Evaluation of Properties of Low-noise Asphalt Mixture

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ABSTRACT

In Korea, low-noise pavements are emerging as a new alternative to soundproof walls, but research into the physical performance of low-noise pavements are insufficient. Low-noise pavements are structurally susceptible due to air voids over 20%. In particular, two-layered low-noise pav ements, constructed by different aggregate size are more vulnerable. In this study, physical tests were conducted on three design alternatives with different maximum aggregate size, t hickness and air-void. Laboratory testing protocol was according to the Korean Standards. Cantabro test, indirect tensile strength test, tensile strength ratio test, and wheel tracking te st, which are used primarily for performance testing of pavements materials, were conduct ed. As a result, all design alternatives met the quality standards of the Korean government. In particular, it was observed that the two-layered low-noise pavements is superior in terms of aggregate-dissipative resistance, crack resistance, moisture and raveling resistance, and r utting resistance.

Keywords: Two-layer porous asphalt, Cantabro loss, Indirect tensile strength, Dynamic stability
I-INCE Classification of Subject Number: 35

1. INTRODUCTION

In Korea, low-noise pavements are emerging as a new alternative to soundproof walls, but researc h into the physical performance of low-noise pavements is insufficient. Low-noise pavements typically ha ve more than 20% air voids, therefore they are structurally more susceptible to pavement distresses. In

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particular, a double-layered low-noise mixture with different aggregate size in each layer is more vulnerab le to these distresses.

In this study, three different low-noise pavement mix design structures with different maximum aggregate size and air voids were tested for evaluation of material properties. Laboratory tests performed were cantabro test, indirect tensile strength test, tensile strength ratio test and wheel tracking test, which are the quality standard of Korea's porous asphalt mixtures. Each pavement structure was evaluated by laboratory tests and results were compared with the Korean standard threshold values.

2. Selection of alternatives and composition of mixture

2.1 Alternative Selection

The Korea Environment Ministry's research report presents key design characteristics and potenti al noise reduction by type of pavement as shown in Table 1. Among road pavement types, it has been rep orted that porous elastic road surface, porous rubberized asphalt concrete, porous asphalt concrete (8mm a ggregate), two-layer porous asphalt concrete, very thin asphalt concrete and porous cement concrete result ed in noise reduction of more than 5 dB(A). [1]

Table 1 Major design characteristics and provisional noise reduction by pavement type (Ministry of Environment, 2016)

Pavement Type	Thickness (mm)	Maximum Aggregate Size (mm)	Air Voids (%)	Noise Reduction (dB(A)) (DAC Contrast)
Porous Elastic Road Surface (PERS)	30	Rubber : 2 Aggregate : 8	30~35	5~15
Rubberized Asphalt Concrete (RAC-0)	30	12	14~20	6
Stone Mastic Asphalt Concrete (SMA 0/16)	30~50	16	4	(-1)~(-2)
Stone Mastic Asphalt Concrete (SMA 0/11)	30~50	11	4	0
Stone Mastic Asphalt Concrete (SMA 0/8)	30~50	8	4	1
Dense Graded Asphalt Concrete (DAC 0/11, 0/8)	30	8/11	4	Reference Value
Porous Asphalt Concrete (PAC 0/16)	45	16	25	3
Porous Asphalt Concrete (PAC 0/11)	45	11	25	4
Porous Asphalt Concrete (PAC 0/8)	45	8	25	5
Two-layer Porous Asphalt Concrete (TPA)	Upper : 25 Lower : 45	Upper : 8 Lower : 16	Upper : 25 Lower : 45	4~6
Very Thin Asphalt Concrete (VTAC)	5~8	5~8	5~25	3~7
Surface Treament	3~20	3~20	-	2~(-3)
Porous Cement Concrete	80	9.5	20~25	4~8

