Quantifying Benefits of Interlocking Block Pavement in Korea

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Abstract :

Block pavement was proposed as a pavement for low-speed and sustainable roads and the performance and effectiveness of Block pavement was assessed to be based on this. For this purpose, the research carried out an analysis on the durability and noise level of the existing Block pavement to assess the potential for quantitative performance of the Block pavment. Further research was conducted on the possibility resuspended dust by disperse in the roadway, Block pavement can reduce the Ultrafine dust than Asphalt pavement. As a result of the performance evlauation, Block pavement was applicable for low speed road.

Key Words : Block pavement ; Performance evaluation ; Speed ; Resuspended dust

1. Introdouction

In advanced countries, such as Europe, the United States, and Japan, Concrete Block pavement are also used in low-speed sections, airport moorings and port yards, which correspond to low-traffic residential and back Roads. However, in Korea, the partial use of Concrete Block pavement is mainly used in sidewalks, parking lots and Highway stop-over , and Block pavement for Roads are only used in certain sections for demonstration.

This is due to the negative perception that domestic Blockpavementis inefficient due to unnecessary replacement work, and the lack of design practices and quantitative performance verification studies that can maintain a certain level of quality for highrepetitive loads, which limits the advantages of domestic Block pavement.

However, the low-speed environment under 30km/h has been developed with positive results in various research and practical application of pedestrian-centered neighborhood through superBlocks, which is a countermeasure to sustainability and environmental pollution in urban areas

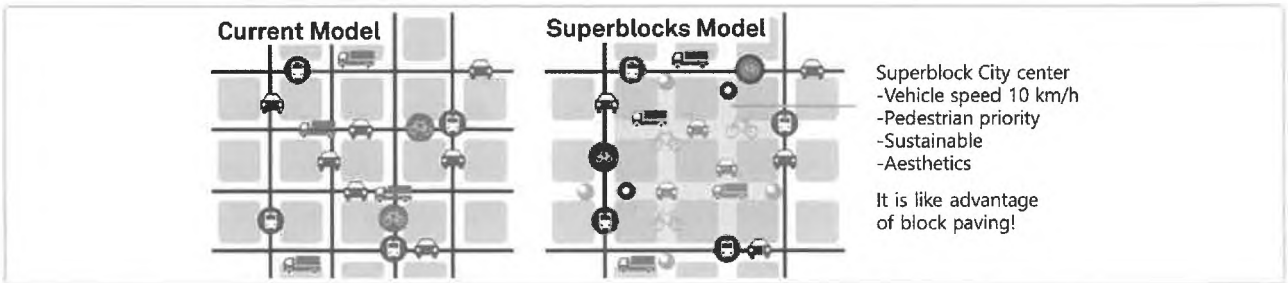


Figure 1. Condition of SuperBlockand Advantages of Block pavement.

Therefore, the purpose of this study was to propose Block pavement for low-speed and sustainable Roads and to evaluate the performance and effectiveness of Block pavement based on it.

For this purpose, this study conducted an analysis of the heat reduction effect, the speed reduction effect, durability and noise of the quantitative performance evaluation in which the Block pavement can be used for the Road which has traditionally been noted as the advantages.

In addition, We assume that the Block pavement effectively filters out alien substances on the Road through the surface drainage between construction joint and the Block, and the irregularity on the surface reduce the air pumping between the tire and the Road, resulting in a reduction of resuspended dust. To reduce Fine particulate dust, the nation's largest environmental problem, further research has been done on the possibility that Block pavement can reduce resuspended dust generation that can be dispersed from the Road.

2. Literature Review

Blockpavement can contribute to reducing urban flood, Roadsurface temperature and improving urban Road aesthetic by improving urban environment like rainwater and developing low impact. As a result of measuring the Road surface temperature, reflection temperature for Block pavement and heat shield pavement compared to the Asphalt pavement, the surface temperature of the heat shield is reduced by about 7°C. Other than that, the temperature reduction was between 0 to 2°C.

Noise from the tyre to surface is caused by a combination of several factors, and according to Gongyan Liao (2014), noise from the Block pavement is likely to be similar or lower than Asphalt pavement.

If the vehicle is driving at speeds above 55 kph, the noise from the tyre to Road is the main cause and at low speeds engine noise is dominant for determining the noise level (Pause Mitchell, 2009).

The assessment criteria for Block Brokenagewere largely divided into material and structural damage in accordance with the guidelines given by the Australian Concrete Block Association (Shackel andPearson 2001). Types of damage caused by sidewalk Block pavementcan be classified into broken and dropped, edge broken, worn (surface peeling), poor flatness and others (Kim Jang-rak, 2017).

According to the Installation and Management Guide of sidewalks(2011), the level of replacement is determined by evaluating the pavement conditions based on a flatness. Sections that fall short of criteria are evaluated by calculating the Brokenage rate, but there is no clear replacement standard for the Brokenage rate. However, according to Shinobu Omoto (2006), Japan is managing Block pavement using a individual evaluation method and a MaintenanceControl Index (MCI) unlike Korea. The Maintenance Control Index (MCI) can be calculated as shown in Table 1 based on the broken rate and the rutting of the Block pavement.



Table 1. Maintenance Control Index of Block pavement in Japan

Rank	Comment	Point
A	No defect (Good)	10
B	Some defects, but it seems good	8
C	Many defects, but do not need to repair	6
D	Need maintenance a little	4
E	Need large scale repair	2
Formula	$\text{Rate of Damage}(\%) = \frac{Number\ of\ Damaged\ Blocks}{Total\ Number\ of\ Blocks} \times 100$	
Formula of MCI	$\text{MCI} = 10 - 1.51C^{0.3} - 0.30D^{0.7}$ C= broken rate(%), D= depth of rutting(mm)	

Concrete Block paving book1 (2009) stated that Concrete Block pavement has a dust-reducing effect and for concrete pavement, the joint is sealed, so that dust and debris cannot penetrate. And Asphalt pavement spreads more sand at higher temperatures to increase sliding resistance, resulting in higher dust generation compared to Block pavement(T willway,2008).

James and w (2003) also confirmed that the Concrete Block pavementhas a dust saving effect through measurement and suggested the possibility of reducing resuspended dust measuring in Water-permeability Block pavement.

