Streamlining Information Transfer between Construction and Structural Engineering
Edited by Shiau, J., Vimonsatit, V., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-7-9

MECHANICAL PROPERTIES OF WARM MIXED USING POLYMER RECLAIMED ASPHALT WITH NEW AGGREGATE (PRAP-WARM MIX)

WEERAKASET SUANPAGA

Dept of Civil Engineering, Kasetsart University, Bangkok, Thailand

The purpose of this study is to determine the appropriated mixed proportion of asphalt concrete using Polymer Reclaimed Asphalt Pavement, new aggregate and Advera (PRAP- Warm Mixed) that were mixed at warm temperature. Then the Mechanical Properties of new mixed asphalt concrete samples were tested following the standards of the Department of Highway, Thailand. In experimental design, the range of mixing temperature varied as 140ºC, 145ºC, 150ºC, 155ºC, and percentage of Advera added varied at 0.20, 0.25, 0.30 and 0.35 percent by weight of aggregate. The engineering properties of PRAP samples obtained from this study showed that the optimum mixing ratio was 0.20 percent at 140ºC has a Stability value of 2530 lbs, a flow of 12 in a particle size of VMA 16.2, a strength index, 85 percent of the test results are in line with the requirements of the Department of Highways. Then using 70 percent of PRAP-warm mix with 30 percent of new material at 140 °C and add 0.20 percent of Advera that is the best-mixed proportion. The normal temperature of PMA mixing is higher than 170ºC, in this case using PRAP-Warm mix can reduce temperature lesser than 150ºC then this mixing process can save fuel consumption. Thus this study is useful for environmental perspectives.

Keywords: Hot mix asphalt, Warm mix asphalt, HMA, WMA, PMA, Pavement.

1 INTRODUCTION GENERAL

Hot Mix Asphalt (HMA) construction requires higher mixing temperatures of 160ºC, which consume a lot of fuel to produce asphalt concrete. If we can reduce mixing temperatures lower than 160ºC then this mixing process can save fuel consumption. Nowadays, not only a few researchers (Jansen and Smirnovs 2010, You *et al.* 2011, NAPA 2010, and Weerakaset *et al.* 2014) have studied the mechanical properties of warm mix asphalt (WMA), but also some researchers have studied the mechanical properties of warm mixed asphaltic concrete using polymer reclaimed asphalt, and new aggregate and Advera mix together at lower than 160 ºC. This new asphaltic concrete is called "PRAP- Warm Mix".

2 OBJECTIVES

To determine the appropriated proportion of asphalt concrete using Polymer Reclaimed Asphalt Pavement, new aggregate and Advera (PRAP- Warm Mix) those were mixed at Warm temperature by considering from physical properties of PRAP- Warm Mix's samples.

3 MATERIALS

The materials of PRAP- Warm Mixed were crush rock size 3/4", 3/8", limestone from Chonburi, Thailand, Polymer Modified Asphaltic (PMA), reclaimed PMA concrete, and a mineral additive (ADVERA). The gradation and mix proportion of Limestone is shown in Table 1, and the gradation curve of a mixed bin of limestone is shown in Figure 1.