The Korea Land and Housing Institute conducted an empirical analysis on the noise reduction effects of two-layer porous asphalt concrete pavement based on driving speed of vehicle. The results are shown in Table 2. According to their study, noise reduction for a two-layered porous asphalt concrete pavement was below 5dB(A) for vehicle speeds above 50km/h.[2]

Table 2 Comparison of absolute noise levels by driving speed of two-layer porous asphalt concrete pavement and dense graded asphalt concrete pavement (LH, 2017)

Driving Speed (km/h)	Dense Graded Asphalt Concrete Pavement (dB(A))	Two-layer Porous Asphalt Concrete Pavement (dB(A))	Deviation (dB(A))
50	91.793	86.209	-5.584
60	94.669	88.312	-6.357
70	97.351	90.174	-7.177
80	99.355	90.952	-8.403

Figure. 1 shows the noise levels for each type of pavement using the ISO 11819-2 CPX measurement method, as shown in the Swedish VTI. The noise level of dense graded asphalt concrete pavement is 99.8 dB(A) and the noise reduction effect of 5 dB(A) or more was only shown by a two-layer porous asphalt concrete pavement and ISO 10844 standard surface.[3]

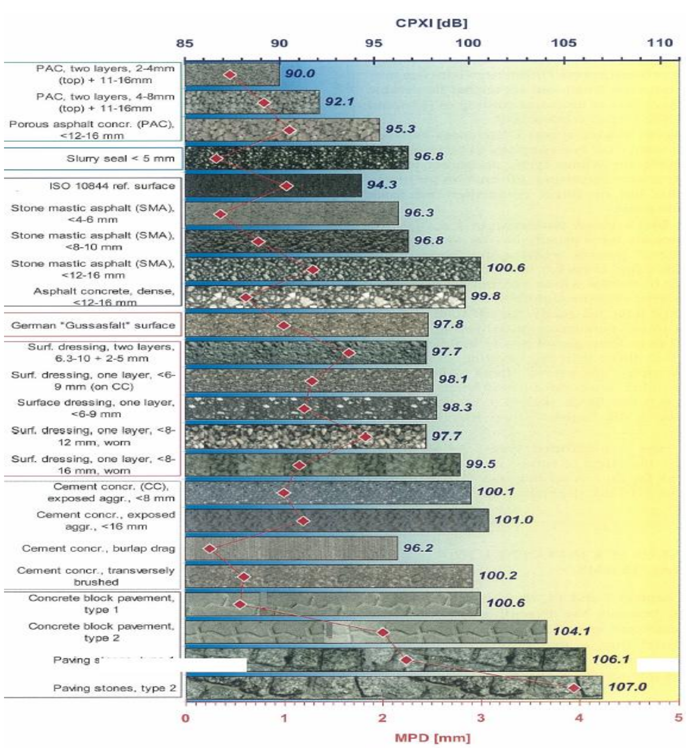


Figure 1 Comparison of noise levels by pavement type using ISO11819-2 CPX measurement method (Sandberg, 2001)

By reviewing the literature studies, three low-noise pavement alternatives were selected as shown in Table 3, taking into account the Korean domestic potential and conditions under which noise reduction effects of 5 dB(A) or more can be expected in comparison to dense graded asphalt concrete pavement.

Table 3 Selection of low-noise pavement alternatives

Classification	Pavement Type	Maximum Aggregate Size (mm)	Air Voids (%)
Alternative 1	Two-layer Porous Asphalt Concrete	8 (Upper)	20%
		13 (Lower)	20%
Alternative 2	Porous Asphalt Concrete	10	20%
Alternative 3	Porous Asphalt Concrete	10	22%

2.2 Production of Alternative Mixtures

Mix design of selected low-noise pavement compounds was carried out. A PG 82-22 asphalt bin der was used in for preparing each mix. The basic constituents of each mixture has been shown in Table 4, and the aggregate gradations are shown in Figure 2.