Shajeev S (2017) believes that the speed of vehicles driving in Block pavement is lower than that of Asphalt pavement and the Block pavementcan be used as facilities for Traffic Calming.

Mission light (2012) analyzed the speed reduction effect in Block pavement compared to Asphalt pavement, indicating that about 80% of measured vehicles drive faster on Asphalt pavement, with the vehicle speed reduction of 2 km. Also, the average rate of speed change for vehicles passing through the two Road pavement is about 13 percent.

3. Method

3.1 Noise level

The noise measurement method of this study was measured using Close Proximity Method (CPX, ISO 11819-). The microphone was installed on the right rear wheel of the measuring vehicle using special equipment designed to attach a tire that is 10 cm above the ground and 20 cm from the center of the tire. [Figure 4.] shows the measurements using CPX method. Measurements was taken for four Block pavement , Asphalt pavement and WMRA(Warm Mix Recycled Asphalt) pavement for comparison. For each section, two times were measured at a speed of 40 km/h, 30 km/h, 20 km/h and 10 km/h respectively on a straight Road of at least 100 meters.

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Figure 1. (a) CPX noise measuring equipment attached to tires (b)Noise Measurement view

3.2 Speed

To analyze the impact of Block pavement on the driver's driving pattern, the individual vehicle's Road speed was detected using a high-performance multi-beam radar sensor developed in a cooperation of Byda. [Table 3.] refers to the features of detection radar sensor in different catagory.

Table 3. The Measurement Time Period for the Performance Evaluation in Each Category

Catagory	Features
Maximum Concurrent Tracking	Under 256 units
Coverage Velocity	-250km/h
Coverage Azimuth FoV	±20°
Maximum Coverage Range	Under 350m
Functions	• Multi-beam radar technology incorporating straight/left turns and queue-path detection • Digital beam formation technology and smart traffic monitoring to maximize vehicle detection performance
Installation	
Advantages	• Using a high-performance multi-beam radar sensor that can accurately detect vehicles in a wide detection range (more than 300 m) and in multi-lane (at least 98% and at a speed of 97%)

[Figure 4.] is the section that research the vehicle speed. It Measures the vehicle's speed changes before and after the vehicle enters the Block pavement.

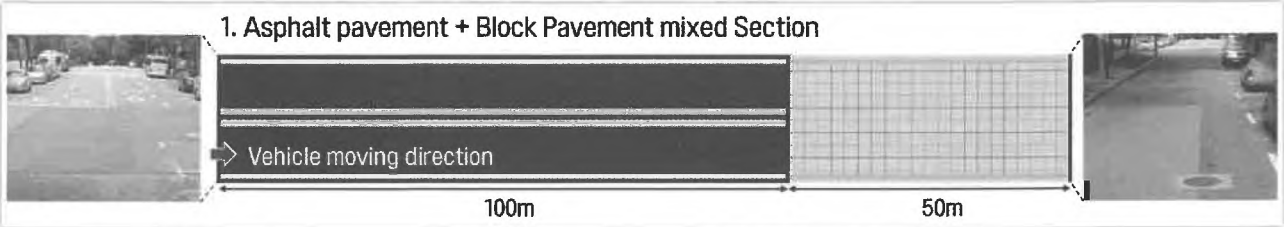


Figure 4. Pavement Sections of measuring vehicle speed

3.3 Brokenage

A visual inspection was conducted to investigate Road Block pavement Brokenage. In this study, Blockbreaks (cracks, losses, port holes), edge breaks, and surface abrasions were classified as material failures, and flatness defects (partial settlement, inter-Blockfaulting, line-up). [Figure 5.] is the Picture of catagorized Block pavement Brokenage whentaken a visual inspection.

In case of cracks, if one Blockis more than 2cm, it is defined as a crack in the Block (Daniele Ferreti, 2015) and damaged edges in case of more than 15% of concrete Blocks (Gel).

In case of partial breakaway, the standard design maintenance guideline for horizontal public facilities, the criteria for failure of construction was defined as settlement when the standard is 2mm or more high with the Block. The ratio of the number of broken Blocks to the total number of Blocks was calculated.

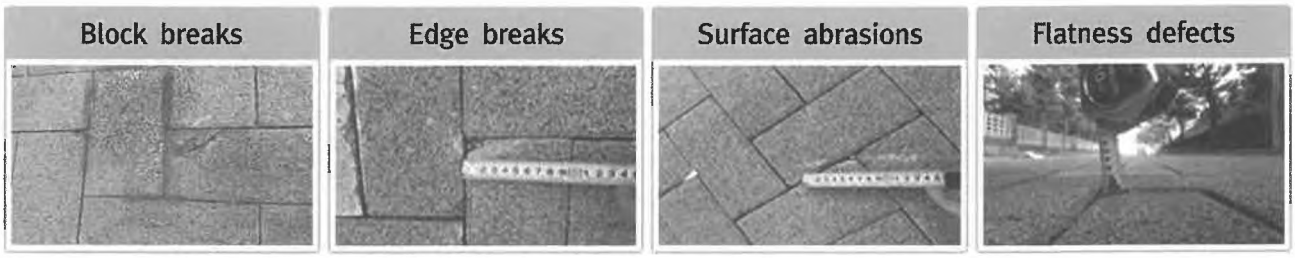


Figure 5. Pictures of Categorized Block pavement Brokenage in visual inspection

[Table 5.] shows the information of pavement where we taken the visual inspection of Block Brokenage. The pavement age of the constructed Blockis 11 months, 21 months, and 45 months respectively, and each of the Block pavement that is located in a different area is investigated. The types of Blocks used in the Road consist of granite Blocks and hall Blocks, Section B and Section C researched 100m of continuous Block pavementand Section A-1 section 90m.

