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THE RELATIONSHIP OF BITUMEN CONTENT, AGGREGATE SURFACE AREA, AND EXTRACTION TIME USING ASPHALT IGNITION FURNACE

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ABSTRACT

Aggregates make up between 80% and 90% of total volume or 94% to 95% of the mass of hot mix asphalt (HMA). For this reason, aggregate properties are very important. It directly affects the workability of the HMA. One of the properties of aggregate is coated surface area. The main objective of this study was to search the relationship of the surface area of aggregate, bitumen content, and extraction time in order to find the coated surface area of aggregate to be correlative with the optimum bitumen content. Three types of aggregate grading including dense grading, open grading, and gap grading that designed as ACW14, PA, and SMA14 were tested in accordance with the JKR Specification. A total of 45 specimens were prepared using Marshall Mix design method with three types of grading: ACW14 (dense graded), SMA14 (gap graded), and PA (open graded) in order to determine the optimum bitumen content (OBC). The second phase was to determine the coated surface area of aggregate by using the surface area factor. Samples (45) were prepared and subjected to extraction of the bitumen content using NCAT ignition furnace to determine the time to remove bitumen from the aggregate in different types of mixes. Based on the results, it was observed that the bitumen content was significantly affected by the aggregate surface area while the aggregate surface area was influenced by the fine aggregate. Moreover, all of the observed parameters fitted highly to the linear relationship. Thus, it can be concluded that the bitumen content, aggregate surface area and the characteristics of bitumen have an influence on the extraction time.

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1 INTRODUCTION

Asphalt has been used as a construction material from the earliest days of civilization. Though it has long been used as a waterproofing material in shipbuilding and hydraulics, its use in roadway construction is much more recent. A recent survey revealed a total of over 2.3 million miles of hard-surfaced asphalt or concrete roads in the United States, of which approximately 96% have asphalt surfaces (Roberts, 2002). In Malaysia, most of the road networks are asphalt surfaces that have expanded rapidly in line with pace of economic growth. There are about 80,000 km of asphalt surfaces in Malaysia. Asphalt mixture consists of asphalt, coarse and fine aggregate and a number of additives occasionally used to improve its engineering properties. The purpose of mixture design is to select optimum asphalt content for a desired aggregate structure to meet prescribed criteria. Hence, aggregate is an important constituent of asphalt concrete. The shape, angularity, and surface texture of aggregates affect the surface area of the coated aggregate that significantly affect mixture properties.

New asphalt pavement roads tend to distress after only few years because of traffic loading even though they have been designed to last longer. These asphalt pavements can exhibit various distresses that will cause the pavement's failure such as rutting, cracking, stripping, bleeding, and so on. Among of these distresses, permanent deformation (rutting) is one of the major distresses in hot mix asphalt (HMA) pavement. Repeated application of traffic loads causes structural damage to asphalt pavements in a form of rutting which occurs along the wheel track. Moreover, the surface area of coated aggregate has an important effect on the characteristic of HMA. If asphalt mixes that have high surface area and low optimum asphalt content are undesirable, these mixes will have a thin asphalt film on aggregate and will probably not have enough durability. As a result, HMA can encounter some distress by insufficient binding aggregate such as raveling, stripping and cracking. On the other hand, if the asphalt content is too high, bleeding and rutting occur. Hence, the asphalt content must be carefully controlled during construction. This optimum content can be obtained by defining a relationship between the bitumen and the coated surface area of aggregate of different grading mixes concentrating of several research efforts on the purpose of overcoming these pavement problems.

The objectives of this study were to establish the relationship of bitumen content, aggregate surface area, and extraction time for different types of mixes.and to determine the relationship between optimum bitumen content (OBC) and the aggregate surface area.