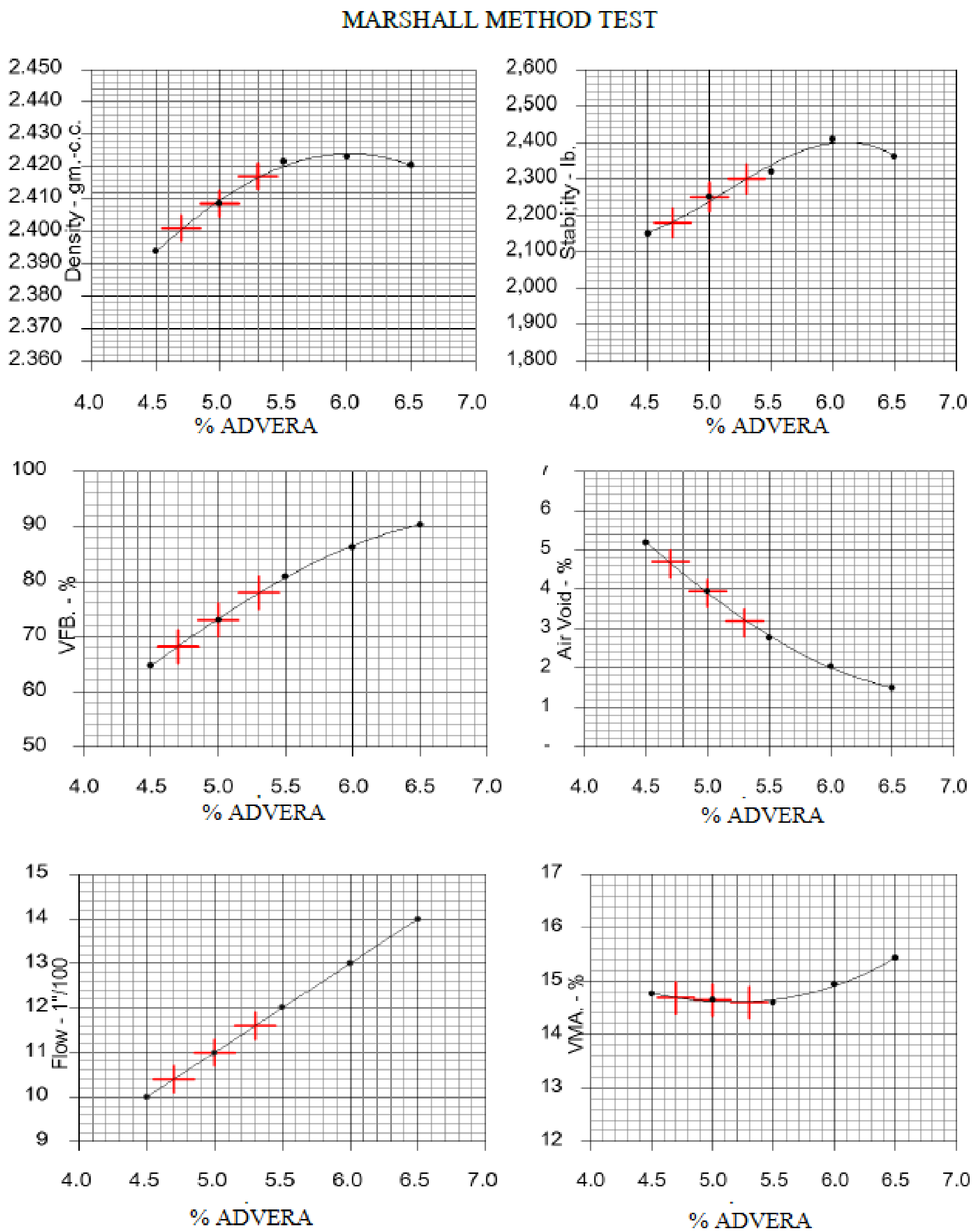

Figure 1. Marshall Method of engineering properties of PRAP- Warm Mix: density, stability, void filled in bitumen (VFB), percentage of air void, flow and voids in mineral aggregate (VMA).

Table 1. Gradation and mix proportion of limestone.

Sieve Size (Inch)	Hot Bin							
	% Passing						Tolerance	
	Rap	Bin 1	Bin 2	Bin 3	Bin 4	mixed	Desired	Limit
3/4"	100	100	100	100	100	100	100	100
1/2”	82.7	100	100	100	2.4	80.6	80-100	76-86
3/8”	63.4	100	100	73.7	0.5	68.2	-	63-73
#4	42.2	100	41.7	18.6		52.5	44-74	48-58
#8	29.3	86.2	0.60	0.50		38.0	28-58	33-43
#16	21.4	58.2				25.6	-	22-30
#30	14.2	37.2				16.4	-	12-20
#50	9.6	25.4				11.2	5-21	7-15
#100	5.6	18.6				8.2	-	6-11
#200	2.8	13.2				5.8	2-10	5-7
Mix proportion	70	13.2	6.0	6.6	4.2	Total 100 (by mass)		

4 METHODS

The specifications standard of testing fine and coarse aggregate were tested both groups referred to American Society for Testing and Materials (ASTM) and the Department of Highway (DOH) standard of testing material.

The specifications of fine materials were tested as follows.

- Gradation testing standard referred to ASTM C136-84A or AASHTO T37-77 or ASTM C136-84A
- Specific Gravity testing standard referred to ASTM C128-84 or AASHTO T84-77 or DOH.209/2517
- Soundness testing standard referred to ASTM C88-83 or AASHTO T104-77 or DOH.213/2531
- The sand Equivalent testing standard referred to ASTM D2419-74 or AASHTO T176-73 or DOH .203/2515

The specifications of course materials were tested as follows.