Table 5. The Measurement Time Period for the Performance Evaluation in Each Category

Section	Locations	Construction Date	Performance Month	Type of Block	Total Blocks
A-1	199 Garak-dong, Songpa-gu, Seoul, Korea	2016.11	21 months	Granito : 200×100×80T Hall : 200×100×80T	10,200
B	Route 23 of Pungseongro, Songpa-gu, Seoul, Korea	2014.11	45 months	Hall : 200×100×80T	20,000
C	26 Seoae-ro, Jung-gu, Seoul, Korea	2017.09	11 months	Granito : 200×100×100T 200×100×80T	20,000

3.4 Resuspended Dust

Depending on the size of the particles, dust is divided into total dust (TSP), fine dust with a diameter of less than 10㎍ and ultra fine dust with a diameter of less than 2.5㎍. The concentration of pollutants in the Road station will be measured much higher as air concentrations will increase the concentration of pollutants emitted from cars (National Institute of Environmental Research.2012) conducted a study under the assumption that the concentration of Ultrafinedust produced by driving the vehicle on the Road would be higher than that of Ultrafine dust in the atmosphere.

In this study, we measured dust (proximity measurement) that is directly redistributed between the tyre and the Roadsurface and dust (distance measurement) on the sides of the main Road. The dust, which is directly resuspended from the ground, installed a sensor at the rear of the vehicle and measured twice at a speed of 30 km/h, taking into account the characteristics of the vehicle's speed at the back of the Road. The dust at the sides of the main Roadwas installed at 1.5 meters, the average height of a person, to determine the level of dust that people feel, and the measured Block pavement and Asphalt section of the vehicle was divided to make use of TSI's DustTrak 2 Aerosol 8530. Ultrafine dust is measured in Section A,E.

In addition, Kang Sung-joo (2015) found that Ultrafine dust in the atmosphere had a small reduction in fine dust levels under 10mm of accumulated rainfall and significantly decreased in excess of 10mm. After 10mm of rain, the concentration of resuspended dust was further compared and analyzed over the date.

[Figure 6.] shows how Road resuspended dust measured by proximity and distance method.

Method	Conditions	Measurements	Device
Proximity	• Speed of 30km/h - Average values of 2 times measurement - Passenger car(petrol)		
Distance	• Away from the center lane 1.0m Measuring height 1.5m		

Figure 6. Measurement conditions for resuspended dust proximity and distance method

3.5 Temperature

Temperature measurement is divided into two parts: surface temperature and air temperature. The surface temperature measurement method uses an infrared thermometer to measure the temperature of the Roadsurface and the air temperature measurement method is to measure the temperature of the Road surface using the weatherStation. The temperature measurement error range is ±1.5° C. [Figure 7.] shows the devices for measuring surface temperature and air temperature.

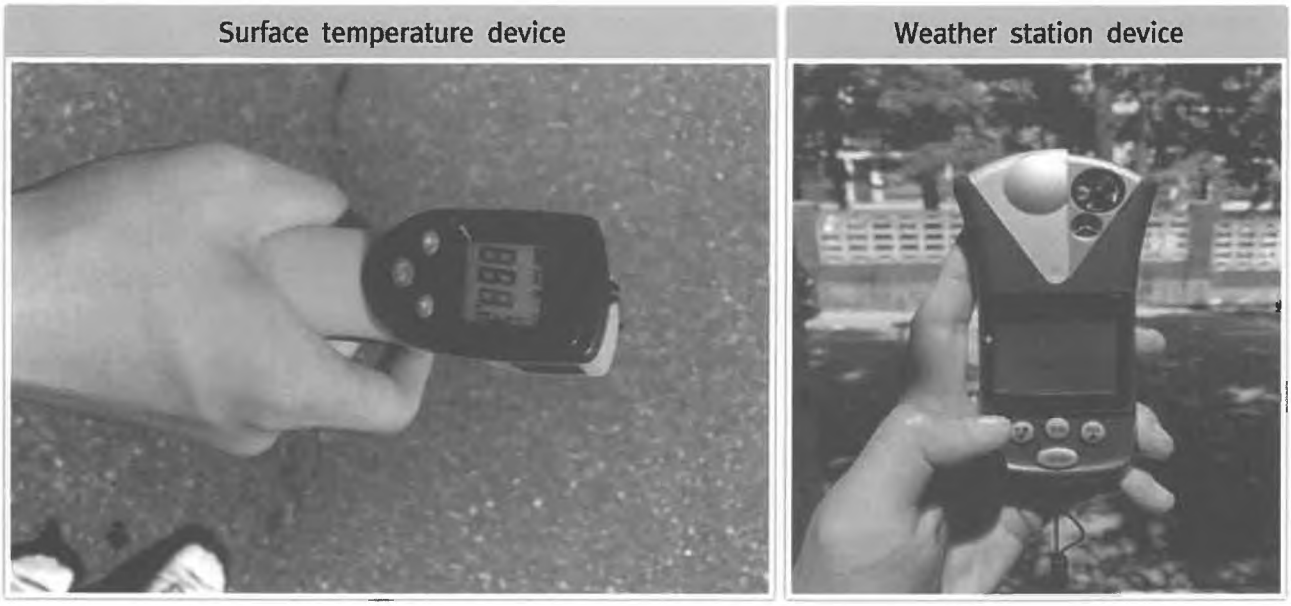


Figure 7. Measurement devices for surface temperature and air temperature

4. Results

4.1 Noise level

The noise measurement results in [Figure 8.] showed that, at vehicle speeds of 40 km/h, 30 km/h and 10 km/h, the noise level in the Blockpavement was approximately 0.9 dB (A) lower than the Asphalt pavement and 0.3 dB lower at speeds of 20 km/h. When comparing the noise levels of the Block pavement and the WMRA pavement, the speeds of 40 km/h, 30 km/h and 20 km/h were all low in the Block pavement. Differences in noise produced by vehicle speed for each measuring area are present but not significant at the level felt by humans. Thus, it is judged that noise under functional conditions need not be taken into account at a level higher than that of Asphalt pavement when designing a Block pavement at low speeds for Road.