Aggregate, bitumen, and filler were evaluated to satisfy the JKR specifications JKR/SPJ/rev2005. Then, coating and Stripping of Bitumen-Aggregate Mixtures were tested based on ASTM D1664-80. The flakiness and elongation index of aggregate also were carried. Later, each sample of HMA mixes was prepared according to JKR/SPJ/rev2005 using Marshall Design and Ignition Furnace Procedures. Three types of mixes were ACW 14 (dense graded), PA (open graded), and SMA14 (gap graded). In designing the mixtures, total of 45 specimens (Marshall) and 45 specimens (Ignition Furnace) were prepared to determine the optimum bitumen content and time to remove the bitumen from aggregate. The tests were performed at Highway & Transportation Laboratory, UTM and UTHM.

2 METHODOLOGY

The laboratory works were carried out in two stages. The first stage was done prior to mixing and prepared specimens was done in the second stage. The aggregates were obtained from the Malaysian Rock Product Quarry (MRP). Bitumen of 80-100 PEN and PG 76 were used in this study. For the first stage, aggregate, bitumen, and filler were evaluated to satisfy the JKR specifications JKR/SPJ/rev2005. Second, sieve analysis coarse and fine aggregate were done (something is missing, not a complete sentence). Then, washed sieve were carried to determine the percentage of dust and silt-clay material in order to check the need for filler material. Next, the process of specific gravity determination for coarse and fine aggregate was taken place. The test for, flakiness and elongation index test were carried out. Besides, Coating and Stripping of Bitumen-Aggregate Mixtures were done. Subsequently, aggregate blending satisfying the JKR gradation limits were used.

For the second stage, a total of 45 specimens were prepared using Marshall Mix design method with three types of grading: ACW 14 (dense graded), PA (open graded), and SMA14 (gap graded) in order to determine the optimum bitumen content (OBC). The sample preparation incorporated specifying the mixing temperatures. An average value of theoretical maximum density (TMD) were obtained through the test as in ASTM D2041 (1992) on six specimens. The stability and flow test were conducted for Marshall specimens in determining the optimum bitumen content according to ASTM D 1559 (1992). The bulk specific gravity and density of compacted mixture samples for three mix design methods were carried out in accordance to ASTM D 2726 (1992). Then, the surface coated areas of aggregate of these samples were calculated by using the surface factor area. Moreover, Binder-drain-down, Cantabro test were carried. Finally, 45 samples of the three mix designs were prepared and using Ignition Method (AASHTO T308) to determine time to extract the bitumen content.

3 RESULTS AND DISCUSSION

The results of aggregate and bitumen test are shown in Table 1 and 2.The results showed that it can be observed that most of tests met the requirement of JKR 2005. However, the results of LAAV test did not satisfy JKR 2005. Moreover, the result of ACV for PA and PSV for SMA14 and PA did not meet the requirement of JKR 2005. It is clear that the aggregate of MRP does not meet the requirement of special mix although it satisfies to conventional mix.

Table 1: The results of aggregate tests

Types of Tests	ACW14	SMA14	PA	JKR 2005 ACW14	JKR 2005 SMA14	JKR 2005 PA
Flakiness Index (%)	12,3	15,7	9,0	≤ 25	≤ 25	≤ 25
Elongation Index (%)	13,6	10,8	17,3	≤ 25	≤ 25	≤ 25
ACV (%)	-	29,42		-	≤ 30	≤ 25
LAAV (%)		35,15		≤ 25	≤ 30	≤ 25
Soundness (%)		2,9		≤ 18	≤ 18	≤ 18
PSV		49**		min 40	min 50	min 50
Water absorption (%)	0,58	0,77	0,67	≤ 2	≤ 2	≤ 2

Table 2: The results of bitumen tests

Types of test	Pen 80 -100	PG -76	JKR 2005 (PG76)
Penetration (mm)	8,4	4,10	-
Softening point (°C)	37	60	60
Viscosity (cP)	500	1500	-
Coating and stripping (%)	99	98	95