- Gradation testing standard referred to ASTM C127-84 or AASHTO T85-77 or DOH.207/2517
- Specific Gravity testing standard referred to ASTM C128-84 or AASHTO T84-77 or DOH.209/2517
- Durability testing standard referred to ASTM C88-83 or AASHTO T104-77 or DOH.213/2531
- The flakiness Index testing standard referred to DOH.210/2518
- The elongation Index testing standard referred to DOH. 211/2518
- The sand Equivalent testing standard referred to ASTM D2419-74 or AASHTO T176-73 or DOH .203/2515
- Soundness testing standard referred to ASTM C131-81 or AASHTO T96-77 or DOH. 202/2515

It is to note that some researchers studied fatigue analysis (Bonnaure *et al. 1982*, Monismith *et al*. 1970, Ruth and Olson 1977, and Sousa *et al*. 1998) but for DOH’s Thailand this testing standard is not set for main requirement.

Job Mix Formula of all specimens was applied in this study. Adhesive mixtures were polymer modified asphalt (PMA) mixed with "ADVERA" to the ratios of 0.20%, 0.25%, 0.30% and 0.35% by weight of aggregate. Mixing and compaction temperatures were controlled at 140ºC, 145ºC, 150ºC, and 155ºC. In this study after found the optimum ADVERA ratio and optimum mixing temperature, this study determined under laboratory conditions the fundamental properties of samples, and evaluated their possible use for WMA, particularly the potential use of ADVERA. These fundamental laboratory conditions included:

- Strength Index
- Temperature Sensitivity
- Maximum Specific Gravity
- Bulk Specific Gravity
- Voids in Asphalt Mixture
- Binder Workability

Table 2 shows the control criteria of engineering properties of each surface course, those course samples should design as follow the DOH Thailand's standard specification.

Table 2. DOH Thailand's standard specification of HMA, WMA and PMA.

Items		Type of Surface Courses				
		Wearing Course 9.5 mm.	Wearing Course 12.5 mm.	Binder Course	Base Course	Shoulder
Blows		75	75	75	75	75
Stability	N	8006	8006	8006	7117	7117
	(lb)	(1800)	(1800)	(1800)	(1600)	(1600)
Flow 0.25 mm (0.01 in.)		8-16	8-16	8-16	8-16	8-16
Percent air voids		3-5	3-5	3-5	3-5	3-5
Percent voids in material Aggregate (VMA, min)		15	14	13	12	14
Stability/Flow, min	N/0.25 mm	712	712	712	645	645
	(lb/0.01 in.)	(160)	(160)	(160)	(145)	(145)
Percent strength index		75	75	75	75	75

5 RESULTS AND DISCUSSION

In total, 75 WMA specimens were examined using a general standard specification test according to standards set by DOH Thailand.

The physical engineering characteristics of each item were as follows: stability, flow voids in mineral aggregate (VMA), density, the percentage of air voids, and voids filled in bitumen (VFB) are shown in Figure 2. The physical engineering characteristics of each item were as below.

5.1 Stability and Flow of PRAP- Warm Mix

Normally, the maximum stability's values of all specimens were determined by controlling the settlement rate of specimens (2 inches per minute) with temperature (60 ºC). The flows values were determined during the same period. The stability's values of all specimens are 2,530-2,950 lbs. also, the flow values of all specimens are 11-12 (1/0.01 in). The stability per flow value (ASF) is 211-384 (lb/0.01 in.) which higher than 160 (lb/0.01 in.). The results show that all stability and flow values give a higher value than DOH Thailand's standard. Also, the results of using ADVERA as 0.2% of aggregate mixed at 140°C indicated that this is the optimum mix proportion.

5.2 Percentage of Air Void (V) and Void in Mineral (VMA) of PRAP- Warm Mix

The average of the percentage of air void is 3.6-5.8 and the average of the percentage of void in the mineral is 14.2-16.2 these results give a higher value than DOH Thailand's standard.

5.3 Strength Index of PRAP- Warm Mix

The strength indexes of WMA's specimens were tested by following the Ontario vacuum immersion Marshall Test. The strength index values are 84.0-93.0 lbs. These results give a higher value than DOH Thailand's standard (75 lbs).