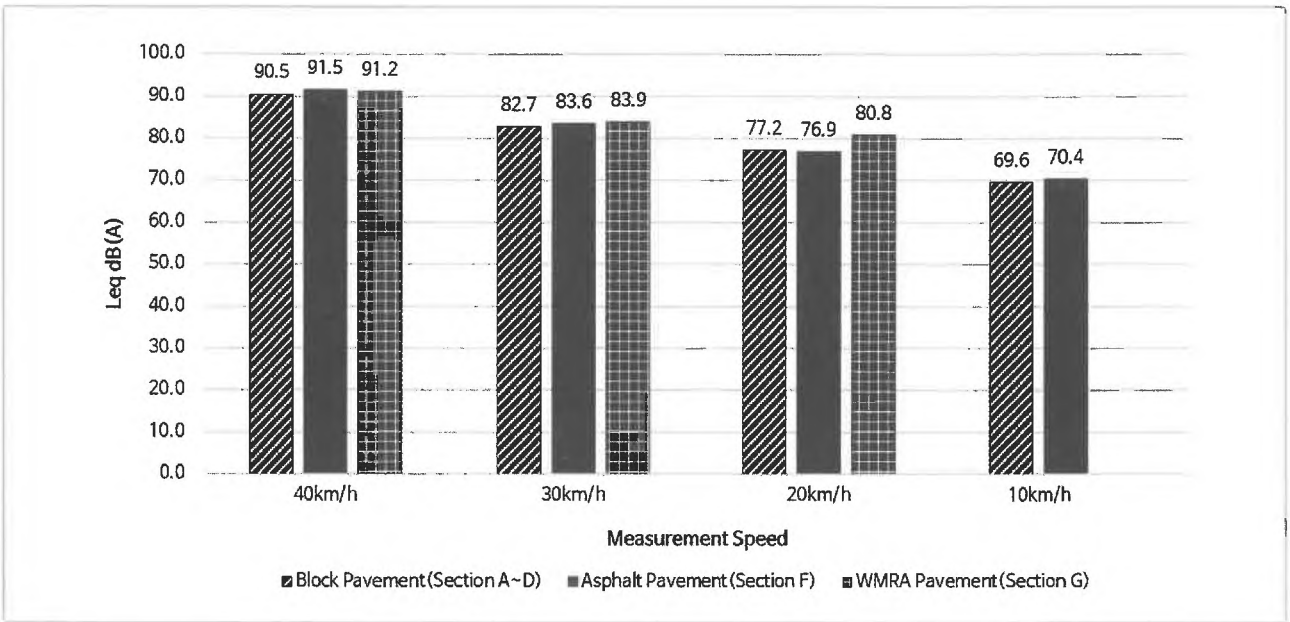


Figure 8. Noise level according to the Vehicle Speed

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Sound Pressure Level (SPL) is the sound pressure expressed as a decibel scale, using dB(A). Frequency ranges are divided into 12.5 to 315 Hz(low frequency), 400 to 800 Hz(medium frequency), high frequencies from 1000 to 2,500 Hz, and ultra high frequencies from 3,150 to 16,000 Hz.

[Figure 9.] is an analysis results based on a sound pressure level. SPL dB(A) by frequency analysis shows that the noise level in Block pavementincreases steadily resulting in the highest dB(A) values at approximately 800 Hz. However, for old section B (Block pavement, 45 months of age), harmonics that occur on Roads with typing and grooving surfaces in high-frequency, ultra-high frequency areas occurred in an inconsistent form. This is expected to be caused by the old Block pavement and poor maintenance. For Asphalt pavement and WMRA pavement, noise increased at regular intervals, resulting in the highest valuesat 1,000 Hz, and then decreased again in high frequency, ultra-high frequency areas.

The most sensitive frequency band for humans is between 1,000 and 4,000 Hz, with overall lower noise levels compared to Asphalt pavement and WMRA pavement, except for older Section B (Block pavement, age 45 months). Therefore, low age and good maintenance would have less impact on people in frequency bands that humans feel sensitive to compared to Asphalt pavement.

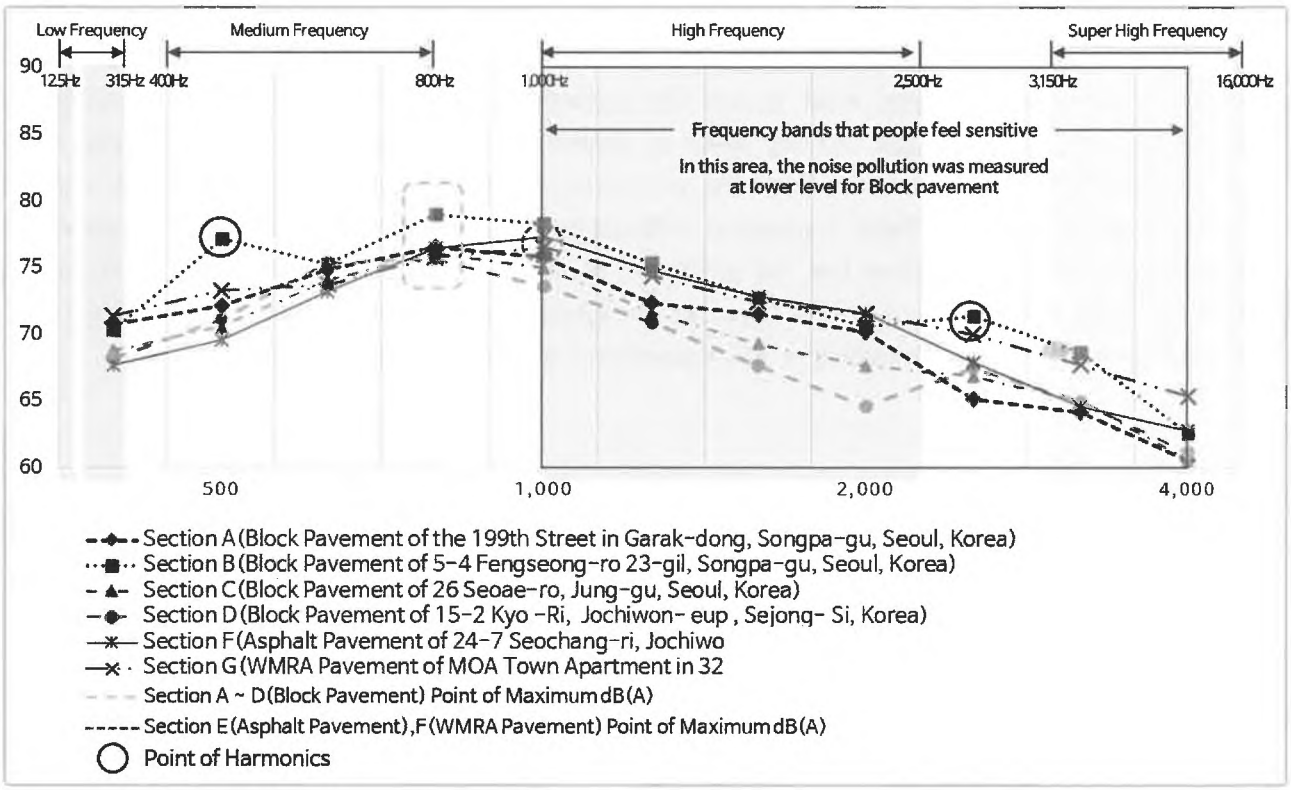


Figure 9. Noise level according to the SPL

4.2 Speed

As a result of measuring the vehicle's Roadspeed, a total of 23 vehicles were detected normally(No Obstruction) after entering the Blockpavement from the Asphalt. [Figure 10.] is a comparison of the driving speed of the same vehicle measured on both pavement. About 80 percent of detected vehicles are driven at lower speeds in Block pavement compared to Asphalt pavement.

