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LABORATORY EVALUATION ON DURABILITY OF GROOVING FOR AIRPORT RUNWAYS

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Grooving for airport runways requires high durability against heavy-duty loads. Through a series of experiments in the laboratory, the influences of factors such as aggregates, asphalt, and curing conditions on the durability of grooving were studied. The results showed the following: a) Both the gradation and maximum size of aggregates have little effect on improvement in durability at high temperature; b) Modified asphalt greatly improves the durability at high temperature; c) The curing period has an effect on performance improvement, whereas traffic loading has a large effect.

Key Words: *grooving, asphalt pavement, airport, wheel tracking test, raveling test*

1. BACKGROUND

The surface texture of newly constructed asphalt pavement is usually quite smooth due to the rolling process carried out to meet the requirements. There are several methods of achieving moderate surface friction, including the usage of special surface materials such as open graded friction course and chip seals, installation of grooving on the surface, and so on [1).

For airport runways, grooving is generally adopted in which transverse grooves are formed on the surface to increase the skid resistance. The grooving also decreases dynamic hydroplaning, because the water is rapidly channeled away from the tire contact area through the grooves during tire contact [2)]. Thus, the number of accidents in wet weather conditions has been decreased.

Runway grooving is becoming the norm worldwide. The standard configuration specified by the Federal Aviation Administration is presently adopted in Japan; that is, 6 mm in depth, 6 mm in width and 32 mm center-to-center spacing [3)].

However, as aircraft become larger and operation frequency is increased, the grooves suffer deterioration such as loss of groove volume at high temperature and wearing of asphalt concrete at low temperature. An early investigation [4)] has revealed that asphalt concrete does not have sufficient durability against heavy-duty loads, which is affected by several factors such as properties of aggregates and asphalt, asphalt content, and environmental conditions.

Sato, et al. investigated this problem through laboratory tests, in which both wheel tracking tests and raveling tests were used to study the stability of grooving under heavy loading conditions [4)]. The former tests are used to evaluate the resistance to closure of grooves in hot weather conditions, and the latter to evaluate the wearing of asphalt concrete in cold weather conditions. The results are summarized as follows: a) Both coarser graded aggregates and modified asphalt with rubber are highly effective to increase the stability of grooving, as shown in **Figure 1**. b) Grooving must be installed at least two months after pavement construction, as shown in **Figure 2**.

The ordinates in the figures indicate the loss of groove volume calculated by **Equation 1**.

$$LV = \frac{a_0 - a_i}{a_0} \times 100 \ (\%) \qquad (1)$$

where,

LV: loss of groove volume,
a_0: groove volume at the beginning,
a_i: groove volume at the measurement.

Airport pavements are often overlaid to support

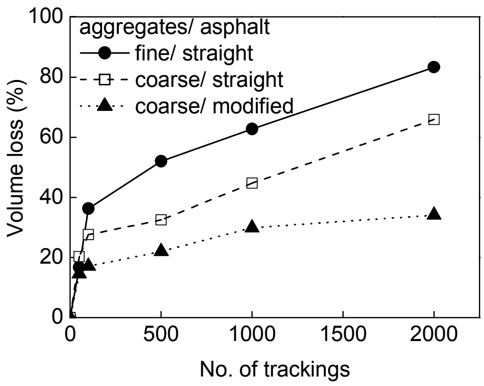

Figure 1 Material types and volume loss [4)]

Table 1 Types of asphalt concretes

No.	Asphalt*	Aggregates	
		Maximum size (mm)	Gradation
1	S 60/80	13	Usual
2	S 60/80	13	Fine
3	S 60/80	20	Usual
4	S 40/60	13	Usual
5	S 80/100	13	Usual
6	M-I	13	Usual
7	M-II	13	Usual
8	M-II	20	Usual

* S, M-I, M-II denotes straight, modified (I), modified (II), respectively.

