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STUDY ON SOME FACTORS INFLUENCING THE PERFORMANCE OF ASPHALT CONCRETES FOR AIRPORT PAVEMENTS

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A series of laboratory tests was conducted to study the asphalt concrete with better performance for airport pavements, with the following results: (1) Asphalt concrete with modified asphalt has higher dynamic stability and lower cracking susceptibility than that with conventional straight asphalt. (2) The gradation of aggregates highly influences the performance of asphalt concrete. Both stone asphalt concrete and Superpave asphalt concrete show better performance for airport pavements. (3) As compaction effort increases, the air void ratio of asphalt concrete decreases and the stability increases. Increasing the compaction effort gives the asphalt concretes better resistance to both rutting and stripping.

Key Words: *asphalt concrete, modified asphalt, aggregate gradation, compaction, laboratory test*

1. INTRODUCTION

As aircraft become larger and their operation frequency increases, the conditions of loading on airport pavements, that is, increases in both wheel loads and tire pressures, are exceeding the values assumed in the traditional pavement design. As a result, rutting, deformation and fatigue cracking of asphalt pavements are becoming more prevalent. It is well known that asphalt concretes currently used for airport pavements do not have sufficient durability against heavy duty loads, which is affected by several factors such as the properties of aggregates and asphalt, asphalt content and environmental conditions [1)].

Consequently, pavement engineers are looking for new approaches to address these problems. In the past few years, they have introduced various modifications to asphalt concrete to alleviate the problems. For example, the addition of some polymers may increase the viscosity of binder at high temperature, which increases the resistance of asphalt concretes to rutting during hot weather, and reduce the stiffness of asphalt concrete at low temperature[2)]. As no modified asphalt is standardized in the specifications on paving works for airports, the mechanical properties of asphalt concrete with modified asphalt were examined in this study.

However, the use of modified binder alone will not solve the most serious problems, that is, both rutting and cracking. The strategic highway research program (SHRP) introduced a new mix design system with binder specifications for performance grading as well as a series of advanced tests on asphalt concretes. The system focuses on binder properties, and quality and gradation of aggregates, and the specifications characterize the binder in relation to rutting and cracking [3)].

Aggregate quality and gradation are particularly important with regard to rutting. Especially, aggregate gradation is the most important element of asphalt concretes because it affects almost all of their physical properties. Therefore, asphalt concretes with various aggregate gradations such as stone mastic asphalt concrete (SMA), stone asphalt concrete (SA) and Superpave asphalt concrete (SP) were studied in comparison with dense graded asphalt concrete (DGA); that is, their resistance to rutting, moisture damage, low temperature cracking and abrasion, and water permeability were evaluated.

SMA, which was developed in Europe approximately 20 yeas ago, was proven to be durable and more resistant to rutting than DGA through field experience [4)].

Table 1 Properties of binders

Item		Straight	Modified
Penetration (1/10mm, 25°C)		73	64
Softening point (°C)		47	64
Ductility (cm, 15°C)		140+	92
Solution (%)		99.8	
Thin film oven test (163°C, 5h)	Loss (%)	0.02	0.01
	Penetration ratio (%)	64.4	82.7
Density (g/cm^3)		1.034	1.028

Table 2 Properties of aggregates

Item	Coarse aggregate				Fine aggregate			Filler
	#4	#5	#6	#7	Screenings	Coarse sand	Fine sand	
Apparent specific gravity (g/cm^3)	2.709	2.723	2.716	2.713	2.740	2.626	2.639	2.710
Absorption (%)	0.61	0.57	0.65	1.24	1.76	1.17	1.58	-
Abrasion (%)	16.3	11.7	13.2	14.8	-	-	-	-
Soundness (%)	8.4	6.3	5.6	3.7	2.1	2.9	3.9	-

Table 3 Aggregate gradations of asphalt concretes

Sieve size (mm)	DGA	SMA	SA	SP-A	SP-B
37.5	-	-	-	-	-
26.5	100	100	100	100	100
19	97.5	97.5	97.5	95	95
16	-	-	86	-	-
13.2	82.5	82.5	74.5	-	-
9.5	-	-	58.5	-	-
4.75	55	35	35	-	-
2.36	42.5	27.5	26.5	33	38
1.18	-	-	20	20	30
0.6	24	-	16	15	22
0.3	15.5	16.5	13.5	11	15
0.15	11	-	11.5	-	-
0.075	6	10.5	8	4	5

SA is a gap graded asphalt concrete, which is similar to SMA but designed a little more towards DGA primarily to eliminate the need for expensive modified binder or fibers. Fairly good stone to stone contact, which increases the resistance to rutting, is achieved by the structural skeleton formed by the coarser aggregates. As SA has higher binder contents than DGA, thus providing thicker asphalt films, it resisted moisture damage and aging more than DGA.

