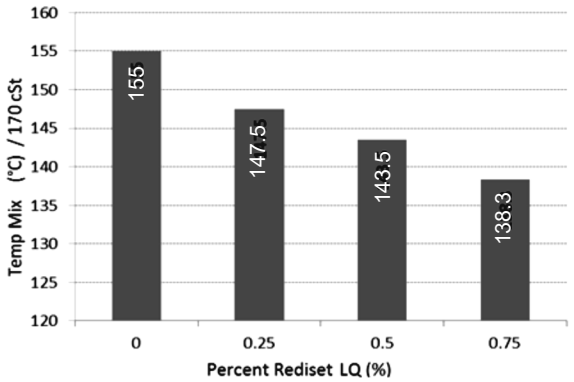

Figure 4. Temperatures mixing at viscosity 170 cSt

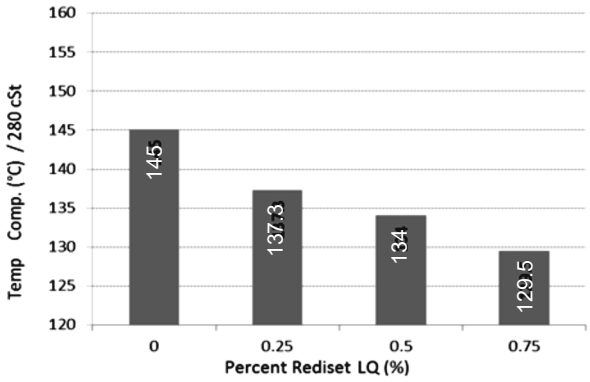

Figure 5. Temperatures mixing at viscosity 280 cSt

evaluation of the mixture from the results of the Marshal compactor. (Bennert, et al., 2010) .

3.3 Workability WMA

The workability test in this study used a Marshal compactor, at the same number of a blow, with the number 2 x 75 blow, on the mixed asphalt WMA (Bennert, et al., 2010; Bennert, et al., 2011). Workability test for WMA (asphalt pen 60/70 with Rediset®LQ additive), this test aims to see the large reduction in mixing temperature from the addition of Rediset®LQ additives with variations in the use of Rediset®LQ 0.25%, 0.5, and 0.75 % (of binder weight) and, trial temperature reduction of 15 ° C, 30 ° C, and 45 ° C is lower than the mixing temperature of HMA which is 155 ºC, then trial mixing temperature becomes 110 °C, 125 °C, 140° C. The test results are as shown in **Figure 6**.

Figure 6.a. Evaluation of the density of the mixture, indicating that the density of the mixture is getting higher with an increase in the percentage of Rediset®LQ and mixing temperature. The optimum density for reference is 2.364 gr/ml (density of control HMA). The density of the WMA mixture is influenced by the percent use of Rediset®LQ and the mixing temperature.

Increased density in the mixture of WMA, because Rediset®LQ is a combination of surfactants (surface active agents) and organic additives (Rheology Modifier) (Kheradmand et al., 2014). Surfactants are surface-active ingredients, which work to reduce the surface tension of liquids, this active property is obtained from the dual nature of their molecules, the surfactant part of this product (such as chemical additives) reduces the surface tension of the asphalt binder (Bennert, et al., 2011) reduce interface friction between the thin film asphalt binder and aggregate (Capitão, et al., 2012) and improve the coating of the aggregate by the asphalt binder (Banerjee, et al., 2012) while the organic part reduces the viscosity of the asphalt binder and provides a lubricating effect for easier coating and compaction (Kheradmand, et al., 2014).

Figure 6.b, Evaluation of the VIM (void in the mix) parameter, the VIM value is getting smaller with an increase in the percentage of Rediset®LQ and an increase in mixing temperature. The optimum VIM value which became the reference was 3.97% (VIM HMA Control).

Figure 6.c, Evaluation of the VMA (void in mix asphalt) parameter, the VMA value is getting smaller with an increase in the percentage of Rediset®LQ and an increase in mixing temperature. The optimum VIM value which becomes the reference is 15.02% (VMA HMA Control).