Table 3 shows the engineering properties of PRAP- Warm Mix specimens using 0.2 - 0.35 % mix at temperature 140°C and Table 4 shows the engineering properties of PRAP- Warm Mix specimens using ADVERA 0.2 %. In conclusion, the engineering properties of PRAP- Warm Mix samples obtained from this study showed that: The optimum mixing ratio was 0.20 percent at 140ºC which has a Stability value of 2530 lbs, a flow of 12 in a particle size of VMA 16.2, a strength index, 85 percent. Using 70 percent of PRAP- Warm Mix with 30 percent of new material at 140 ºC and add 0.20 percent of Advera that is the best-mixed proportion.

Table 3. Engineering properties of PRAP- Warm Mix specimens using ADVERA 0.2 - 0.35 % mix at temperature 140°C.

Test at mix temperature 140°C	%ADVERA				DOH standard
	0.20	0.25	0.30	0.35	
Average Stability (lb)	2530	2840	2760	3700	1600-1800
Average Flows (1/100 in)	12	11	11	11	11-13
Stability/Flow (1/100 lb/in)	211	258	251	336	>210
Average Density	2.330	2.348	2.359	2.364	2.368-2.385
Percent Air Voids	5.8	5.1	4.7	4.5	3-5
Percent Voids in Mineral Aggregate (VMA)	16.2	15.5	15.1	14.9	>12
Voids Filled with Bitumen (VFB)	63.9	67.1	69.2	70.2	69-79
Strength index	85	85	87	87	>75

Table 4. Engineering properties of PRAP- Warm Mix specimens using ADVERA 0.2 %.

Test	Mix Temperature			
	140°C	145°C	150°C	155°C
Average Stability (lb)	7760	7820	8310	9290
Average Flows (1/100 in)	14	14	13	12
Stability/Flow (1/100 lb/in)	554.2	558.5	639.2	774.1
Average Density	2.282	2.287	2.295	2.312
Percent Air Voids	7.8	7.6	7.3	6.6
Percent Voids in Mineral Aggregate (VMA)	17.9	17.7	17.4	16.8
Voids Filled with Bitumen (VFB)	56.5	57.2	58.4	61.0
Strength index	85	84	84	87

6 CONCLUSION

The results show that the PRAP- Warm Mix process reduces the mixing temperature from 170ºC to 140 ºC that means this mixing process can save fuel consumption. Also using reclaims PMA. Thus this study is useful for environmental perspectives.

Acknowledgments

We acknowledge Mr.Tanach Sripatin, Department of Highway, Thailand for supporting job mixed testing and PQ Chemicals (Thailand) Co. Ltd. for providing ADVERA.

References

Bonnaure, F., Huibers, A., and Boonders, A., *A Laboratory Investigation of The Influence of Rest Periods on The Fatigue Characteristics Of Bituminous Mixes*, Proceedings of The Association of Asphalt Paving Technologists, St. Paul, MN., 51, 105-121, 1982.

Jansen, J., and Smirnovs, J., *Warm Mix Asphalt Investigation*, Master of Science Thesis, Department of Civil Engineering, Technical University of Denmark, Denmark, 2010.

Monismith, C., Epps, J., Kasianchuk, D., and Mclean, D., Asphalt Mixture Behavior in Repeated Flexure, *Transportation Engineering Report Number 70-5*, University of California, Berkeley, CA., 1970.

NAPA, Warm-Mix Asphalt Best Practice, *Quality Improvement Publication 125*, National Asphalt Pavement Association, Lanham, MD, 2010.

Ruth, E., and Olson, K., Creep Effects on Fatigue Testing of Asphalt Concrete, *Proceedings of AAPT*, Association of Asphalt Paving Technologists, St. Paul, MN., 46, 177-196, 1977.

Sousa, J., Pais, J., Prates, M., Barras, R., Langlois, P., and Leclerc, A., Effect of Aggregate Gradation on Fatigue Life of Asphalt Concrete Mixes, *France Portution Research Record 1630*. 62-70, Paris, 1998.

Weerakaset, S., Watcharin, W., Somsak, C., and Thaweesak, P., *Mechanical Properties of Warm Mix Asphalt Concrete Application Using ADVERA*, Proceedings of Sustainable Solutions in Structural Engineering and Construction, ASEA-SEC02, Bangkok, Thailand, 419-423, 2014.

You, Z., Goh, S., and Dai, Q., Laboratory Evaluation of Warm Mix Asphalt, *Report No. RC-1556*, Michigan Technological University, Houghton, MI, 2011.