MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Comparison of Noise Reduction Performance Evaluation Methods for Low-Noise Pavement in Korea- Part II

Kim, Byungchae[1]
Chae, Gyeongwon[2]
Kim, Hyunjin[3]
Poinix Inc.
Gwanggyoro 105, Suwon-si, Suite 520
Gyeonggi-do, Korea, Republic of, 16229

ABSTRACT

In order to compare the noise reduction performance on the roadside and the measuring point, this study was evaluated by comparing the Leq measurement and the CPX measurement on the highway where RSBS DLPAC is constructed. The Leq measurement was made before and after construction by simultaneous measurements at the roadside and at the receiving point. The CPX measurement was made simultaneously for RSBS DLPAC and SMA pavement using a sealed trailer. As a result, the Leq difference between before and after construction was an average of 10.4dB(A) at the roadside and at the measuring point. In the case of CPX measurement, the noise reduction performance of the RSBS DLPAC showed 7.8dB(A) for the side microphone and 10.7dB(A) for the rear microphone position compared to the SMA pavement. Through this study, it was confirmed that the difference in noise level was identical for the Leq measurement regardless of the distance between the roadside and the receiving point without interfering noise and obstacles. For the CPX measurement, it was also confirmed once again that the difference in noise level at the rear microphone position is more like the difference in Leq measurement than the difference of the side microphone position.

Keywords: Tire/Pavement Noise, CPX, DLPAC
I-INCE Classification of Subject Number: 72

1. INTRODUCTION

It was introduced at the Internoise 2018 that both roadside equivalent noise level measurement (the Leq measurement) and CPX (ISO 11819-2, Close-Proximity Method) are being used in Korea to measure the noise reduction performance of low noise pavement. Also, it compared the noise level from the side position of the tire and from the rear position which had a similar result with the roadside Leq measurement.

---

1 bcpoinix@hanmail.net
2 poinixin@nate.com
3 hjkim.poinix@gmail.com

This study presents in-depth result of the noise level before and after the construction of RSBS DLPAC (Radial type SBS modified Double Layer Porous Asphalt Concrete) measured by the roadside equivalent noise level measurement, receiving point equivalent noise level measurement and the CPX. In this paper, the contents and results of equivalent noise level measurement has been introduced from the final paper of The Korean Society for Noise and Vibration Engineering *"Measuring and Analysing the Noise of Double Layer Low Noise Pavement, Final Report"*, (2018).

2. TEST LOCATION and MEASUREMENT METHODS

2.1 Test Location

The Seoul Ring Expressway has 8 lane and ADT of 200,000 vehicles (including 16% of heavy vehicle traffic) and the residents of newly developed town nearby the expressway has been suffering from the traffic noise. Therefore, as one of countermeasure against the noise, RSBS DLPAC is planned to be applied for 2.8km long and 700m was test paved in 2018. The previous road surface condition was fine without any cracks and defects and was paved with SMA and Concrete for each direction. The main noise source was the SMA pavement which was close to the noise measuring points. Fig.01 shows the RSBS DLPAC test location and Fig.02 shows the before and after pictures of the measuring points.