Aggregate gradation of SP incorporates a restricted zone and the control points to avoid the "hump" in the gradation curve, depending on the nominal maximum size of aggregate. According to the Superpave specification, any gradation that passes above or below the restricted zone and within the relevant control points, is expected to produce good asphalt concrete [5)].

The resistance of asphalt pavements to rutting will be improved if the asphalt concrete layers are compacted well during construction, for the tire pressure of aircraft is higher than that of motor vehicles. Therefore, the influence of compaction effort on the mechanical properties of asphalt concretes was additionally examined.

2. LABORATORY TESTS

(1) Asphalt concretes

a) Materials

A straight asphalt 60/80 and modified asphalt II were used in the study, the properties of which are given in **Table 1**. The properties of aggregates used in the laboratory tests are also given in **Table 2**. The gradations of aggregates contained in asphalt concrete used here are presented in **Table 3**.

Table 4 Results of Marshall test

Item	DGA	SMA	SA	SP-A	SP-B
Optimum asphalt content (%)	5.4	5.3	5.2	5.3	5.3
Density (g/cm^3)	2.407	2.397	2.428	2.417	2.422
Maximum density (g/cm^3)	2.481	2.487	2.501	2.492	2.495
Air void (%)	3.0	3.6	2.9	3.0	2.9
VMA (%)	15.6	15.9	15.1	15.4	15.3
Stability (kN)	11.76	9.03	9.64	10.63	13.21
Flow (1/10mm)	31	36	37	32	33
VFA (%)	80.8	77.4	80.8	80.5	81.0
Retained stability (%)	86.0	88.0	85.4	89.4	88.0

Table 5 Influence of asphalt on properties of asphalt concretes

Item	Straight 60/80	Modified
Dynamic stability (cycles/mm)	1286	7875
Dynamic stability with high-pressure wheel (cycles/mm)	231	2250
Stripping ratio (%)	8.7	0
Strength (MPa)	6.997	8.927
Strain at failure (1×10^{-3})	5.54	6.04
Stiffness (MPa)	1541.1	1478
Permeability coefficient (1×10^{-7} cm/sec)	1.57	2.71
Abrasion loss (cm^2)	0.29	0.20

SMA was prepared by using fibers as the stabilizer at 0.4% by total weight of the asphalt concrete. In the Superpave asphalt concretes, two kinds of aggregate gradations were used: SP-A and SP-B, which designate the gradation passing below and above the restricted zone, respectively.

b) Mix design

Marshall mix designs of asphalt concretes were performed to determine the optimum asphalt content. **Table 5** summarizes the properties of asphalt mixtures at the optimum asphalt content.

This table shows that DGA and SP-B have higher stability and lower flow than the SMA, SA and SP-A, but the retained stability is not significantly different in all the asphalt concretes. SMA has low VFA, which is related to larger air void and lower asphalt content.

(2) Test methods

The mechanical properties of various asphalt concrete were evaluated as follows:

a) Rutting evaluation

Wheel tracking tests were conducted on all the asphalt concretes in the dry condition at 60°C, to evaluate the resistance to rutting. The dimensions of each specimen were 300 mm long, 300 mm wide and 50 mm thick. In addition to the standard tire pressure, high pressure equivalent to that of a B747-400 (1.38 MPa) was used. The dynamic stability was calculated as the test result.

b) Moisture damage evaluation

Immersed wheel tracking tests were conducted on all the asphalt concretes at 60°C in the water to evaluate the moisture susceptibility of asphalt concrete. The specimens, each 500 mm long, 300 mm wide and 50 mm thick, were loaded repeatedly for six hours, then the stripping ratio was calculated.

c) Low-temperature cracking evaluation

High stiffness, low strain and low stress of asphalt concrete at cold temperatures are equated with low flexibility and high susceptibility to cracking. In the study, the flexural tests were conducted at -10oC. The dimensions of the specimens were 250 mm long, 100 mm wide and 50 mm thick and the rate of loading of 1 mm/min was used.

d) Water permeability evaluation

The permeability test was conducted for all the asphalt concretes in accordance with JIS A 1218-1990 (variable water table method).

e) Abrasion evaluation

Raveling tests [6)] were conducted to evaluate the resistance to abrasion, based on the standard method with back-and-force chain movements. The results were expressed as the abrasion loss.