Table 4 Basic properties of each alternative low-noise pavement mixture

Classification		Content (%)		
		Aggregate	Filler	Asphalt Binder
Alternative 1	8mm, Air Voids 20% (Upper)	91.90	2.84	5.26
	13mm, Air Voids 20% (Lower)	92.15	2.85	5.00
Alternative 2	10mm, Air Voids 20%	92.44	2.86	4.70
Alternative 3	10mm, Air Voids 22%	92.64	2.86	4.50

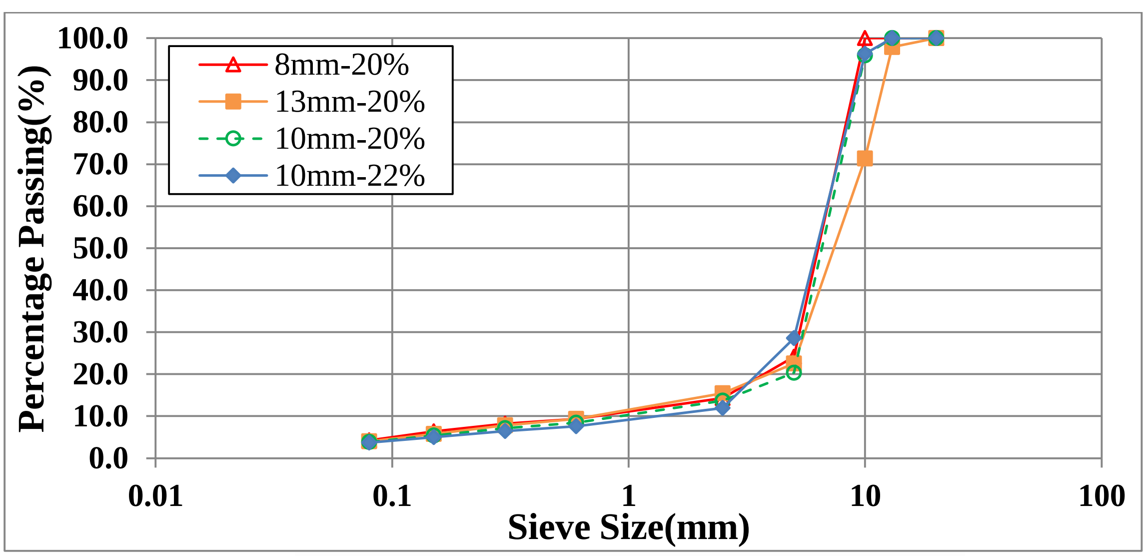


Figure 2 Aggregate Gradation chart for alternative mixture types

3. LABORATORY TESTS

In this study, the selected alternative mixtures were tested with cantabro test, indirect tensile strength test, tensile strength ratio test and wheel tracking test, which are the quality control criteria for porous mixtures in Korea.

3.1 Cantabro Test

The cantabro test evaluates the scattering resistance of aggregates in the porous asphalt mixtures. After curing the Marshall test specimen at test temperature, for more than 20 hours, the test specimen is placed in a Los Angeles test machine and 300 rotations were applied at a speed of 30 to 33 rotations per minute. The mass of the specimen was measured to calculate the mass loss rate through the following formula.[4]

$$C.L(\%) = \frac{A - B}{A} \times 100$$

where $C.L$ is the cantabro loss rate (%), A is the pre-test specimen weight, B is the post-test specimen weight

According to Korea's quality standards, it was conducted at 20℃ and -20℃. The conditions of the pre- and post-test specimens with cantabro are shown in Figure 3, and the results are shown in Table 5. All four mixtures met Korea's quality standard requirements. The cantabro loss rate at 20℃ indicated the least loss of 6.07% for the upper 8mm mixture layer of Alternative 1. The cantabro loss rate at –20℃ was the lowest loss rate of 15.99% for the lower 13mm mixture layer of Alternative 1. Since the test is an evaluation of the resistance of aggregates to scattering, the results of the lower layer are considered meaningless. Among the mixtures that are in contact with the actual vehicle tyres, the 8 mm mixture; the upper layer of Alternative 1, has the lowest loss rate of 20.58%. The 10mm mixture with an air voids of 22% has the highest mass loss rate at 20℃ and –20℃ with a value of 10.62% and 22.51%, respectively.