Fig.01 The 700m test location of RSBS DLPAC on the Seoul Ring Expressway

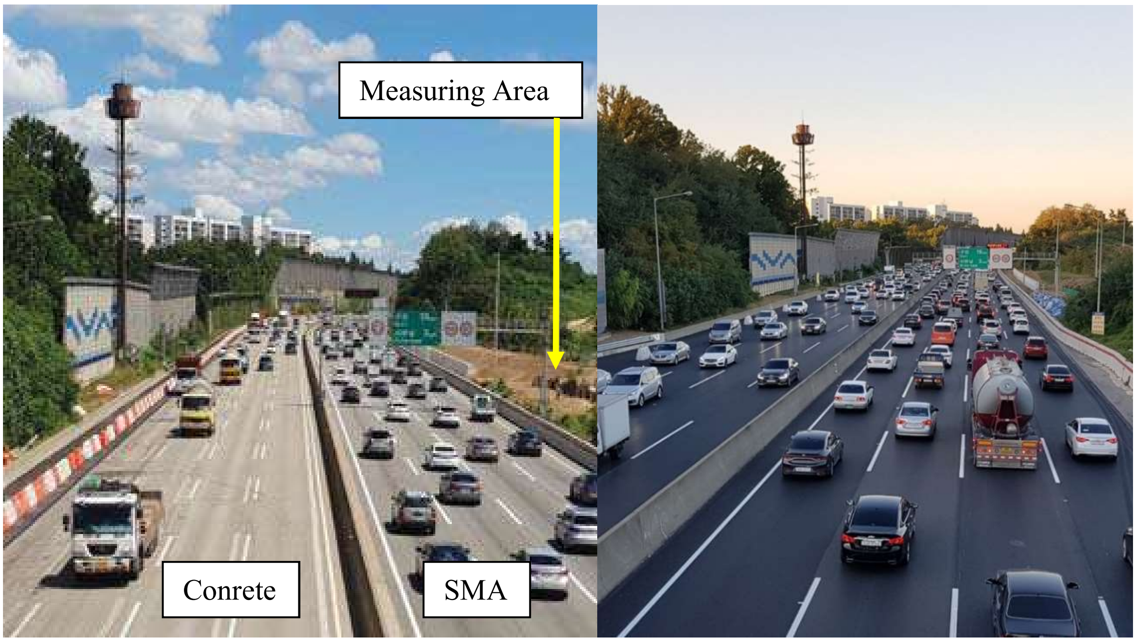


Fig.02 Before (Left) and After (Right) applying RSBS DLPAC on the test location

2.2 Measurement Methods

In this paper, only the equivalent noise measurement method with institutional standards (Measurement Method of Exterior Noise Emitted by Road Vehicle for Management Standards, ES 03305. 1b, the Ministry of Environment) and the CPX(ISO11819-2) measurement are adopted and those results are compared.

The results of the equivalent noise level measurement are cited from *"DLPAC Noise Measurement and Analysis Final Report"* (The Korean Society for Noise and Vibration Engineering, Dec. 17, 2018). The CPX measurement was carried out after applying RSBS DLPAC with closed type CPX trailer.

2.2.1 Equivalent Noise Level Measurement

In Korean standards, the equivalent noise level is measured for more than 5 minutes or more than 10 minutes, and the noise level quoted in this paper is 1-hour equivalent noise level.

In Korea, the measurement of the equivalent noise level has been carried out at the same time on the roadside of both DAC and DLPAC. However, the reliability of the roadside measurement was low due to the argument that there is recognizable difference of noise reduction effect between the roadside and the receiving points (current/future residential area which could be close and/or far from the noise source).

Therefore, in this cited report, a noise meter was installed to compare noise reduction effects on the roadside and receiving point, and it was measured for two weeks before and after RSBS DLPAC construction.

The roadside point was away from the centre line of the last lane on the road by 7.5m, and the receiving point was separated by 15m, 30m, and 50m. The noise meter was installed at 1.5m and 7.5m height at the roadside point and at 3m, 7.5m and 15m height at the receiving point reducing the influence of other noise.

Fig.03 shows the location of equivalent noise level measurement and Fig.04 and Fig.05 show the distance and the height of noise meters installed in table and picture.

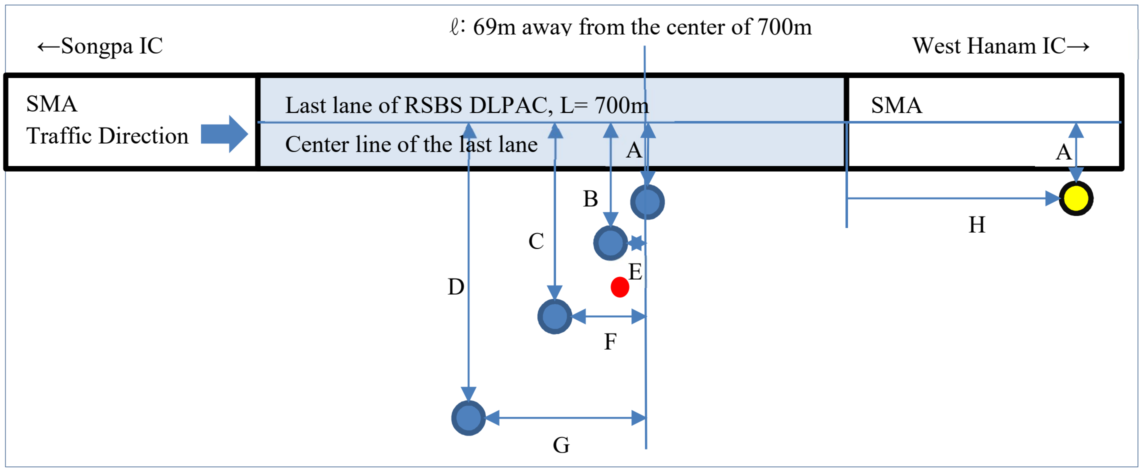
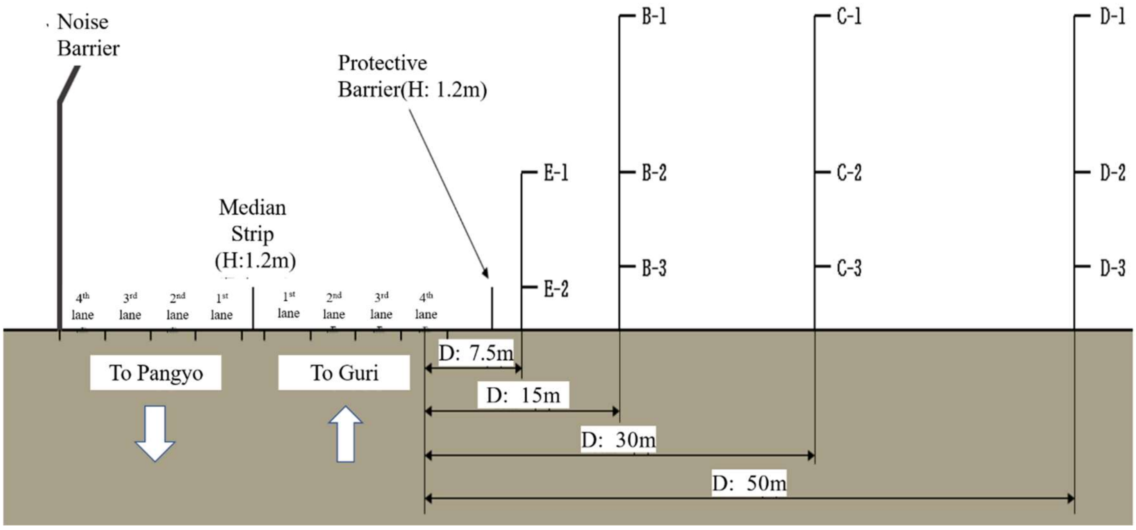