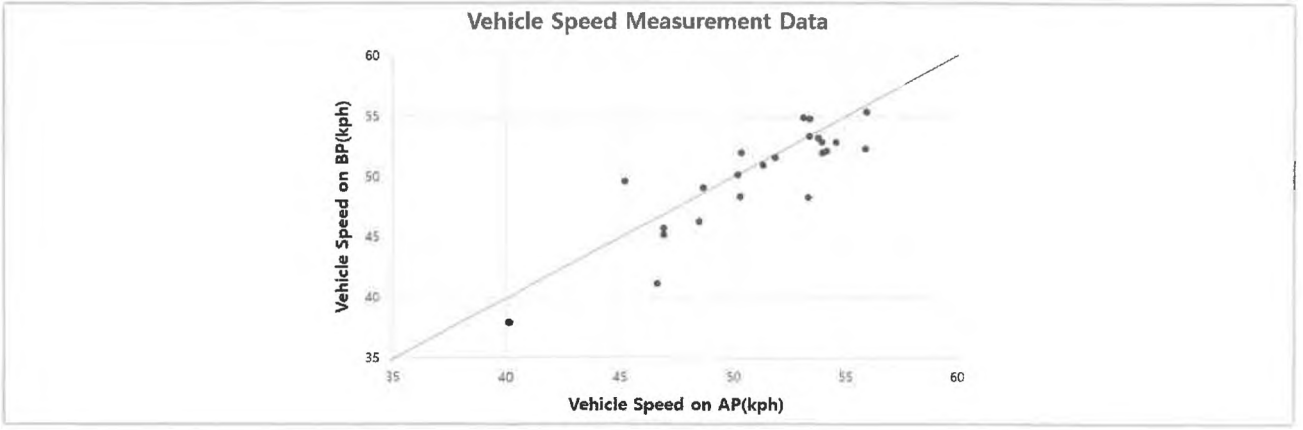


Figure 10. Vehicle Speed Measurement Data

In order to analyse the impact of the Block pavementon the driving pattern of individual drivers, a range of speed-distance graph was shown. The driving pattern was analyzed through the average speed of 19 vehicles that excluding 4 vehicles with no deceleration pattern among the 23 vehicles. As shown in the [Figure 11.], the driver noticed the Block pavement from 100 m(speed : 54.95kph) and started to slow down the Roadspeed at the lowest speed before the Block pavement (speed:50.81kph) It is judged that the small increase in the Roadspeed in the Block pack entry section of approximately 15 m is considered to be the process of re-applying the accelerator due to vibration physically applied to the driver from the Asphalt pavement to the Block pavement. The average driving speed of the vehicle, which slowed down again after entering the Block pavement, remained at 51.02 kph, and the detected vehicles were driving at a 4 kph reduction in Block pavement compared to the Asphalt pavement. Therefore, if the Block pavement is extended up to 30m before accident control and danger zone when applying the Road Blockfor Traffic Calming, the driving speed will be reduced without additional speed bump when applying for low speed highway.