Figure 6.d, Evaluation of the VFA (void filled in asphalt) parameter, the VFA value is getting smaller with an increase in the percentage of Rediset®LQ and

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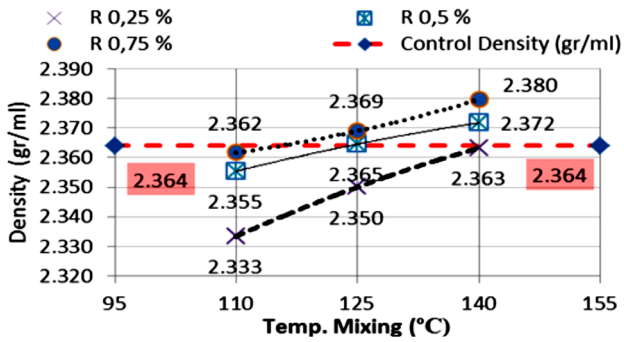
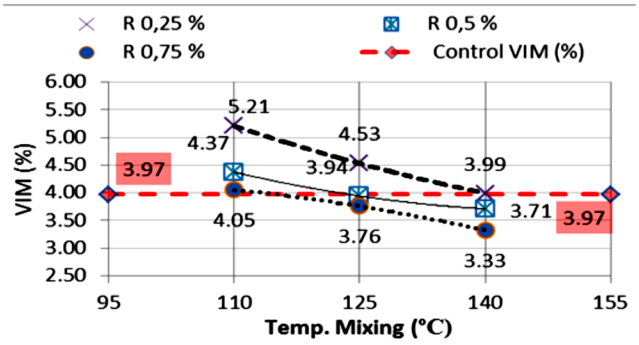
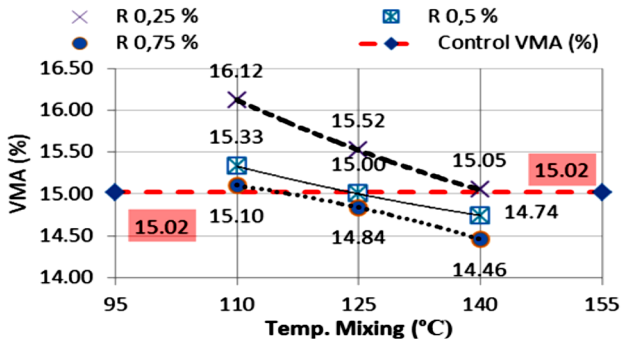


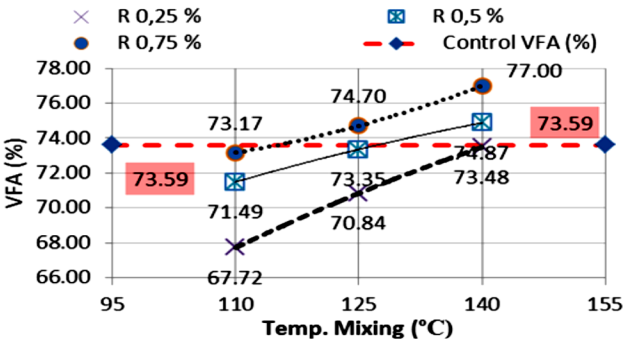
a. Density WMA with varying temperature and percentage of Rediset®LQ