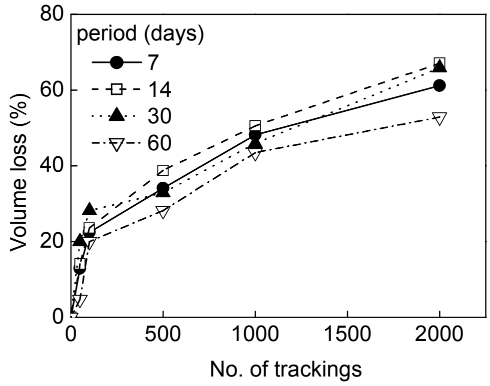

Figure 2 Curing period and volume loss [4)]

Table 2 Conditions of acceleration method

Case	Aging (hours)	Tracking (times)
a-1	12	-
a-2	24	-
a-3	36	-
a-4	72	-
b-1	12	1,400
b-2	24	2,800
b-3	36	4,200
b-4	72	8,400

the heavy-duty aircraft loads. In some instances, it is necessary to install the grooving within two months after construction, to ensure safer aircraft operation. To determine whether this is possible, a series of laboratory tests was conducted in this study. The following items were investigated.

- Aggregates

As asphalt concrete for surface course, the ranges of aggregate gradation for two maximum aggregate sizes are presently described. The influence of aggregates is studied.

- Asphalt

Though straight asphalt is usually used for asphalt concrete in airport pavements, some other asphalt is adopted to improve its durability. The influence of the properties of asphalt is examined.

- Curing period before installation

Aging and aircraft loading before installing grooving are two factors that influence the mechanical properties of asphalt concrete. Both are investigated using accelerated testing.

2. EXPERIMENTS

(1) Plan

The wheel tracking test is used to evaluate the loss of groove volume at high temperature, and the raveling test to examine the wearing of material at low temperature, in accordance with the early study [4)]. In these tests, various asphalt concretes are investigated as shown in **Table 1**. Several gradations with two maximum sizes are tested for aggregates, whereas straight asphalt with three penetration grades and modified asphalt are examined.

The grooving is installed in a specific period, i.e. two months or more, after pavement construction [5)]. Therefore, both the accelerated aging method and accelerated tire loading method are used in this study to simulate the actual situation. **Table 2** shows the conditions. Assuming that the accelerated aging for twelve hours corresponds to the actual aging for four weeks [6)], the period after construction will be equivalent to one to six months in this study. As the number of aircraft passages is assumed to be about 50 per day, 1,400 repetitions are used for four weeks.

(2) Materials

In this study, the following materials were used: coarse aggregate (S-4, S-5, S-6 and S-7), fine aggregate (screenings, fine sand and coarse sand), filler, straight asphalt (40/60, 60/80 and 80/100 penetration grade) and modified asphalt (type I and II). The properties of these asphalt are shown in **Table 3**. According to the common specifications for airport civil engineering work [3)], the compositions of

Table 3 Properties of asphalt

Items	S 40/60	S 60/80	S 80/100	M-I	M-II
Penetration (25˚C) (1/10 mm)	51	70	87	55	56
Softening point (˚C)	50	48.0	46.0	54.5	58.5
Ductility (7˚C) (cm)	-	-	-	63	-
Ductility (15˚C) (cm)	150	150	150	-	97
Viscosity (60˚C) (Pa.s)	280	200	130	580	670
Toughness (N.m)	-	-	-	14.1	19.9
Tenacity (N.m)	-	-	-	9.4	14.2
Density (g/cm^3)	1.036	1.036	1.032	1.030	1.032