(a) (b) (c) (d)

Figure 3 Sample conditions after the cantabro test: (a) 8mm mixture with air voids of 20%, (b) 13mm mixture with air voids of 20%, (c) 10mm mixture with air voids of 20%, and (d) 10mm mixture with air voids of 22%

Table 5 Results of the Cantabro test by alternative low-noise pavement

Classification		Cantabro Loss Rate (%)			
		20℃		-20℃	
		Avg.	**Std.**	**Avg.**	**Std.**
Alternative 1	8mm, Air Voids 20% (Upper)	6.07	0.94	20.58	2.55
	13mm, Air Voids 20% (Loewr)	8.18	1.52	15.99	0.78
Alternative 2	10mm, Air Voids 20%	7.71	1.07	22.16	3.75
Alternative 3	10mm, Air Voids 22%	10.62	1.08	22.51	3.12

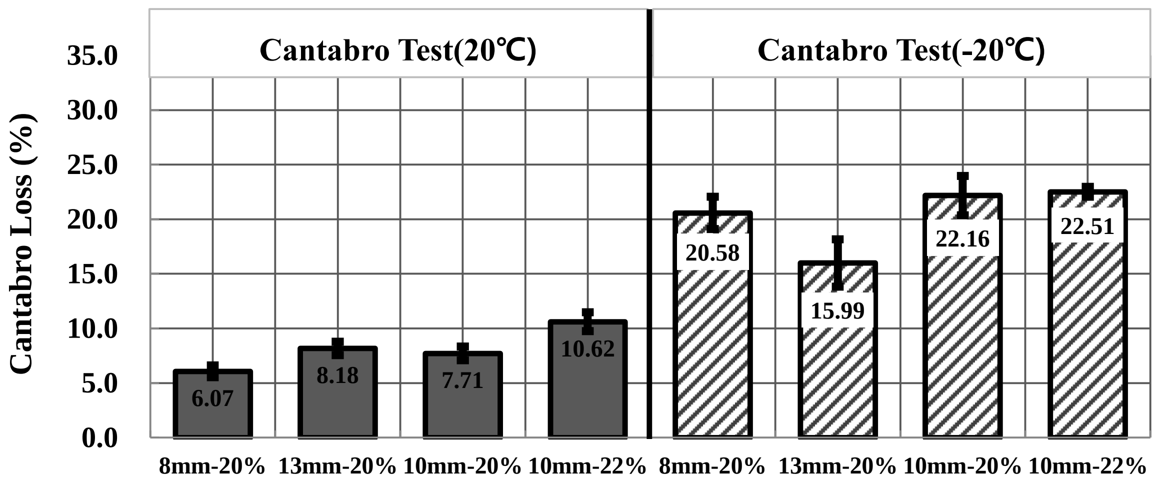


Figure 4 *Results of the Cantabro test by alternative low-noise pavement*

3.2 Indirect Tensile Strength Test and Tensile Strength Ratio Test

The indirect tensile strength test is used to evaluate the cracking resistance of asphalt mixtures. Th is test is carried out by storing the specimen at a test temperature of not less than 6 hours and loading it at a speed of 50mm/min. The indirect tensile strength is calculated from the following equation. [5]