The volumetric properties of three type mixes are shown in Table 3

Table 3: Marshall results for three type mixes

Parameters	PEN 80-100	PG76	PG76	JKR/SPJ/rev/2005		
	ACW14	SMA14	PA	ACW14	SMA14	PA
OBC (%)	4,48	6,80	4,26	-	-	-
Stability (kg)	1529,6	1141,4	887,3	> 815	Min 632	-
Flow (mm)	2,22	2,15	2,58	2 - 4	2 - 4	-
VFA (%)	71,41	83,68	31,40	70 - 80	-	-
VTM (%)	4,0	4,0	20,0	3.0 - 5.0	3.0 -4.0	18 -25
VMA (%)	14,1	17,9	26,2	-	Min 17	-
Stiffness (kg/mm)	679,4	526,7	342,4	>204	-	-
Draindown (%)	-	0,04	0,11	-	Max 0.3	Max 0.3
Cantabro (%)	-	-	19,2	-	-	≤ 15

The results of ignition furnace are shown in Figure 1, 2, 3, 4, 5 and 6, below:

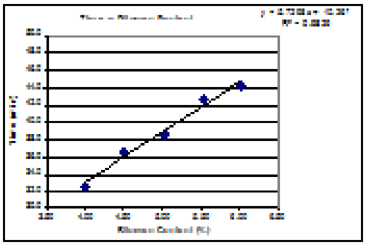

Fig. 1: Time vs Bitumen of ACW14

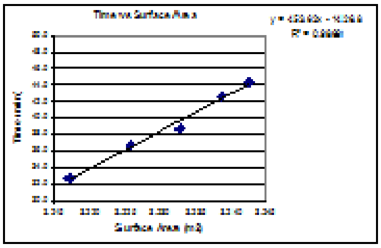

Fig. 2: Time vs Bitumen of SMA14

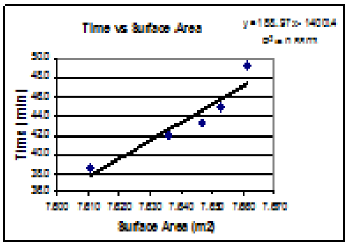

Fig. 3: Time vs Bitumen of PA

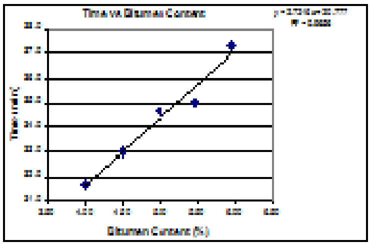

Fig. 4: Time vs Surface area-ACW14

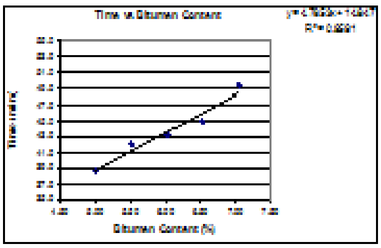

Fig. 5: Time vs Surface area-SMA14

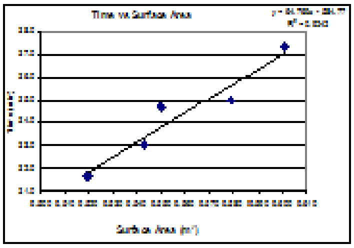

Fig. 6: Time vs Surface area-PA

From the results, it was observed that different bitumen content has various time to extract bitumen. It can be seen that time needed to extract bitumen is getting more as bitumen content increase. On the other hand, for SMA14 and PA, the aggregate surface area is lower than the aggregate surface area of ACW14 but the extraction time of SMA14 and PA is longer than ACW14. This could be due to PG76 has longer time to extract than PEN 80 -100 (the softening point of PG76 is higher than PEN 80 -100). Furthermore, it can be noticed that different of aggregate surface area has diverse time to extract bitumen. For SMA and PA, both two types mixes were used PG76. However, time to extract bitumen of SMA has longer than PA. This could be due to the aggregate surface area of SMA is higher than PA. It is clear that the more aggregate surface area the mixture has, the more bitumen will be coated. As a result, the more time is needed to extract bitumen.