Table 4 Composition and Marshall test results

Items		No. 1	2	3	4	5	6	7	8
Aggregate content (%)	S-4								
	S-5			15.0					15.0
	S-6	37.5	31.0	30.0	37.5	37.5	37.5	37.5	30.0
	S-7	22.0	24.0	13.0	22.0	22.0	22.0	22.0	13.0
	Screenings	11.5	13.0	12.0	11.5	11.5	11.5	11.5	12.0
	Coarse sand	17.0	15.0	17.0	17.0	17.0	17.0	17.0	17.0
	Fine sand	6.0	11.0	7.0	6.0	6.0	6.0	6.0	7.0
	Filler	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Asphalt content (%)		5.6	5.8	5.3	5.6	5.6	5.6	5.6	5.3
Density (g/cm^3)		2.39	2.37	2.40	2.39	2.39	2.39	2.38	2.40
Air void (%)		3.0	3.3	3.0	3.0	2.9	3.0	3.2	2.8
VFA (%)		81.1	80.0	80.2	81.3	81.7	81.1	79.9	81.6
Stability (kN)		12.2	12.2	11.9	11.9	10.8	14.6	13.3	16.4
Flow (1/100 cm)		28	28	30	33	27	36	37	34
Retained stability (%)		84.4	94.2	86.3	85.6	83.0	85.1	94.7	89.4

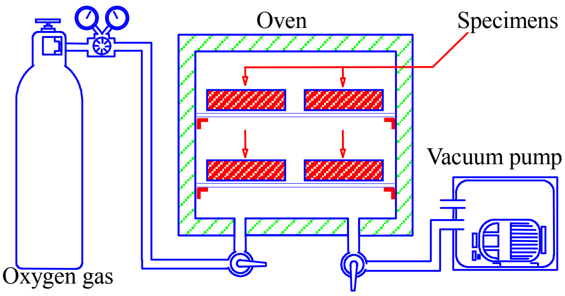

Figure 3 Accelerated aging system

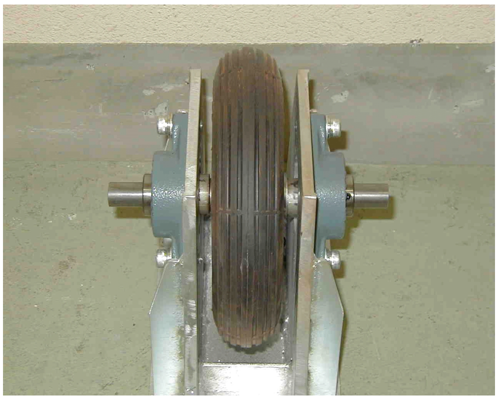

Figure 4 Appearance of tired wheel

asphalt concretes were designed by the Marshall stability test method. The results are summarized in **Table 4**. The properties of these mixtures, such as air void, stability, flow and retained stability, satisfied the specified values.

(3) Accelerated Curing Method

To evaluate the durability of grooving installed on in situ asphalt concrete, two different curing procedures are employed as mentioned above: that is, asphalt concrete specimens are aged and trafficked before groove installation.

In the accelerated aging method [6], the ambient temperature of the oven was intentionally kept high at 60°C to accelerate the aging process of asphalt concrete through oxidation reaction (**Figure 3**). The aging procedure was conducted as follows:

1) Remaining air was discharged from the oven using

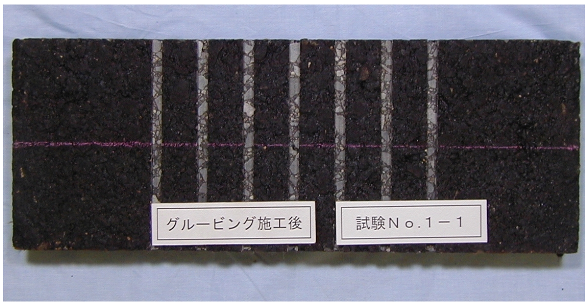

Figure 5 Grooved specimen

Table 5 Specifications of tired wheel

Item	Specification
Outer diameter (mm)	202
Width (mm)	54
Air pressure (kPa)	200
Load (N)	700
Contact pressure (kPa)	320

a vacuum pump.
2) Pressurized oxygen was let into the oven.
3) Asphalt concrete specimens were kept in the oven for six hours as a cycle.
4) Steps 1) through 3) were repeated for another cycle.