$$S_T = \frac{2P}{\pi D h}$$

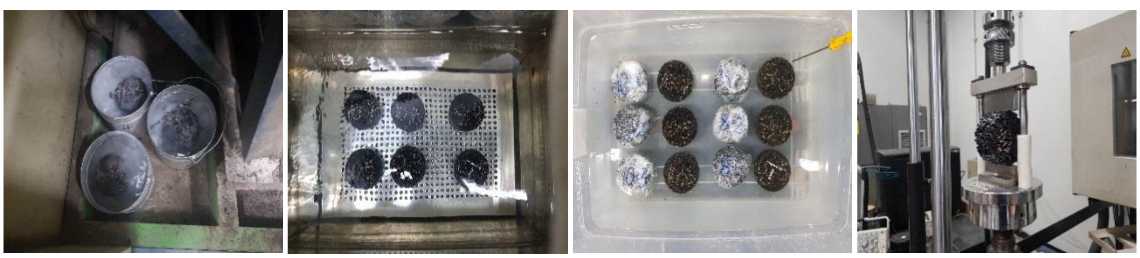
where S_T is the indirect tensile strength (MPa), P is the test specimen breaking load (N), D is the diameter (mm), and h is the height of the specimen (mm).

Tensile strength ratio test is used to assess the moisture susceptibility by measuring indirect tensile strength in the dry state of asphalt mixture and indirect tensile strength in the state after water saturation fr eezing and thawing. This test is carried out by dividing the specimens into two categories: dry and frozen-thaw. For dry specimens, store them at room temperature before testing and seal them with vinyl sheets fo r waterproofing. Before testing, put the samples in a water bath at 25℃ for two hours, and conduct an indirect tensile strength test. The frozen-thaw specimen is first saturated with water through a vacuum device and kept frozen for 16 hours at a temperature of –18℃. Afterwards, the specimen was submerged in water for 24 hours at a temperature of 60℃. Before testing, the specimen was put in water bath for 2 hours at 25℃ and an indirect tensile strength test was conducted. The tensile strength ratio was then calculated by using the indirect tensile strength values from two categories.[6]

$$TSR = \frac{S_2}{S_1}$$

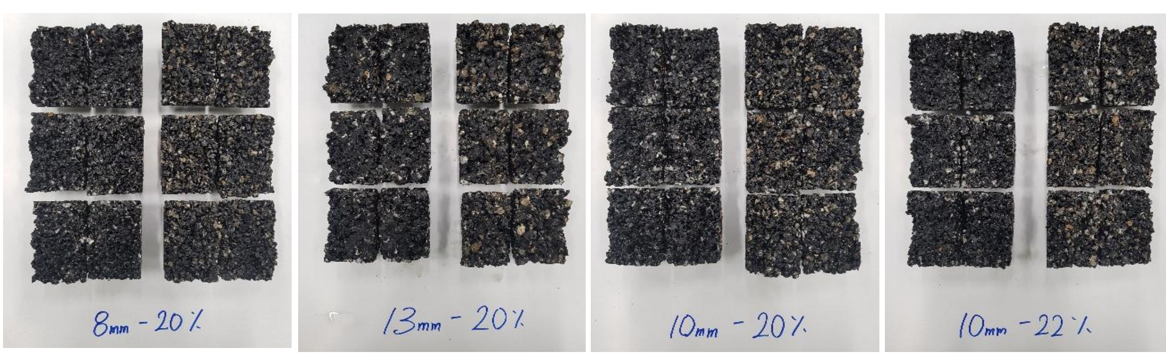
Here, TSR is the tensile strength ratio, S_1 is the average of the indirect tensile strength of the dry specimen (MPa), and S_2 is the average of the indirect tensile strength of the frozen-thaw specimen (MPa).

The indirect tensile strength and tensile strength ratio tests were conducted as shown in Figure 5 and the results as shown in Table 6 were obtained For indirect tensile strength, the 13mm mixture; the lower layer of Alternative 1, represented the highest indirect tensile strength of 0.85 MPa. For the tensile strength ratio, the 8mm mixture represented the highest tensile strength ratio of 0.77.