b. VIM WMA with varying temperature and percentage of Rediset®LQ

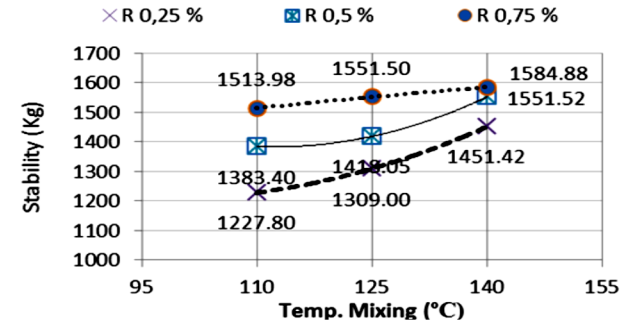


c. VMA WMA with varying temperature and percentage of Rediset®LQ

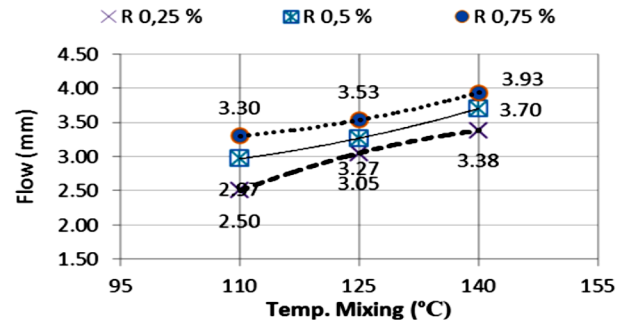


d. VFA WMA with varying temperature and percentage of Rediset®LQ

Figure 6. Volumetric WMA with variant percent additive Rediset®LQ and variant temperature compaction



a. WMA stability with varying temperature and percentage of Rediset®LQ



b WMA flow with varying temperature and percentage of Rediset®LQ

Figure 7. Stability and Flow WMA with variant percent additive Rediset®LQ and variant temperature compaction

an increase in mixing temperature. The optimum VFA value which became the reference was 73.57% (VFA HMA Control).

Evaluation of the parameters of Density, VIM, VMA, and VFA, for a mixture of WMA with different percent use of the Rediset®LQ , namely 0.25%, 0.5%, and 0.75%, resulting in different ideal mixing temperature differences, namely 140 °C, 125 °C, and 110 °C. It can be concluded that the use of Rediset®LQ is effective in reducing the luminescence temperature of asphalt. The use of 0.5% Rediset®LQ can reduce the mixing temperature by 30 °C without affecting the volumetric value compared to the volumetric HMA control value, so the mixing temperature used for WMA (0.5% Rediset®LQ) is 125 °C and a compaction temperature of 115 °C.

3.4 OBC and volumetric properties mix

At this stage testing the mixture to determine the Optimum Binder Content (OBC) and volumetric values of each mixture of HMA, WMA, and WAR. RSNI M-01-2003, Testing Methods of Hot Asphalt Mixtures with Marshall Tools, 2003 dan General Specifications Bina Marga, Ministry of Public Works, 2018. The test results can be seen in **Table 4**.

3.5 Modulus resilient test result

Resilient modulus is the ability of the asphalt mixture to accept loading with a condition that remains elastic as measured by the ratio of the load and recoverable stress (Karami, et al., 2017).

Resilience Modulus Testing using UTM (Universal testing machine) tools at the Road and Traffic

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Table 4. OBC and Volumetric Properties HMA and WMA

Properties	HMA	WMA
OBC (%)	5.5	5.45
Density (gr/ml)	2.364	2.363
VIM (%)	3.97	3.89
VFA (%)	73.59	73.51
VMA (%)	15.02	15.00
Stability (Kg)	1401	1418
Flow (mm)	3.20	3.23
MQ	438	439
Durability (%)	90.30	90.10

Engineering Laboratory of the Bandung Institute of Technology refers to Standard of Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures (ASTM D4123, 1995).

The test conditions are set at a loading pulse width of 250 ms, pulse repetition period 3000 ms. Horizontal deformation measurements were carried out on two sides of the sample. The test temperature was carried out at 20 °C, 30 °C, 41°C, 50 °C (Road Paving Manual, 2017). Resilient modulus testing of a mixture of HMA Control and WMA.

Resilient modulus test samples were compacted using a gyratory compactor according to the Standard Method of Test for Preparing and Determining the Density of Asphalt Mixture Specimens using the Super pave Gyratory Compactor (AASTHO T 312, 2013)

Figure 8. The resilient Modulus of the WMA mixture is almost equivalent to the HMA mixture, while in testing at high temperatures, the resilient modulus of WMA is almost equal to that of HMA. The high modulus value is also influenced by the rheology of the asphalt wherefrom the results of the penetration test, the addition of the percentage of Rediset®LQ makes the asphalt harder but flaccidity becomes lower (Vahora & Mishra, 2017a) (Bethary, et al., 2020) The addition of Rediset®LQ additives to asphalt reduces the value of PG grade. The modified asphalt Rediset®LQ is softer than pure asphalt, the viscosity of the asphalt is getting smaller, with the addition of the Rediset®LQ content, it shows that the asphalt is getting more liquid along with the addition of the Rediset®LQ content. From the rutting parameter, G*/Sin δ shows the same trend where the addition makes the asphalt tend to be softer (Kataware & Singh, 2017) (Sihombing et al., 2020).