To conduct accelerated wheel loading, a weighted wheel passes over the specimen after each cycle of the accelerated aging process; that is, a tired wheel with contact pressure of 320 kPa moves 700 times back and forth with a transverse shift. **Figure 4** shows the tired wheel, and **Table 5** its specifications.

(4) Preparation

Asphalt concrete is compacted into a 300 mm wide, 300 mm long and 50 mm deep mold to a compaction degree of 98% or above in the wheel tracking test, and into a mold of 150 mm wide, 400 mm long and 50 mm deep in the raveling test.

After the specified curing procedures are applied, grooves are formed by using a cutter with diamond heads. Seven grooves with width and depth of 6 mm are cut transversely at an spacing of 32 mm on the specimen for both tests. **Figure 5** shows the grooved specimen for the raveling test.

(5) Test Method

The wheel tracking test is employed to evaluate the loss of groove volume at high temperature, whereas the raveling test is used to examine the wearing of material at low temperature, as mentioned above. Both procedures generally follow the standardized ones [7].

a) Wheel tracking test

Table 6 gives the test conditions. To evaluate the results, the loss of groove volume calculated by

Table 6 Conditions of wheel tracking test

Items	Condition
Temperature	40°C
Wheel type	Solid tire
Wheel size	200 mm deep, 50 mm wide
Load	700 N
Tracking speed	42 times/min

Table 7 Conditions of raveling test

Item	Condition
Temperature	0°C
Material of chains	Solid chains
Number of chains	10 pieces × 12
Number of wheel rotations	200 times/min
Number of specimen moves	66 cycles/min

Equation 1 is adopted. The groove volume was measured with the sand patch method in the central portion.

b) Raveling test

Table 7 gives the test conditions. For evaluating the results, the change of groove volume calculated by **Equation 2** is used.

$$CV = \frac{a_i}{a_0} \times 100 \ (\%) \tag{2}$$

where,

CV: change of groove volume,
a_0: groove volume at the beginning,
a_i: groove volume at the measurement.

3. TEST RESULTS AND DISCUSSION

The test results of the influences of the above-mentioned three factors on the grooving stability are described below.

(1) Aggregate Gradation

Asphalt concretes made using the same asphalt are compared to evaluate the influence of different aggregate gradations. **Figure 6** and **7** show the loss of groove volume at high temperature and change of groove volume at low temperature, respectively, in case of straight asphalt 60/80. While the asphalt concrete with larger aggregates shows smaller loss at the early stage of the test, there is little difference in the durability between those with various gradations at the final stage. Different from the early study, the asphalt concrete with coarse aggregate gradation does not show better performance, in comparing No. 1 and No. 2. The fine aggregate gradation rather does. However, it shows the larger volume change of