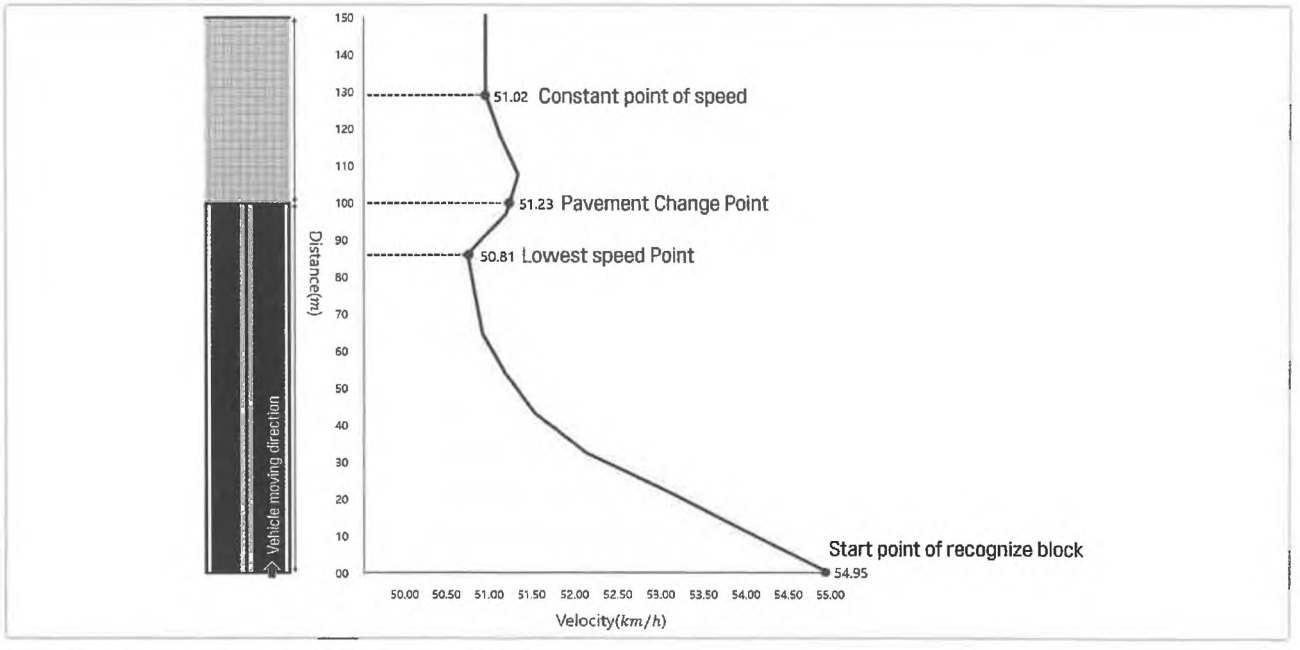


Figure 11. Vehicle Speed Measurement Data

4.3 Brokenage

[Table 6.] shows the result of the visual inspection on the Block pavementstaus, material damage occurred out of each test Road compared to structural damage, of which, about 41% of the total number of edge break Blocks were found in Section A and 54% in Section B. The damage rate of the test Roadwas calculated as 0.0025% for section A, 0.0013% for section B and 0.0035% for section C. According to the results of applying the maintenance index (MCI), all sections will receive high scores and the constructed Block pavement will not have any problems with the functioning of the Road.

Table 6. Block Brokenage measurement data by visual inspection

Section	Block breaks	Edge breaks	Surface abrasions	Flatness defects	Number of Brokenage Block	Rate of Brokenage(%)
A-1	0	7	1	5	13	0.0013%
B	3	42	3	1	49	0.0025%
C	7	55	6	2	70	0.0035%

As a result of a visual inspection, the researchwas conducted by setting a rating for each type of damage to compensate for the fact that different opinions are drawn or quantitative results are limited. [Table 7.] is the a quantitative valuess to classify by degree of Block brokenage. The regulations for each damage are selected as the minimum criteria and divided into upper, middle and lower level depending on the size of the damage.

Table 7. Quantitative values for classify the degree of Block brokenage

Level	Block breaks	Edge breaks	Surface abrasions	Flatness defects
High	More than 6cm	More than 30%	More than 30%	More than 4mm
Middle	4~6cm	20~30%	20~30%	3~4mm
Low	2~4cm	15~20%	15~20%	2~3mm

Most of the Brokenage Blocks examined in each section were edge break, which is a material problem, and the degree of damage was mainly for middle and lower level. The structural safety was shown to be good, as the total number of Blocks was very small in the case of partial settlement indicating structural problems in the pavement. [Table 8.] shows the number of Block brokenage in each section.It is analyzed that the section C with the largest number of performance months had the highest damage rate, while the section A had the lowest number of performance months, but due to heavy traffic and heavy traffic, the damage rate was measured more than other sections. It will be possible to follow up on this in the future and further researchof traffic volume to analyze how much traffic affects damage over the performance period.

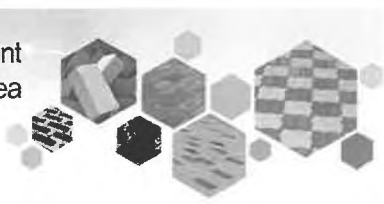


Table 8. Number of Block brokenage for each sections by visual inspection

Section	Level	Block breaks	Edge breaks	Surface abrasions	Flatness defects
A-1	High	0	4	0	3
	Middle	0	2	1	2
	Low	0	1	0	0
B	High	0	5	1	0
	Middle	2	25	1	0
	Low	1	12	1	1
C	High	2	8	1	0
	Middle	2	20	2	1
	Low	3	27	3	1

4.4 Resuspended dust

4.4.1 Proximity method

[Figure 12.] shows the Ultrafinedust result of 30 kph of Block pavement (BP) and Asphalt pavement (AP) measured in Suwon and it is a result of measuring the concentration of Ultrafine dust generated when driving on a randomly selected Roadat 30 kph in Garak-dong of Seoul. The Block construction site was located on a side Road, making it impossible to drive at high speed. The graph shows that when the vehicle is driving at low speed, the concentration of the resuspended dust in the Block pavementis on average 1(㎍/㎥) lower than that resuspended in Asphalt pavement. In addition, the concentration of Ultrafine particles observed over time after rain has increased, indicates that the higher the concentration of Ultrafinedust that is resuspended from the Road that progresses without rain. However, section A-1, as a perspective of Block pavement, the level of Ultrafine co-exist with high and low density compared to Asphalt pavement. This means that the difference in the dust concentration directly generated by the tire at low speeds is relatively low as a emission sources.

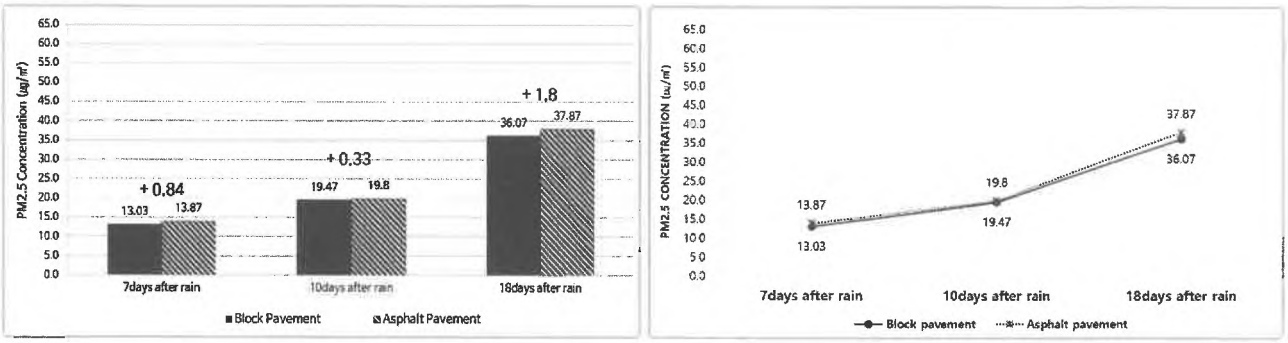


Figure 12. Road resuspended dust measurement by proximity method

4.4.2 Distance method

[Figure 13.] are the results of vehicles driving on Block pavement or Asphalt pavement at a distance of 1.0 m from the center of the lane at a height of 1.5 m. When the concentration of Ultrafine dust by pavement was compared in the section E area, the concentration of dust generated by the Block pavement was 3 (㎍/㎥) lower than that of Asphalt pavement. Considering

that there is a greater deviation than the average 1 (㎍/㎥) measured in the proximity method, it is judged that the concentration of Ultrafine dust is higher than that generated directly from the tire and affects people. In addition, the concentration of Ultrafineparticles observed over time after rain has increased, indicates that more and more Ultrafine dust has been deposited on the Roads. The effects of Ultrafinedust measured 10 days after rain were most significantly reduced from 7.57 (㎍/㎥) in Block pavement compared to Asphalt pavement. According to a study by Kioumutzoglu et al. (2016), increased Ultrafine dust concentrations by 1 (㎍/㎥) per year, the rate of Alzheimer's, Parkinson's and dementia can increase, Therefore, the concentration of resuspended dustgenerated by vehicle driving was reduced compared to Asphalt pavement in case section E(Hangung-dong in Suwon) Block pavement based on Ultrafinedust standard of 1 (㎍/㎥).