The results of relationship between bitumen content and aggregate surface area illustrated in Figure 7, 8, and 9.

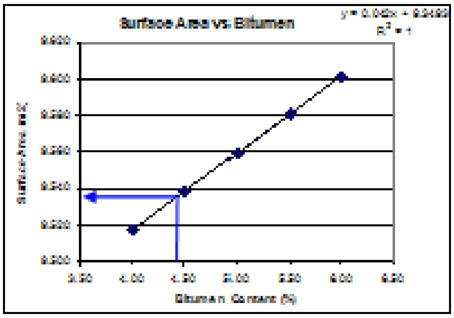

Fig. 7: Surface area vs Bitumen Content-ACW14

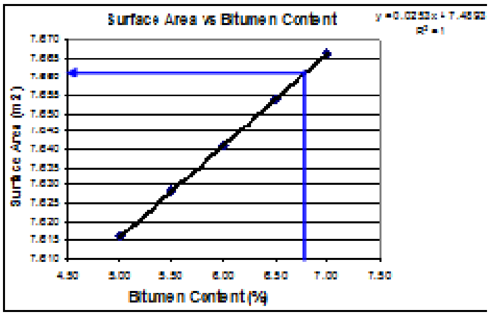

Fig. 8: Surface area vs Bitumen Content-SMA14

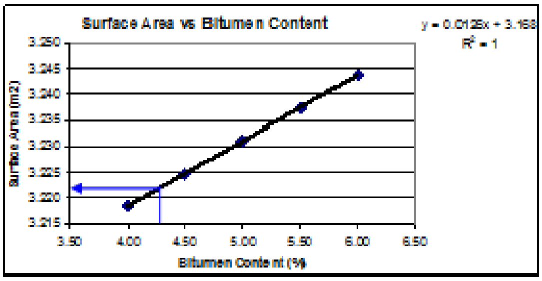

Fig. 9: Surface area vs Bitumen Content-PA

The equations of the relationship between extraction time – bitumen content, extraction time – surface area, and surface area - bitumen content are shown in Table 4. The optimum of bitumen content, aggregate surface area, and extraction time are illustrated in Table 5.

Table 4: The equations of the relationship of extraction time - bitumen content, extraction time - surface area, and aggregate surface area - bitumen content

Relationship	ACW14	SMA14	PA
Time - Bitumen	y = 2.7216x + 20.777	y = 4.7853x + 14.847	y = 5.7298x + 10.267
Time - Surface area	y = 64.769x - 584.77	y = 188.97x - 1400.4	y = 453.62x - 1426.8
Surface area - Bitumen	y = 0.042x + 9.3493	y = 0.0253x + 7.4893	y = 0.0126x + 3.168

Based on the results as shown in Table 4 and 5, it can be observed that different grading has various optimum aggregate surface areas. It could be due to the fine aggregate of ACW14 is more than the fine aggregate of SMA14, and PA. It is clearly seen that the aggregate surface area increases as the fine aggregate rises. For bitumen content, it can be noticed that OBC of SMA is the highest, while the OBC of PA is the lowest. It could be due to the aggregate surface area affect to the bitumen content. The grading has more fine aggregate that will need more bitumen coated. However, for SMA14, although the surface area of ACW14 is higher than SMA14, the bitumen content of SMA14 is higher than ACW14. This is due to the bitumen content of SMA14 needs to fill to the air voids in order to get