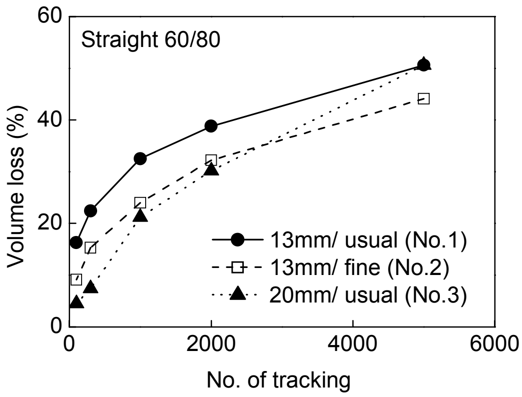

Figure 6 Aggregate gradation and volume loss

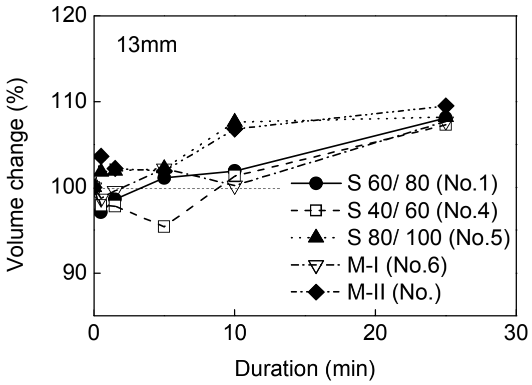

Figure 10 Asphalt types and volume change

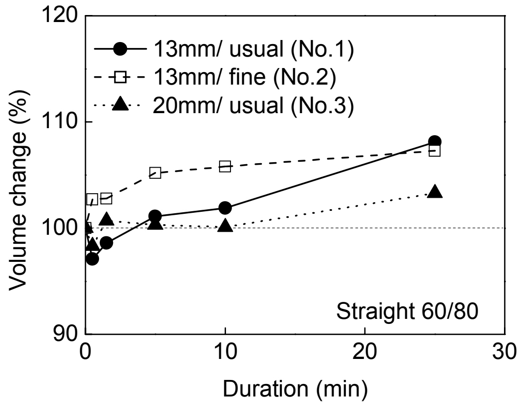

Figure 7 Aggregate gradation and volume change

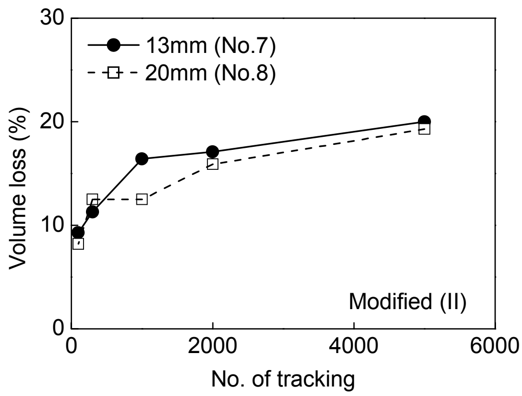

Figure 8 Aggregate size and volume loss

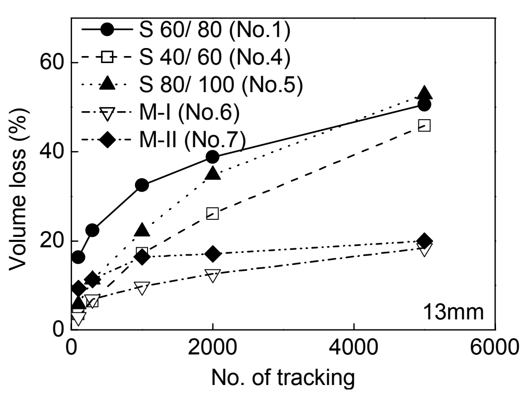

Figure 9 Asphalt type and volume loss

grooves at low temperature.

Figure 8 shows the influence of maximum aggregate size on volume loss at high temperature in the case of modified asphalt. The influence is not so large as that in the case of straight asphalt.

(2) Asphalt

Asphalt concretes made of five different types of asphalt are evaluated in the case of aggregates withmaximum size of 13 mm and the usual gradation. **Figure 9** shows the variation of volume loss with the number of trackings at high temperature. Asphalt concretes are grouped into two: those with straight asphalt and those with modified asphalt. As the latter shows better resistance to volume loss under repeated loading, the viscosity of asphalt might be a useful indicator of it, as shown in **Table 3**.

The difference in asphalt does not affect the volume change at low temperature, as shown in **Figure 10**.

(3) Curing Method

To clarify the influence of curing method before groove installation, the specimens with different accelerated curing method are tested, using conventional asphalt concretes made of straight asphalt 60/80 and well graded aggregates with maximum size of 13 mm.

Figure 11 shows the test result for specimens without traffic loading. After 72 hours of curing, the performance of specimens is improved. On the contrary, the traffic loading has an enormous effect on the resistance of asphalt concrete against volume loss at high temperature, as shown in **Figure 12**.

Table 8 shows the properties of asphalt recovered from the tested asphalt concretes. The viscosity of asphalt increases with curing period, especially in the tracked specimens.