Fig.03 Blue dots: The location of equivalent noise level measurement

- A: 7.5m away from the centre line of the last lane
- B: 15m away from the centre line of the last lane
- C: 30m away from the centre line of the last lane
- D: 50m away from the centre line of the last lane
- E: 2.7m away from the centre of line ℓ
- F: 8m away from the centre of line ℓ
- G: 15m away from the centre of line ℓ
- H: 350m away from the end of RSBS DLPAC

- Red dot: Climate Meter Pole is installed separately to measure the climate at a height of 1.5 meters and 15 meters to check the refraction of sound as temperature changes. Simultaneous measurement of wind speed, wind direction and relative humidity.



Installation	Distance(m)	Height(m)	Installation	Distance(m)	Height(m)
A-1(SMA)	7.5	7.5	C-1	30	15
A-2(SMA)	7.5	1.5	C-2	30	7.5
E-1	7.5	7.5	C-3	30	3.0
E-2	7.5	1.5	D-1	50	15
B-1	15	15	D-2	50	7.5
B-2	15	7.5	D-3	50	3.0
B-3	15	3.0			

Fig.04 the distance and the height of noise meters installed

Fig.05 Picture of noise meters installation

2.2.2 CPX Measurement

CPX was measured according to ISO11819-2 after applying RSBS DLPAC. During the time of measuring the equivalent noise level, both RSBS DLPAC and the

SMA pavement which connected to the RSBS DLPAC were measured. The CPX trailer mounted SRTT tires and total 6 microphones; 2 microphones on the side position and 1 microphone on the rear position for each tire. In case of the rear position of the tire, it is prescribed as an option in the ISO standard, but in Korea, the rear side of the tire has been measured since before the 2009 so this study maintained the ordinary customs. The measurement speed were 80km/h and 100km/h. Fig.06 illustrates the CPX measurement trailer appearance and microphone installation status.