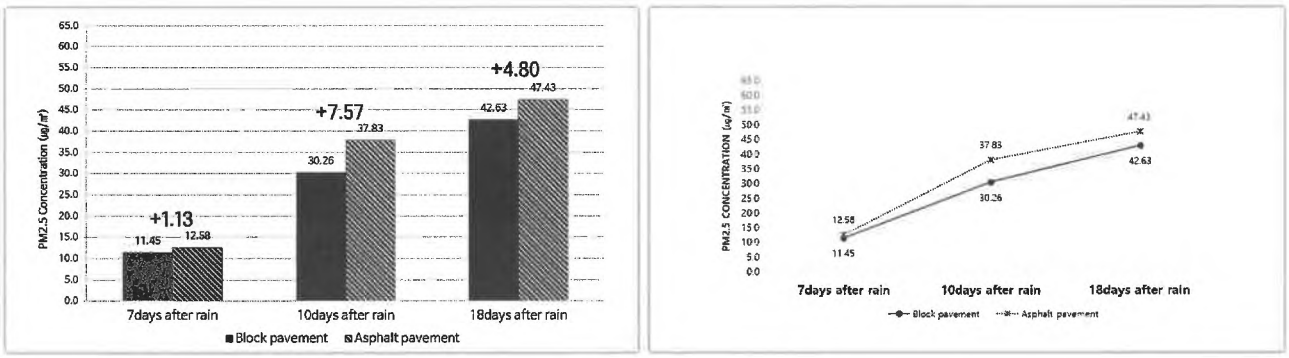


Figure 13. Road resuspended dust measurement by distance method

[Figure 14.] and [Table 9.] observed Ultrafine dust concentrations in Garak-dong of Seoulareas when measured by Block pavement and its surrounding environment. The lowest concentration of Ultrafine dust measured at 28.6(㎍/㎥) was measured for section A-1, and the average concentration of Ultrafinedust measured in Asphalt pavement was 31.2 (㎍/㎥). So we evaluate that Block pavement compared has the effect of reducing Ultrafine dust compared to Asphalt pavement.

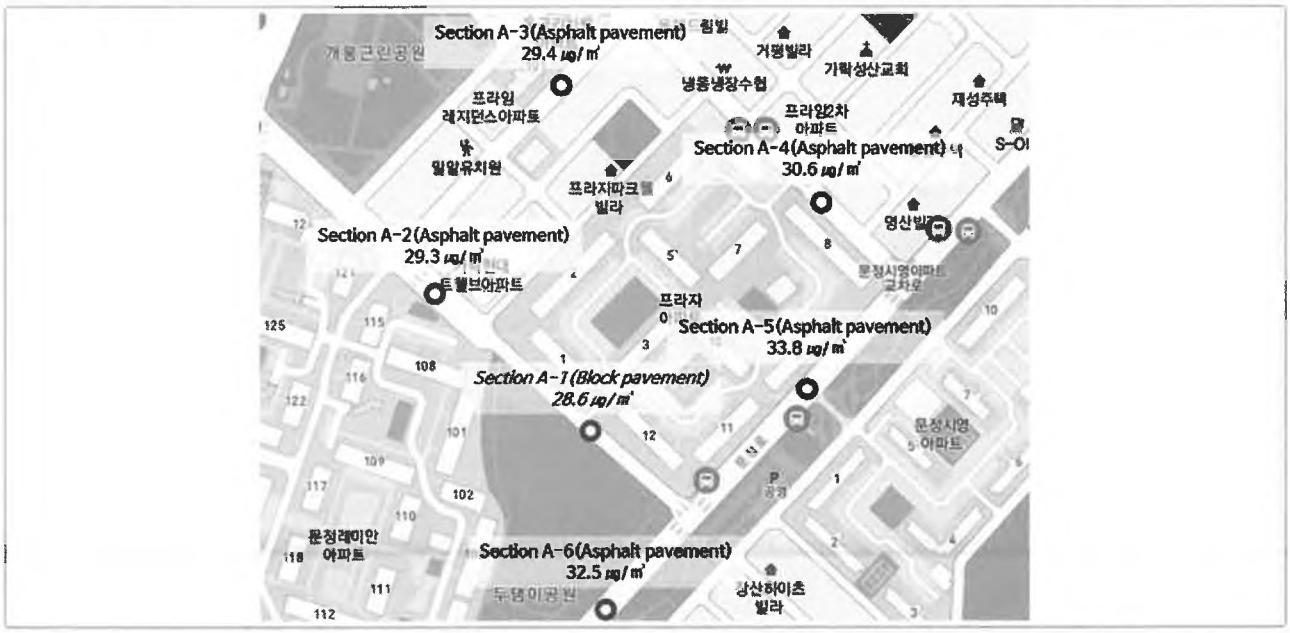


Figure 14. Road resuspended dust measurement by distance method

Table 9. Features of measurement locations using distance method

Section	Surrounding Features	Concentration of Ultrafine dust
A-1	Two-lane Roads between Green and APT (Block Pavement)	28.6 (㎍/㎥)
A-2	Four-lane Roads between two APT (Block Pavement)	29.3 (㎍/㎥)
A-3	Two-lane Roads between two APT (Asphalt Pavement)	29.4 (㎍/㎥)
A-4	Two-lane Roads between arcade and APT (Asphalt Pavement)	30.6 (㎍/㎥)
A-5	Four-lane Roads between Public park and APT(Asphalt Pavement)	33.8 (㎍/㎥)
A-6	Four-lane Roads between Public park and Green (Asphalt Pavement)	32.5 (㎍/㎥)

4.5 Temperature

[Figure 15.] shows the average values by measuring the temperature of the Block pavement surface, Asphalt pavement surface, and atmosphere at the research point. The surface temperature of the Block pavement was 36.8°C, about 2.5°C higher than the air temperature of 34.3°C, and the surface temperature of the Asphalt pavement was 43.4°C, about 9.1°C higher than the air temperature.