3. RESULTS AND DISCUSSIONS

(1) Effect of modified asphalt

The effects of modified asphalt on the properties

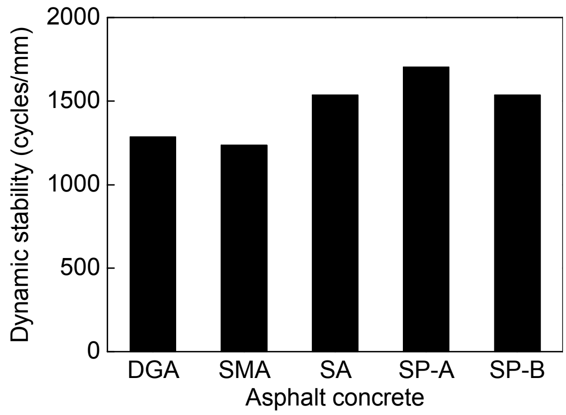

Fig. 1 Dynamic stability in the standard condition

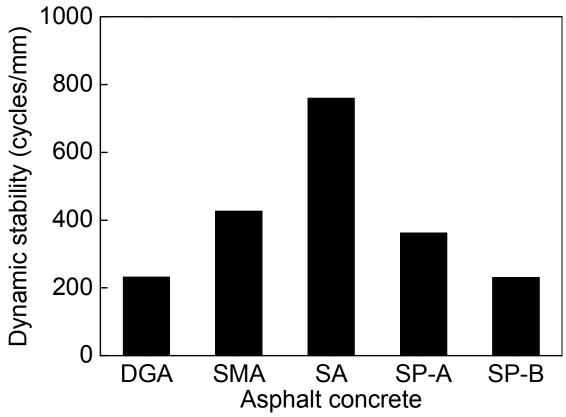

Fig. 2 Dynamic stability in the high-pressured condition

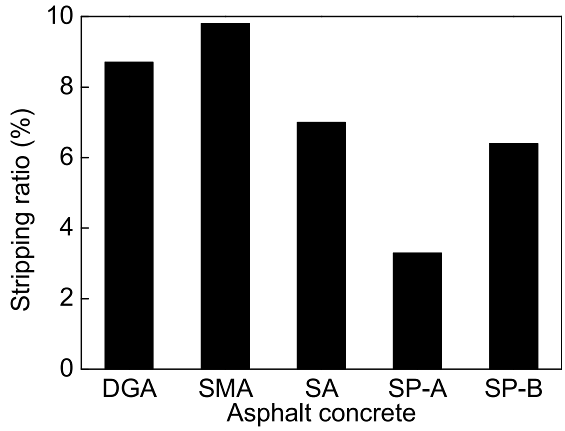

Fig. 3 Stripping ratio

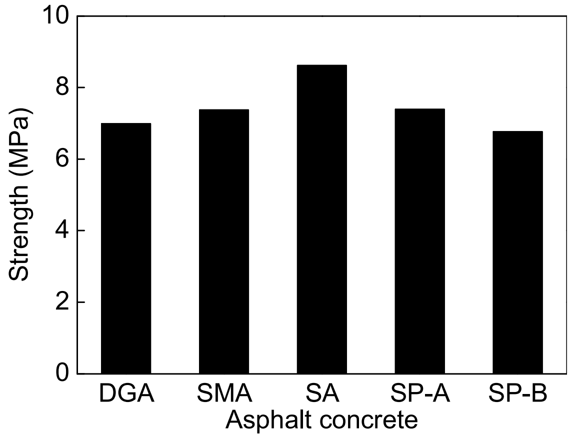

Fig. 4 Strength at low temperature

of asphalt concretes were studied by the use of DGA. The results are summarized in **Table 7**. The asphalt concrete with modified asphalt has a much higher dynamic stability than that with straight asphalt, and also higher resistance to water damage.