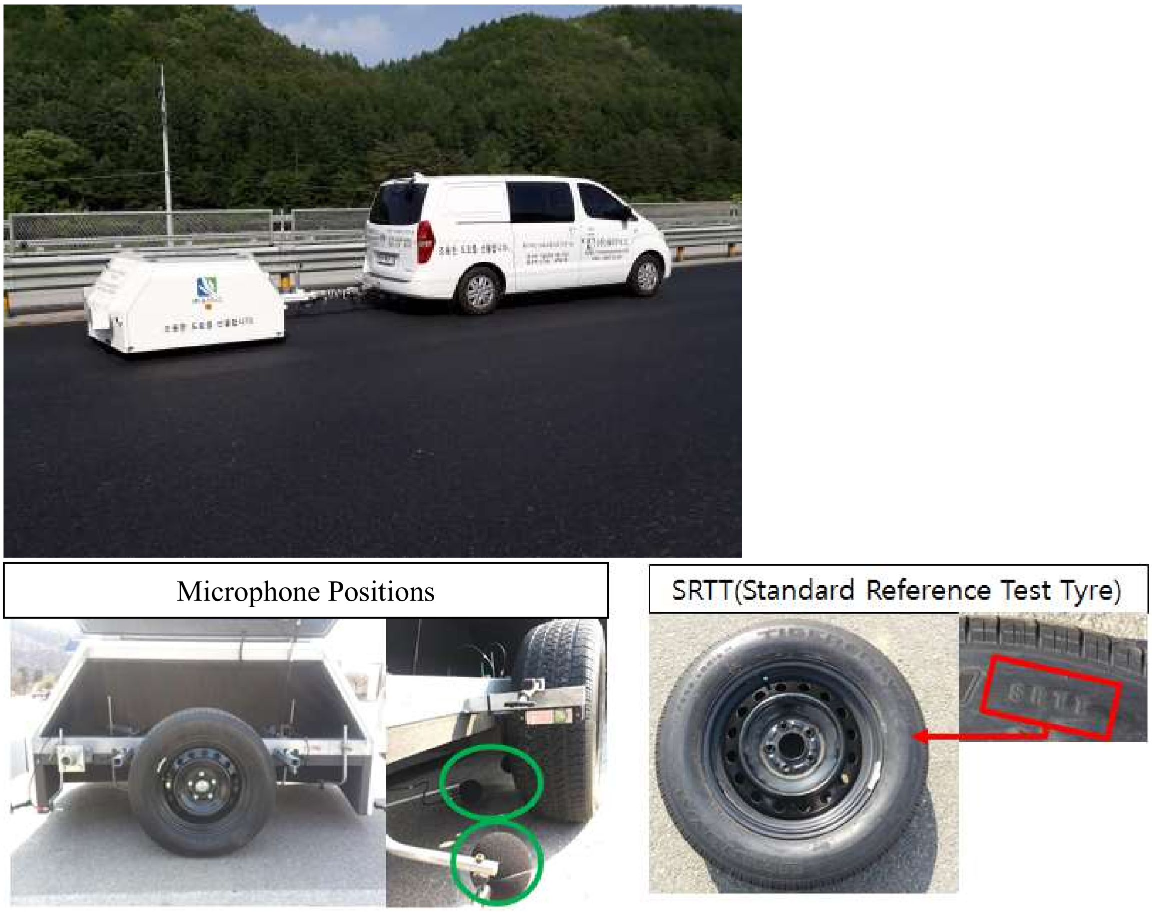


Fig.06 Picture of CPX Trailer, Microphones and SRTT

3. MEASUREMENT RESULTS

3.1 Equivalent Noise Level

A total of 13 noise meters were installed at two roadside points (at 7.5m distance) and three receiving points (at 15m, 30m, and 50m distances) so that the difference in noise level measured at the roadside and the noise level measured at a receiving point spaced a certain distance from the road could be compared. The noise meters were installed and measured 24 hours continuously for 2 weeks before and after RSBS DLPAC construction

Two time zones were selected, from 22:00 to 23:00 at night and from 5:30 to 6:30 in the morning and analysed by three analysis methods. The analysis methods are as follows: First, all valid data of two time zone of each measurement period before and after construction were compared by statistical method. Second, two different day of similar condition (traffic volume, heavy vehicle ratio, driving speed) were selected and compared before and after the construction. Third, two different day with similar noise levels from SMA pavement before and after construction were selected and compared.

3.1.1 Statistical Comparison

As a result of comparing the average valid data for all 2 weeks before and after RSBS DLPAC with the one-hour equivalent noise level during the two time zones, the noise difference was 9.9 ~ 10.9dB(A) on the road side (E-1) and 9.7~ 11.5dB(A) on the receiving points (B-1 to D-3). Table 01 and 02 present the noise level of one-hour equivalent noise level measurement and the difference between before and after the construction.

	E-1	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	Avg.
Before	83.8	82.5	82.0	79.7	80.2	79.0	75.0	77.1	75.3	72.9	-
After	73.9	72.3	71.5	70.0	70.1	68.6	65.4	67.2	64.9	62.6	-
-Δ	**9.9**	**10.2**	**10.5**	**9.7**	**10.1**	**10.4**	**9.6**	**9.9**	**10.4**	**10.3**	**10.1**

Table 01. The noise level and the difference before and after RSBS DLPAC application (05:30-06:30am) [in dB(A)]

	E-1	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	Avg.
Before	82.0	80.7	80.2	77.7	78.3	77.1	72.8	75.2	73.3	79.2	-
After	71.1	70.1	68.7	67.6	67.7	65.9	62.6	65.2	62.4	60.0	-
-Δ	**10.9**	**10.6**	**11.5**	**10.1**	**10.6**	**11.2**	**10.2**	**10.0**	**10.9**	**10.2**	**10.6**

Table 02. The noise level and the difference before and after RSBS DLPAC application (22:00-23:00pm) [in dB(A)]

3.1.2 Comparison of two different day of similar condition (traffic volume, heavy vehicle ratio, driving speed)

The equivalent noise measurement method has difficulty in evaluating the accurate noise reduction effect because the energy amount of sound changes when the traffic conditions traveling on two roads to be compared are changed.

As a result, it was found that 9.6 ~ 10.2dB(A) was different on the road side (E-1) and from 9.4 to 11.3dB(A) at the receiving points (B-1 to D-3) compared with the days when the traffic conditions (traffic volume, heavy vehicle ratio, driving speed) were similar.