(a) (b) (c) (d)

Figure 5 Indirect tensile strength and tensile strength ratio test process : (a) specimen freezing (-18℃, 16 hours), (b) specimen thawing (60℃, 24 hours), (c) indirect tensile strength test temperature composition (25℃, 2 hours), (d) indirect tensile strength test



(a) (b) (c) (d)

Figure 6 Sample section after indirect tensile and tensile strength tests: (a) 8mm mixture with air voids of 20%, (b) 13mm mixture with air voids of 20%, (c) 10mm mixture with air voids of 20%,, and (d) 10mm mixture with air voids of 22%

Table 6 Test results for indirect tensile strength and tensile strength ratio by alternative low-noise pavement

Classification		Indirect Tensile Strength(MPa)				Tensile Strength Ratio
		Dry		Frozen-thaw		
		Avg.	Std.	Avg.	Std.	
Alternative 1	8mm, Air Voids 20% (Upper)	0.70	0.07	0.53	0.06	0.77
	13mm, Air Voids 20% (Lower)	0.85	0.02	0.63	0.10	0.75
Alternative 2	10mm, Air Voids 20%	0.72	0.08	0.51	0.07	0.71
Alternative 3	10mm, Air Voids 22%	0.81	0.07	0.53	0.02	0.65

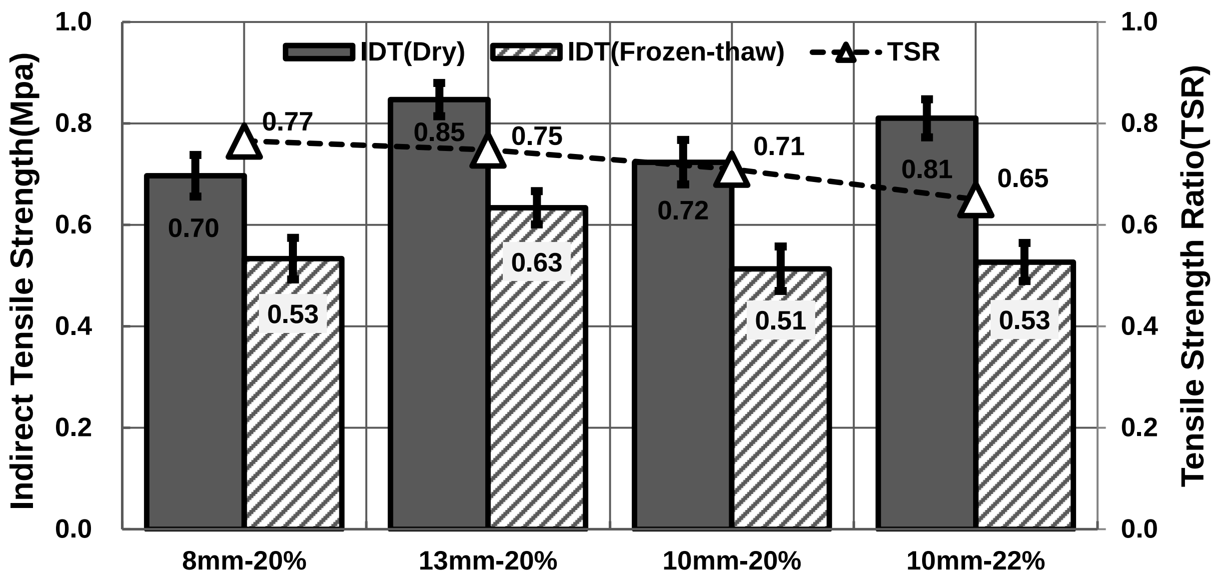


Figure 7 Test results for indirect tensile strength and tensile strength ratio by alternative low-noise pavement

3.3 Wheel Tracking Test

Wheel tracking test is carried out to evaluate the plastic deformation resistance of asphalt mixture s. This test measures the depth of depression over time by applying a wheel load of 686 N at 42/min at the center of the specimen 30cm×30cm×5cm at a temperature of 60℃. The test measures the deformation fo r 45 minutes, 60 minutes, and 15 minutes, when the strain rate is constant, and calculates the deformation velocity through the following equation.

$$RD = \frac{d_{60} - d_{45}}{15}$$

where RD is deformation velocity (mm/min), d_{60} is deformation(mm) at 60 minutes, and d_{45} is the deformation(mm) at 45 minutes.