In addition, the asphalt concrete with modified asphalt has a higher stress and strain and lower stiffness at low temperature, compared with that having straight asphalt. The test results also indicate that the binder is the main contributor to the better performance of asphalt concrete, as the modified asphalt increases the resistance of asphalt concrete to both rutting at high temperature and cracking at low temperature.

(2) Influence of aggregate gradation

a) Rutting evaluation

The results from the wheel tracking tests are presented in **Figs. 1** and **2**, in the standard and high-pressure condition, respectively.

Fig. 1 indicates that the aggregate gradation plays a significant role in the resistance of asphalt concrete to permanent deformation; that is, SPs and SA have lower rutting potential than SMA and DGA. In the Superpave asphalt concretes, the coarse gradation (SP-A) shows lower rutting potential than the fine gradation (SP-B). **Fig. 2** shows that SA has better resistance to rutting than other asphalt concretes, followed by SMA and SP-A under high tire pressure, as SA emphasizes stone to stone contact. This also means that the gradation has a very important influence on rutting susceptibility.

b) Moisture damage evaluation

The results of the immersed wheel tracking tests are presented in **Fig. 3**, showing that SPs and SA have low stripping ratios. This is expected due to the thicker binder film in these gradations, which provides improved adhesion between aggregates and thus protection against moisture damage. On the contrary, SMA and DGA have high stripping ratios, for SMA is related to large air voids and DGA to gradation.

c) Low temperature cracking evaluation

The results of flexural tests at low temperature are presented in **Figs. 4**, **5** and **6**. From these figures, it can be seen that SMA and SA have higher strength and failure strain, and lower stiffness than other asphalt concretes. Therefore, the asphalt concretes with these aggregate gradations would have better resistance to low temperature cracking. DGA and SPs show no significant difference in resistance to

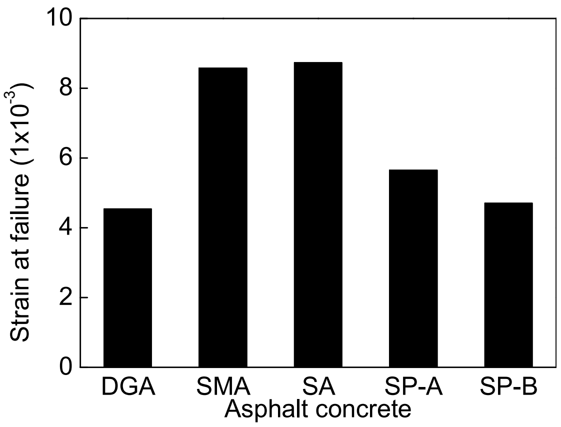

Fig. 6 Failure strain at low temperature

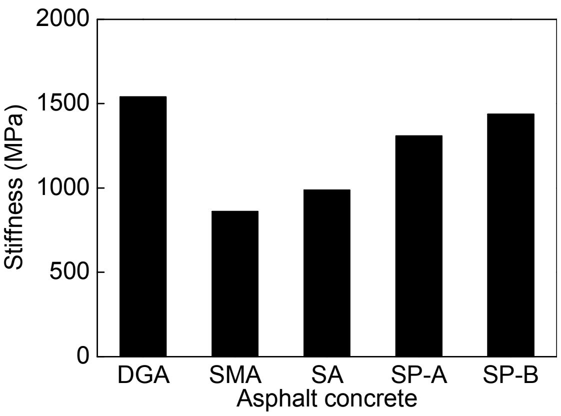

Fig. 7 Stiffness at low temperature

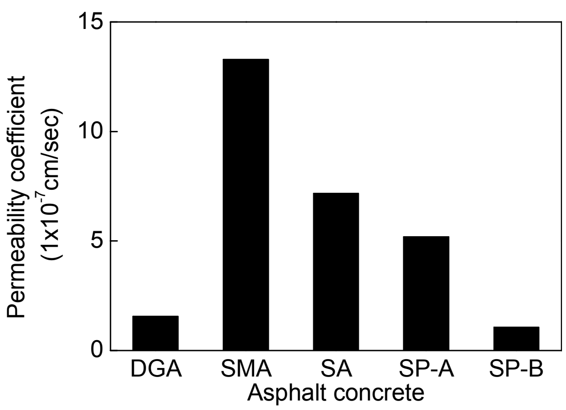

Fig. 8 Permeability coefficient

low temperature cracking.

d) Water permeability evaluation

The permeability of asphalt concretes is shown in **Fig. 9**.