(4) Discussion

In comparison with the results obtained through former research, the ability of modified asphalt to

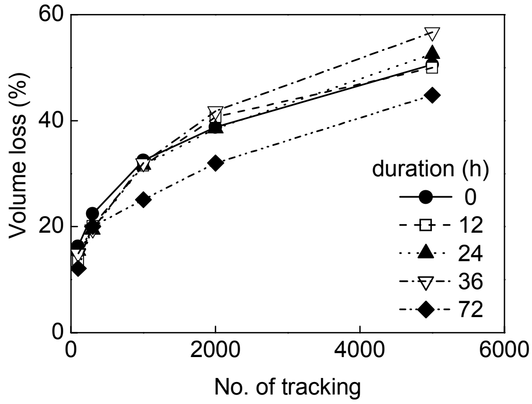

Figure 11 Volume loss without tracking

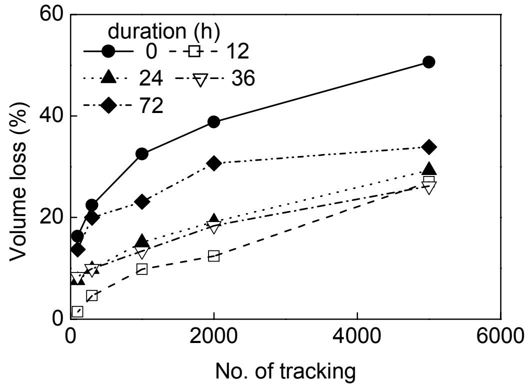

Figure 12 Volume loss with tracking

Table 8 Properties of recovered asphalt

Items	Without	a-1	a-2	a-3	a-4	b-1	b-2	b-3	b-4
Penetration at 25˚C (1/100cm)	48	49	45	45	46	44	44	41	43
Softening point (˚C)	51.5	52	52	52.5	52.5	52.6	53	53.5	53
Ductility (15˚C) (cm)	42	41	31	16	13	16	15	11	13
Viscosity (60˚C) (Pa.s)	3900	4000	4200	4600	4500	4700	5000	5900	4900
Density (g/cm^3)	1.042	1.043	1.043	1.042	1.043	1.044	1.044	1.044	1.045

retain the groove shape was confirmed in this study. In addition, both the maximum size and gradation of aggregates had some effect on improvement of performance at high temperature.

When asphalt pavements are newly constructed as runways, they should be cured for a long period before groove installation. In this test, 72 hours of curing is required to improve the stability; i.e. almost six months according to reference [6]. Therefore, modified asphalt will be used if sufficient curing time cannot be secured.

In case of overlay construction, the curing period before installation can be shortened as traffic loading has a great effect on the performance of grooves. Modified asphalt might be used when the curing period needs to be much shorter.

4. SUMMARY AND CONCLUSIONS

The results of experiments conducted in this study can be summarized as follows: a) Both the gradation and maximum size of aggregates have some effect on improvement in durability at high temperature; b) Modified asphalt greatly improves the durability at high temperature; c) The curing period has an effect on performance improvement, whereas traffic loading has a large effect.

Based on the above-mentioned results, modified asphalt will be recommended for both new construction and overlay construction, if sufficient curing period cannot be secured. Straight asphalt is, however, applied to both, especially at overlay construction when there is a longer period before groove installation. To verify the results of this study and to specify the curing periods for actual works, field studies must be conducted.

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空港滑走路のグルービングの耐久性評価

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空港滑走路のグルービングは厳しい荷重条件下においても高い耐久性が必要とされる．本研究では一連の室内試験により，骨材，アスファルト，養生方法等の要因がそれに及ぼす影響を検討した．得られた結果は次のようなものである．a) 骨材の粒度配合，最大粒径は高温時の耐久性向上にあまり寄与しない．b) 改質アスファルトは高温時の耐久性を改善する．c) グルービング設置までに養生期間を確保することは耐久性の改善に影響を及ぼすが, さらに交通荷重を繰返し与えることは著しい効果がある.