The following equation also calculates the dynamic stability, the number of wheel passes required to deform 1mm from the surface of the test specimen [7]

$$DS = 42 \times \frac{t_2 - t_1}{d_2 - d_1}$$

Here, DS is the dynamic stability (passes/min), d_1 is the deformation(mm) at t_1(typically 45 minutes), and d_2 is the deformation(mm) at t_2(typically 60 minutes).

For wheel tracking testing, three specimens are made according to alternatives as shown in Figure 8. Alternative 1 was divided into 3cm of the 13mm mixture in the lower layer and 2cm of the 8mm mixture in the upper layer, while Alternative 2 and 3 were placed in 5cm single layer. The specimen was compacted with 30 oscillations using a wheel tracking condenser as shown in Figure 9 (b). After making the test specimen, the wheel tracking test was conducted as shown in Figure 9 (d) at a temperature of 60 ℃.

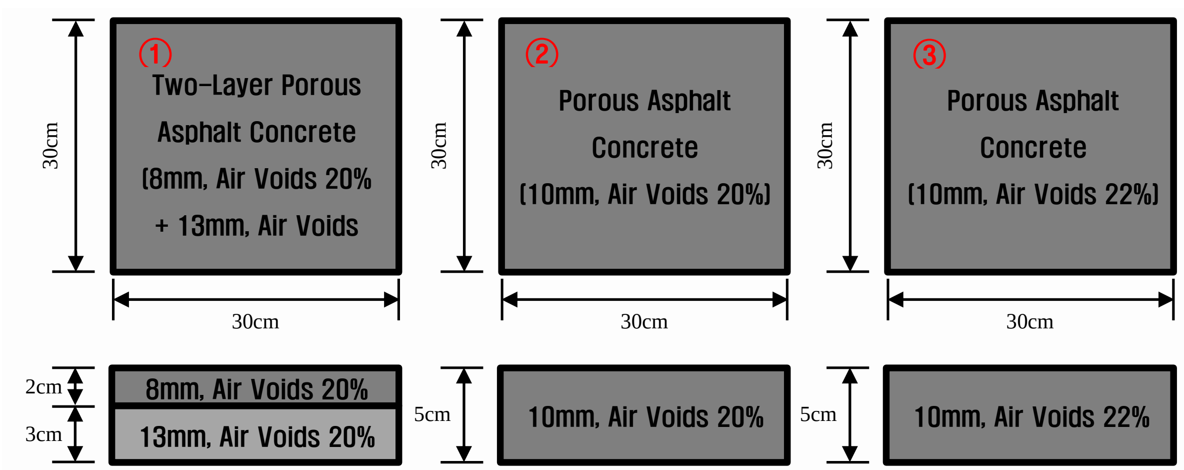


Figure 8 Wheel tracking specimen planning by alternative low-noise pavement

(a) (b) (c) (d)

Figure 9 Wheel tracking testing process: (a) Mixture in moulding, (b) Wheel tracking compounds conducted, (c) Wheel tracking specimens completed, (d) Wheel tracking test

The wheel tracking test results are shown in Table 7. The two-layer low noise mixture showed the highest dynamic stability of 15,750 passes/min. For the deformation velocity, the two-layer low-noise pavement and the 10mm one-layer low-noise pavement with air voids of 20 % were 0.003 mm/min, indicating the lowest deformation velocity.