	E-1	B-2	C-1	C-2	C-3	D-1	D-2	D-3	Avg.
Before (08/11)	84.0	82.2	80.3	79.1	75.4	76.9	75.4	73.0	-
After (10/23)	74.4	71.6	70.4	68.8	65.6	67.5	65.2	63.2	-
-Δ	**9.6**	**10.6**	**9.9**	**10.3**	**9.8**	**9.4**	**10.2**	**9.8**	**10.0**

Table 03. The noise level and the difference before and after RSBS DLPAC application on the similar condition (05:30-06:30am) [in dB(A)]

	E-1	B-2	C-1	C-2	C-3	D-1	D-2	D-3	Avg.
Before (08/11)	82.5	80.9	77.8	77.8	73.9	75.4	74.0	71.3	
After (10/27)	72.3	69.6	68.4	67.2	64.2	65.6	63.6	61.4	
-Δ	**10.2**	**11.3**	**9.4**	**10.6**	**9.7**	**9.8**	**10.4**	**9.9**	**10.2**

Table 04. The noise level and the difference before and after RSBS DLPAC application on the similar condition (05:00-05:30am) [in dB(A)]

3.1.3 Comparison Based on the Reference Point Noise Level

Equivalent noise measurements were conducted during the same period using the reference pavement at 350 m away from the RSBS DLPAC boundary as a yellow dot in Fig.03. This reference point should be measured before and after the construction of the RSBS DLPAC to check the noise level on the existing road, and the noise reduction effect of the RSBS DLPAC should be corrected as the noise level on the reference point increases or decreases.

The noise level at the reference point was found to be higher after construction than before construction. Among all the data, the day with the similar noise levels, before and after construction were selected at the reference point, 08/06 and 10/18 for the night noise level and 08/03 and 10/26 for the morning noise level, and the noise levels of each same day before and after construction were compared on the RSBS DLPAC side. The noise levels were 10.0 ~ 10.5dB(A) on the roadside (E-1) and showed 8.7 ~ 10.7dB(A) at the receiving points (B-1~ D-3). Table 05 and Table 06 present the noise level based on the reference point noise level.

	E-1	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	Avg.
Before (08/06)	81.8	80.3	80.3	76.5	78.0	77.1	72.6	75.1	73.1	70.1	
After (10/18)	71.3	70.0	69.4	67.8	67.9	66.4	63.3	65.4	62.6	60.4	
-Δ	**10.6**	**10.3**	**10.9**	**8.7**	**10.1**	**10.7**	**9.3**	**9.7**	**10.5**	**9.7**	**10.0**

Table 05. The noise level and the difference before and after RSBS DLPAC application based on the reference point noise level (22:00-23:00pm) [in dB(A)]

	E-1	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	Avg.
Before (08/03)	83.6	82.3	81.7	79.4	80.1	78.7	74.6	77.2	75.0	X	-
After (10/26)	73.6	X	71.0	X	69.7	68.1	65.1	67.5	64.6	62.4	-
-Δ	**10.0**	**-**	**10.7**	**-**	**10.4**	**10.6**	**9.5**	**9.7**	**10.4**	**-**	**10.2**

Table 06. The noise level and the difference before and after RSBS DLPAC application based on the reference point noise level (05:30-06:30am) [in dB(A)]

3.1.4 Frequency Analysis

As a result of analysis of frequency band (1/3 octave) for measured noise before and after construction of RSBS DLPAC, the reduction effect at 630Hz or higher, especially at 1000Hz frequency band, was clearly large. Fig. 07 and Table 07 show the variation graph by frequency band before and after construction of RSBS DLPAC and the noise level difference by frequency band.