SMA, SA and SP-A exhibit higher permeability. This is due to the fact that they contain larger percentages of coarse aggregates, which might be larger air voids formed by the aggregate skeleton with stone to stone contact.

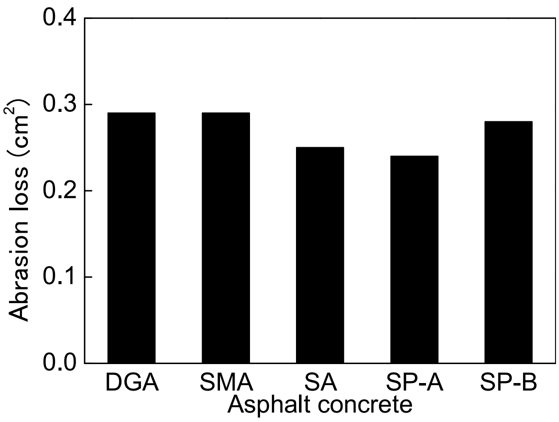

Fig. 9 Abrasion ratio

Table 6 Compaction method

ID	hammer mass (kg)	Drop height (cm)	Blow (times)	Compaction effort (kg·cm)
A	4.5	45.7	75	15424
B	4.5	45.7	113	23238
C	10.2	45.7	50	23238
D	10.2	45.7	66	30765

e) Abrasion evaluation

The result of the raveling tests is presented in **Fig. 10**, showing that SA and SP-A exhibit lower abrasion loss than others.

In summary, the test results show that both the stone asphalt concrete and the Superpave asphalt concretes with two different aggregate gradations are superior in all the properties to other asphalt concretes. Therefore, the aggregate gradation is recognized as the dominant factor to improve the resistance of asphalt concretes to both rutting and low temperature cracking.

(3) Influence of compaction effort

In order to evaluate the influence of different compaction efforts on the performance of asphalt concretes, three different compaction efforts were used as shown in **Table 8**. Two hammers were used and their drop heights were adjusted to obtain the specified compaction efforts: that is, the standard (A), and 1.5 (B and C) and 2 times (D) of the standard.

Representative results of Marshall tests for DGA are shown in **Figs. 11**, **12** and **13** for air void, stability and flow, respectively. The relationships between asphalt content and them are greatly influenced by the compaction effort: the air void decreases and the stability increases with an increase of compaction effort for the same asphalt content. The smaller asphalt content is enough to satisfy the specifications with higher compaction effort, in