Table 7 Results of wheel tracking tests by alternative low-noise pavement

Classification		d_{45} (mm)	d_{60} (mm)	Deformation Velocity (mm/min)	Dynamic Stability (passes/mm)
Alternative 1	8, 13mm, Air Voids 20% (Two-layer)	1.29	1.33	0.003	15,750
Alternative 2	10mm, Air Voids 20%	1.41	1.46	0.003	12,600
Alternative 3	10mm, Air Voids 22%	1.64	1.74	0.007	6,300

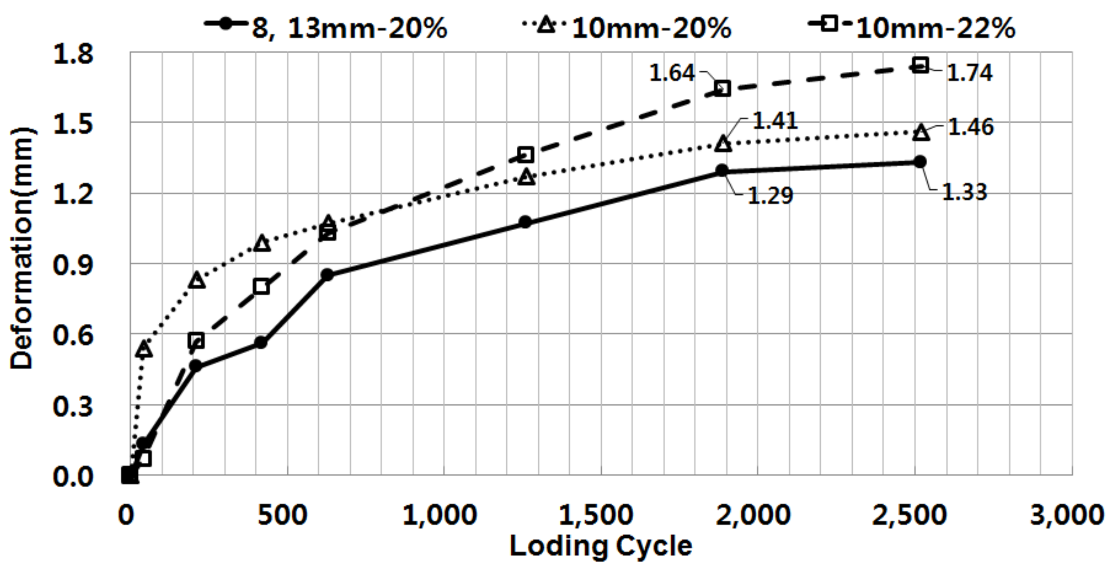


Fig. 10 Deformation according to load by low-noise pavement alternative

4. CONCLUSIONS

Based on the literature review, we selected three low-noise pavement alternatives that can be produced in Korea and conducted laboratory tests. The low noise packaging alternatives were chosen as two-layer porous asphalt concrete pavement with a mixture of 8mm upper layer with air voids of 20% and 13mm lower layer with air voids of 20%, porous asphalt concrete pavement with a mixture of 10mm with air voids of 20%, and porous asphalt concrete pavement with a mixture of 10mm with air voids of 22%.

Laboratory tests were conducted with cantabro test, indirect tensile strength test, tensile strength ratio test and wheel tracking test, which are the quality control standards of Korea, and the following results were obtained.

1) The cantabro test showed that the 8mm mixture with a 20% air voids has the highest aggregate sc

attering resistance at 20℃ and 13mm mixture with a 20% air voids has the highest aggregate scat tering resistance at -20℃.

2) Indirect tensile strength tests showed that a 13mm mixture with air voids of 20% has the highest c rack resistance with an indirect tensile strength of 0.85MPa.
3) According to the tensile strength ratio test, the 8mm mixture with air voids of 20% has the highes t moisture resistance with a tensile strength ratio of 0.77.
4) Wheel tracking test results showed that the two-layer low-noise pavement with 20% air voids rep resents the highest plastic deformation resistance with a dynamic stability of 15,750 passes/min.
5) A comprehensive evaluation of laboratory tests of three low-noise pavement alternatives revealed the best performance by two-layer low-noise pavement.
6) This result is a comparative evaluation between alternatives through laboratory testing. However, it is necessary to prepare check these mixture alternatives for low-noise pavement application ba sed on the actual traffic loads using accelerated pavement test and field test.

5. ACKNOWLEDGEMENTS

This research was supported by the Seoul R&BD Program (PS160001)

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