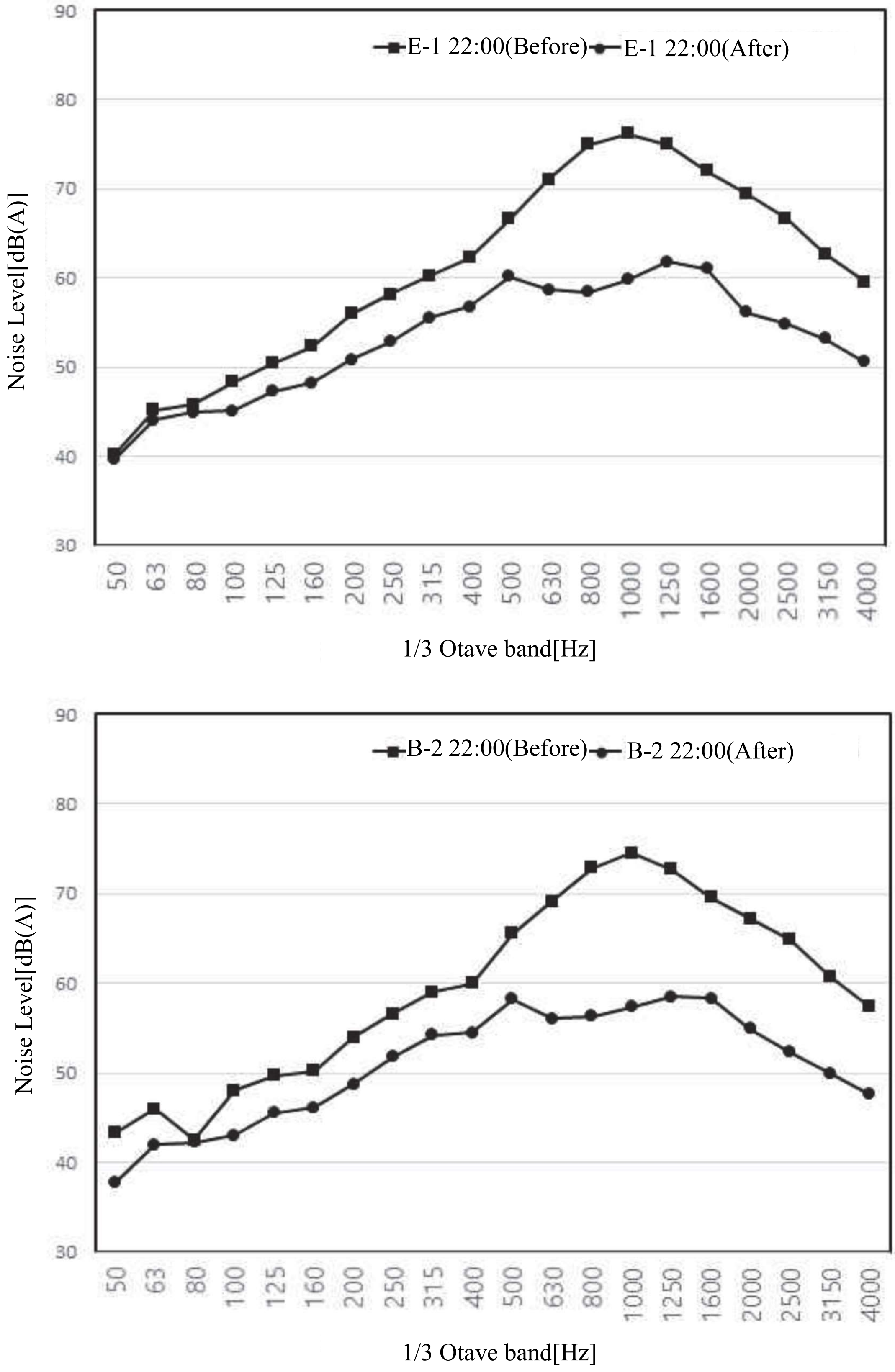


Fig 07. the variation graph by frequency band before and after construction of RSBS DLPAC at E-1(road side) and B-2(receiving point)

Frequency Band(Hz)	50	63	80	100	125	160	200	250	315	400
Diff. in Sound Pressure(dB)	**0.5**	**1.1**	**0.9**	**3.2**	**3.2**	**4.1**	**5.1**	**5.3**	**4.7**	**5.5**
Frequency Band(Hz)	500	630	800	1000	1250	1600	2000	2500	3150	4000
Diff in Sound Pressure(dB)	**6.4**	**12.3**	**16.6**	**16.4**	**13.2**	**11.0**	**13.3**	**11.8**	**9.4**	**9.0**

Frequency Band(Hz)	50	63	80	100	125	160	200	250	315	400
Diff in Sound Pressure(dB)	**-0.7**	**1.2**	**0.9**	**0.5**	**1.6**	**2.6**	**3.5**	**2.0**	**2.6**	**3.5**
Frequency Band(Hz)	500	630	800	1000	1250	1600	2000	2500	3150	4000
Diff in Sound Pressure(dB)	**4.6**	**10.2**	**14.0**	**12.6**	**9.4**	**7.9**	**10.7**	**9.1**	**7.1**	**6.5**

Table 07. the noise level difference by frequency band at E-1 at 22:00-23:00(above) and at 05:30-06:30(below)

3.2 CPX Measurement Results

RSBS DLPAC and SMA pavement were measured in continuous at 80km/h and 100km/h. The microphone was installed at the side and the rear side of the tire for comparison with the equivalent noise level measurement. In addition, GPS running speed and ambient temperature were measured in real time and corrected according to ISO 11819-2 standard.

3.2.1 CPX Noise Level Difference

The CPX noise difference showed 7.8dB (A) at the side position of the tire and 10.7dB (A) at the rear position. Table 08 shows the noise level and the difference by speed and Fig. 08, the change in noise level for each microphone position by velocity is shown in a graph.