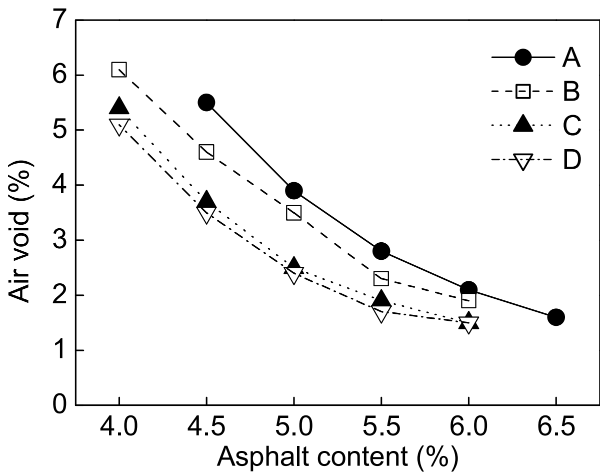

Fig. 10 Change of air void with compaction effort

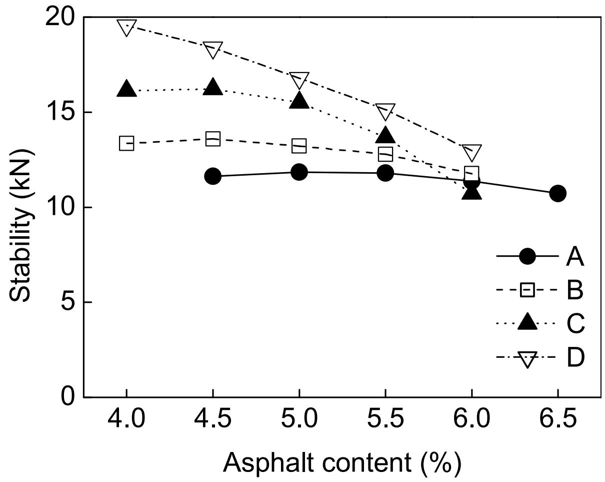

Fig. 11 Change of stability with compaction effort

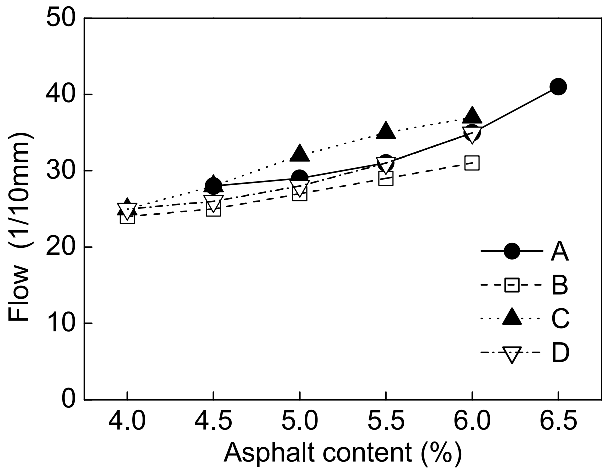

Fig. 12 Change of flow with compaction effort

comparison with the case of standard compaction effort. In contrast, the relationship between asphalt content and flow does not vary according to the compaction effort with a specific tendency.

The wheel tracking test result shows that the

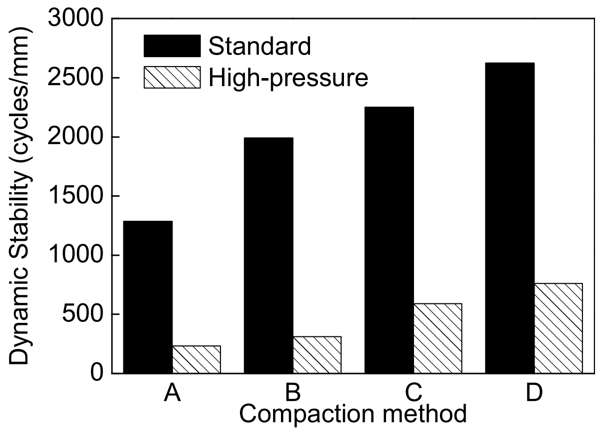

Fig. 13 Dynamic stability and compaction effort

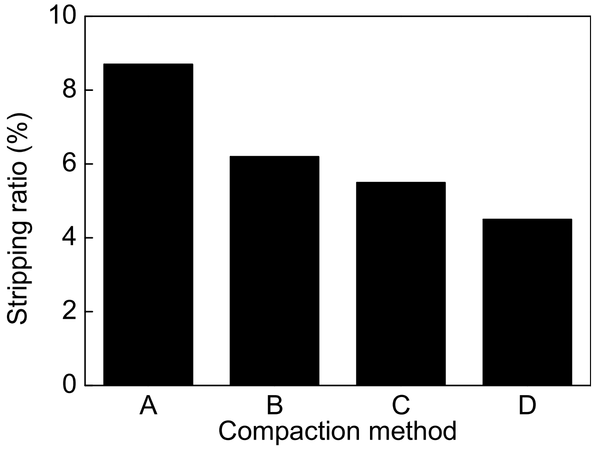

Fig. 14 Stripping ratio and compaction effort

dynamic stability increases with the compaction effort in both standard and high tire pressure cases (**Fig. 16**). In addition, the immersed wheel tracking test result shows that the stripping ratio decreases with an increase of compaction effort (**Fig. 17**). As the properties of asphalt concrete are improved with an increase of hammer mass for the same compaction effort, increasing the roller mass improves the quality.

4. SUMMARY AND CONCLUSIONS

On the basis of the laboratory test results, the following conclusions were drawn:

(1) The asphalt concrete with modified asphalt has a higher dynamic stability than that with conventional straight asphalt, and also has lower cracking susceptibility at low temperature and lower abrasion loss.

(2) The gradation of aggregates highly influences the resistance of asphalt concrete to rutting at high temperature and cracking at low temperature. Both stone asphalt concrete and

Superpave asphalt concrete show better performance for airport pavements.

(3) As the compaction effort increases, the air void ratio of asphalt concrete decreases and the stability increases. Increasing the compaction effort gives asphalt concrete better resistance to both rutting and stripping.

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