Reduction in mixture temperature and compaction with an equivalent modulus value makes the Rediset®LQ good for use in Indonesia using Pen 60/70 asphalt, this temperature reduction provides economic benefits in the form of fuel savings, environmental emissions reduction, and in terms of performance where the risk of temperature reduction the result of the hauling process (material mobilization) can be reduced, so that even at lower temperatures, the asphalt mixture still gives a good performance (Almeida-Costa & Benta, 2016) (Kristjánsdottir, et al., 2007). At a temperature of 25 °C, the average resilient modulus of all HMA mixtures is greater than that required in the Planning of Flexible Pavement Thickness with Deflection Method, which is 2,000 MPa.

4. Conclusion

From the test results of WMA (warm mix asphalt) with variations percent Rediset®LQ and variations in mixing temperature, several conclusions can be drawn:

1. The addition of Rediset®LQ to the asphalt pen 60/70 reduces penetration so that the asphalt becomes harder with an indication of better stability and decreases the softening point temperature with an indication that it is more sensitive to high temperatures.
2. The range to decrease in the optimum mixing and compaction temperature depends on the percentage of Rediset®LQ content used.
3. The characteristics of 0.75% Rediset®LQ additive has too low melting point and too low burning point, so it is not recommended for Pen 60/70 asphalt .
4. Based on the workability test of the mixture and the specifications issued by AkzoNobel, the optimum mixture performance is reached when 0.5%

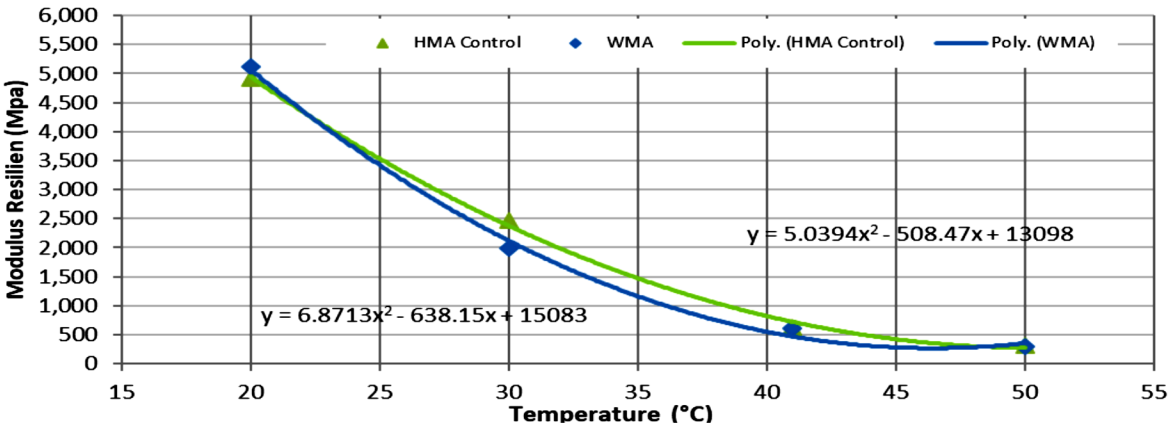

Figure 8. Resilient modulus HMA and WMA 20 ºC, 30 ºC, 41 ºC and 50 ºC.

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Rediset®LQ is used. This condition will be achieved in 30 °C drop in the mixture temperature.

5. The use of asphalt for WMA 5.45% is almost the same when compared to HMA for Control 5.50%.
6. In general, the performance of WMA with 0.5% Rediset®LQ additive, as well as a mixing temperature of 125 °C and a compaction of 115 °C (reduced temperature of 30 °C), is the same as HMA with a higher temperature (155 °C).
7. Resilient Modulus of WMA mixture is equivalent to HMA but with lower mixing and compaction temperature.

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