[In dB(A)]	80km/h			100km/h			Avg. Noise reduction
	RSBS DLPAC	SMA	Noise reduction	RSBS DLPAC	SMA	Noise reduction	
Side microphone	93.0	100.3	7.3	95.2	103.4	8.2	7.8
Rear microphone	88.9	99.3	10.4	91.8	102.8	11.0	10.7

Table 08. the noise level by speed and by the location of the microphone

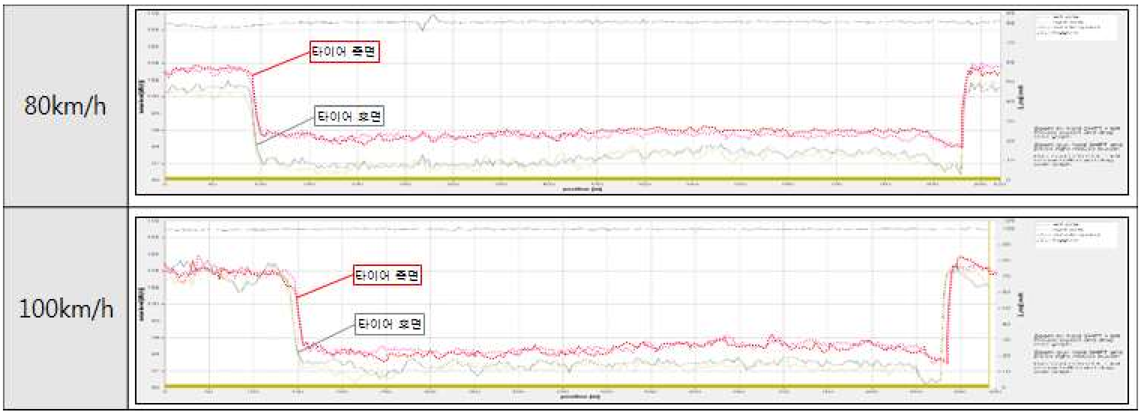


Fig.08. the change in noise level for each microphone position by speed (Line in Red: Side position, Line in Black: Rear position)

3.2.2 Frequency Analysis of CPX Noise Level

The RSBS DLPAC compared to SMA pavement showed low noise level in all frequencies above 630Hz. Especially the difference is 10.8dB (A) at the side position of the tire in 1000Hz band, and at the rear position, the noise level difference was the largest as 16.4dB (A). Fig.09 shows the difference by frequency for side and rear position of the microphone.

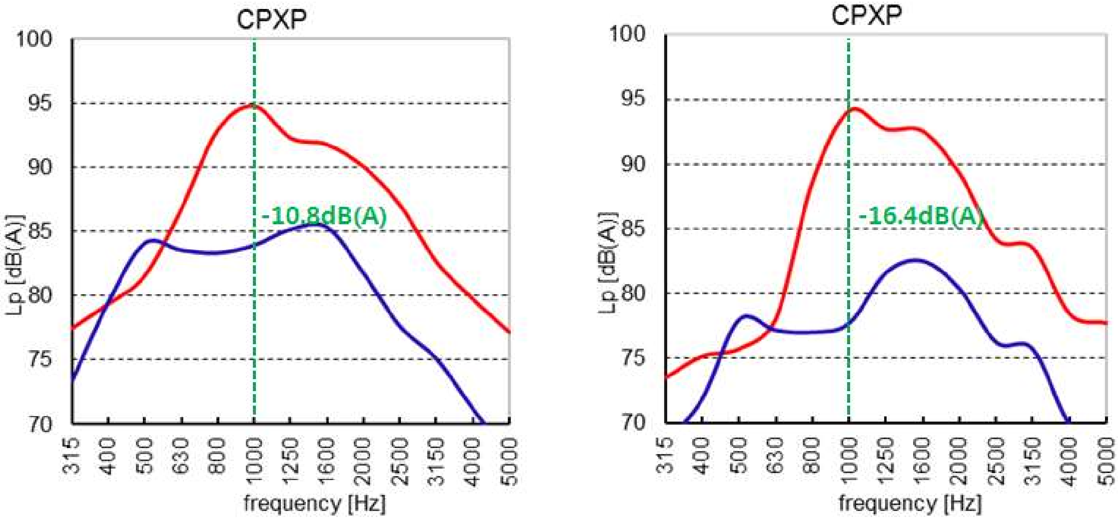


Fig.09 Graph of change in frequency band (1/3 octave) by microphone position at speed of 80km/h (Side position: left, Rear Position: Right)

4. SUMMARY of the STUDY

The equivalent noise level of the RSBS DLPAC was measured simultaneously on both roadside and at the receiving point at the maximum distance of 50m of the RSBS DLPAC before and after the construction for 2 weeks. CPX was measured at 80km/h and 100km/h after the construction on both RSBS DLPAC and SMA pavement in continuous.

As a result, the equivalent noise level difference of RSBS DLPAC was more than 10dB(A), and the noise difference before and after RSBS DLPAC construction was shown in Table 09 ~ Table 11 by the analysing methods.