4% air voids. As a result, the optimum bitumen content of SMA14 is higher than ACW14. It is clear that the aggregate surface area affects to the bitumen content. For extraction time, it can be observed that optimum extraction time of SMA is the highest, while the optimum extraction time of ACW14 is lowest. It can be seen that different bitumen content has different extraction time. The mix with high bitumen content will have more extraction time. Moreover, Although ACW14 has more aggregate surface area than SMA14 and PA, the extraction time of ACW14 is shorter than SMA14 and PA. This could be due to PG76 has longer time to extract than PEN 80 -100 (the softening point of PG76 is higher than PEN 80 - 100).It can be clearly seen that the characteristics of bitumen also affect to extraction time. Furthermore, it can be noticed that different of aggregate surface area has diverse time to extract bitumen. For SMA and PA, both two types mixes were used PG76. However, time to extract bitumen of SMA14 has longer than PA. This could be due to the aggregate surface area of SMA is higher than PA. It is clear that the more aggregate surface area the mixture has, the more bitumen will be coated. As a result, the more time is needed to extract bitumen. From these reasons above, it can be conclusion that the bitumen content, aggregate surface area and extraction time have relationships each others. If the mixes have higher surface area, they will have more bitumen content need to be coated. As a result, these mixes will have more time to extract. On the contrary, if the mixes with lower aggregate surface area, they will have lower bitumen content coated. As a result, these mixes will have less extraction time.

Table 5: Optimum of bitumen content, aggregate surface area, and extraction time

Type	Optimum		
	Bitumen Content (%)	Surface Area (m^2)	Extraction Time (min)
ACW14	4,48	9,537	33
SMA14	6,80	7,661	47
PA	4,26	3,222	35

4 CONCLUSIONS

From on the results presented above, the following conclusions drawn from the study are below:

Different grading has different aggregate surface areas. The aggregate surface area of dense graded is more than the gap graded and open graded. It could be due to the fine aggregate. In one word, the fine significantly affect to the aggregate surface area. The bitumen content was significantly affected by the aggregate surface area. The mix which has higher aggregate surface area will have more coated bitumen content.

Different bitumen content has different extraction time. The mix with high bitumen content will have more extraction time. The characteristics of bitumen also affect to the extraction time. Furthermore, different of aggregate surface area has diverse time to extract bitumen. The mix with high aggregate surface area will has more extraction time.

Based all the conclusions and discussions above, it was observed that aggregate surface area, bitumen content, and extraction have linkages and affect each others. It was obvious that from this study, the characteristics of bitumen content, the types of grading and the characteristic of aggregate effect to the mix. It is suggested that the study must be further researched with variation in gradation, bitumen and the types of aggregate to look into the relationship deeper in order to get the best hot mix asphalt can be achieved to overcome the problems such as rutting, bleeding, and stripping with high economic and effective hot mix in pavement design.

REFERENCES

Roberts, F.L., Mohammad, L.N. and Wang, L.B., 2002. "History of hot mix asphalt mixture design in the United States", Journal of Materials in Civil Engineering, ASCE, pp. 279-293.

Asphalt Institute, 1988. Principles of Construction of Hot-Mix Asphalt Pavement. United States of America: Asphalt Institute.

Roberts, F.L., Kandhal, P.S., Brown, E.R., Lee, D.Y., Kennedy, T W., 1996. Hot Mix Asphalt Material, Mixture Design, and Construction. 2nd Edition. Maryland: NAPA Research and Education Foundation.

Lavin, P., 2003. Asphalt Pavements: A Practical Guide to Design, Production, and Maintenance for Engineers and Architects. London: Spon Press.

Hunter, R.N. (ed), 1994. Bituminous Mixtures in Road Construction. London: Thomas Telford Services Ltd.

Asphalt Institute, 1989. The Asphalt Handbook. MS-4. Kentucky: Asphalt Institute.

Garber, N. J. and Hoel, L. A. (2002). Traffic and Highway Engineering. Third Edition. United States of America: Brooks/Cole.

Atkins, H.N., 2003. Highway Materials, Soils and Concretes. Fourth Edition. Upper Saddle River, New Jersey: Prentice Hall.

Aggregate Evaluation Project, 2008. Faculty of Civil Engineering - Universiti Teknologi Malaysia.