In addition, the CPX noise difference was 10.7dB(A) at the rear side of the tire and 7.8 dB(A) at the side position. Table 12 shows the noise level and noise level difference at each speed. Furthermore, similar changes in frequency band of noise before and after construction were observed for both measurement methods.

Time zone \ Noise Meter	E-1	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	AVG.
22:00~23:00	10.9	10.6	11.5	10.1	10.6	11.2	10.2	10.0	10.9	10.2	10.6
05:30~06:30	9.9	10.2	10.5	9.7	10.1	10.4	9.6	9.9	10.4	10.3	10.1
AVG	10.4	10.7	11.0	9.7	10.4	10.8	9.9	10.0	10.7	10.3	10.4

Table 09. statistical analysis results of the noise level difference before and after RSBS DLPAC application [in dB(A)]

	E-1	B-2	C-1	C-2	C-3	D-1	D-2	D-3	AVG.
08/11 and 10/23	9.6	10.6	9.9	10.3	9.8	9.4	10.2	9.8	10.0
08/11 and 10/27	10.2	11.3	9.4	10.6	9.7	9.8	10.4	9.9	10.2
AVG.	9.9	11.0	9.7	10.5	9.8	9.6	10.3	9.9	10.1

Table 10. The noise level difference on the similar condition before and after RSBS DLPAC application [in dB(A)]

Time zone \ Noise Meter	E-1	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	AVG.
22:00~23:00	10.5	10.3	10.9	8.7	10.1	10.7	9.3	9.7	10.5	9.7	10.0
05:30~06:30	10.0	X	10.7	X	10.4	10.6	9.5	9.7	10.4	X	10.2
AVG	10.3	10.3	10.8	8.7	10.3	10.7	9.4	9.7	10.5	9.7	10.1

Table 11. The noise level difference based on the reference point before and after RSBS DLPAC application [in dB(A)]

Microphone Position	80km/h	100km/h	AVG. Noise Difference (Noise reduction)
Side	7.3	8.2	7.8
Rear	10.4	11.0	10.7

Table 12. CPX noise level difference between SMA pavement and RSBS DLPAC[in dB(A)]

5. CONCLUSIONS

This study was carried out on RSBS DLPAC applied to expressway in order to provide reasonable and effective noise reduction effect measurement method for low noise pavement in Korean road environment so that it can be institutionalized.

As a result of the study, it was confirmed that the noise reduction effect is 10dB(A) or more on average in the case of the equivalent noise measurement method which measures and evaluates the noise level which is heard by a person. The noise level at the receiving point in distance from the sound source and the noise level at the roadside is very similar and the difference was below ±1dB(A).

In CPX measurement method, it was confirmed that the noise level difference by microphone position was 7.8dB(A) at the side position and 10.7dB(A) at the rear position similar to the equivalent noise level difference. The comparison of the difference in noise level between the two measurement methods is shown in Table 13.

<table>
<tr><td colspan="3"></td><td>Avg. Noise Reduction[dB(A)]</td></tr>
<tr><td rowspan="2">CPX Measurement</td><td colspan="2">Side Microphone</td><td>7.8</td></tr>
<tr><td colspan="2">Rear Microphone</td><td>10.7</td></tr>
<tr><td rowspan="4">Equivalent Noise Level Measurement</td><td rowspan="3">Analysis Methods</td><td>1. statistical analysis</td><td>10.4</td></tr>
<tr><td>2. similar condition analysis</td><td>10.1</td></tr>
<tr><td>3. reference point analysis</td><td>10.1</td></tr>
<tr><td colspan="2">Average noise reduction</td><td>10.2</td></tr>
</table>

Table 13. Comparison of the difference in noise level between the two measurement methods

Therefore, in measuring noise reduction effect of low noise pavement compared to another pavement, A. In case of the measurement at the receiving point is impossible according to the change of traffic condition and road condition, the equivalent noise level measurement method seems to be reasonable by measuring at the road side, and B. In case of CPX measurement, it seems reasonable to measure and evaluate at the rear position which has similar noise reduction effect to the roadside equivalent noise level measurement than the side position of the tire.

6. ACKNOWLEDGEMENTS

This work is supported by the Korea Agency for Infrastructure Technology Advancement (KAIA) grant funded by the Ministry of Land, Infrastructure and Transport (Grant 18TBIP-C125188-02)

7. REFERENCES

1. Korean Society for Noise and Vibration Engineering, *"Measuring and Analysing the Noise of Double Layer Low Noise Pavement, Final Report"*, (2018)
2. *Measurement Method of Exterior Noise Emitted by Road Vehicle for Management Standards*, ES 03305. 1b, the Ministry of Environment
3. ISO 11819-2:2017(en) Acoustics , " *Measurement of the influence of road surfaces on traffic noise — Part 2: The close-proximity method"*, International Organization for Standardization, Geneva, Switzerland, (2017)