The surface temperature of the Asphalt pavement was 6.6°C higher than the surface temperature of the Block pavement compared to the surface temperature of the Asphalt pavement.

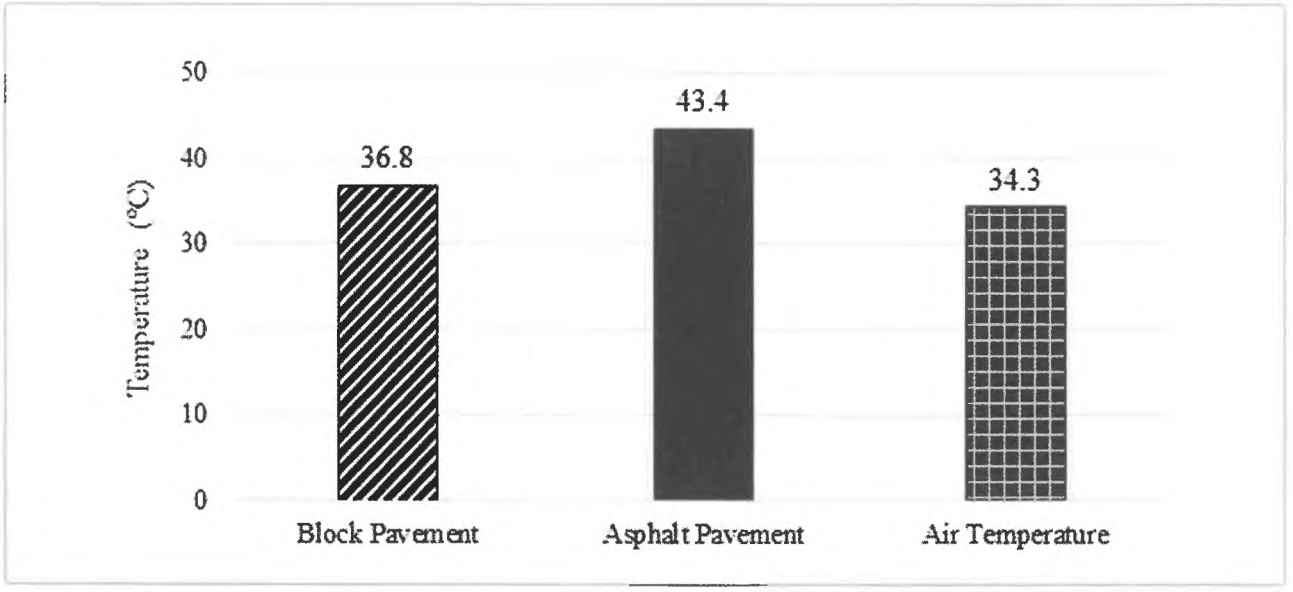


Figure 15. Results of Temperature measurement on pavement surface and atmosphere

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5. Quantifying Benefits

In this study, we measured and evaluated noise level, vehicel road speed, Brokenage, surface temperature of pavement and ultrafine dust to provide the basis that Block pavement is applicable for road. From literature review, we quantified the effectiveness of Block pavement compared to Asphalt pavement and calculated as an prices. If these quantified methods are used, the benefits of Block pavement will be clearly analyzed and used as an economic index.

1) Noise level

As a way of determining the benefits of noise level reduction, the Damage Cost method derived that the cost of noise damage in Korea was 41,737-601,910 won per person per year.(Jeong dong jae.2017). In this study, at a vehicle's speed of 40 kph, the Block pavementis measured at 90.5 dB(A) and the Asphalt pavement is measured at 91.5 dB(A). 1 dB(A) noise increase can make a damage cost about 601,910 won/year.

Noise level (dB)	Road
55-55	41,737 won/(person·year)
55-60	111,219 won/(person·year)
60-65	180,747 won/(person·year)
65-70	250,231 won/(person·year)
70-75	415,581 won/(person·year)
76-80	531,971 won/(person·year)
80+	601,910 won/(person·year)

Kim Chae-man (2018) made the noise effect monetary by making the difference in the noise generated by the installation of before-after soundproof wall project. Method of Avoidance Cost Approach, its value units is 4550 won per m per year. This study shows a reduction in noise by 1 dB(A) in Block pavement compared to Asphalt pavement, it is estimated that the maintenance method will provide a benefit of about (4,550*100(m)**91.5(dB(A)) - (4,550*100(m)**90.5(dB(A)) = 455,500 won.

2) Vehicle Speed

According to the Transportation Research Institute of the U.K, a reduction in vehicle speed by 50km/h can reduce the pedestrian death for 20% . In 2016, the cost of human injury for each catagories was 43,139 million won for death, 591.7 million won for serious injuries, 42 million won for slight and 1.91 million won for injuries(The national Highway Traffic Authority, 2016). Therefore, it is expected that traffic accident rate and pedestiran death rate will decrease by 20% since driver entering block pavement from Asphalt pavement decreass from 55km/h to 51km/h. According to the Korea TransportationSafety Authority, 4292 people died in traffic accidents in 2016 and 62.7 percent of pedestrian dead from 2014 to 2015 occured on the side roads. Therefore, it can be assumed that the number of traffic deaths on the side road is 2,691 and that the number of deaths will be benefits of 2320 billion won, which is 538 people.

3) Brokenage

Asphalt maintenance costs are estimated at 14,300 won per $1m^2$ for overlay method and about 50,000 won per $1m^2$ during Block pavement construction. If a crack of the same size occurs, such as Fig.16, the Asphalt pavement must be maintenace the entire area of the crack, but the Block pavement can be replaced seperately for Blocks. Calulating the cost, it is estimated that the benefits of Asphalt pavement will be around 12,000 won, as maintenance of $1.44m^2$ and will cost about 20,000 won, and Block pavement for 12 Blocks costs up to 8,000 won.

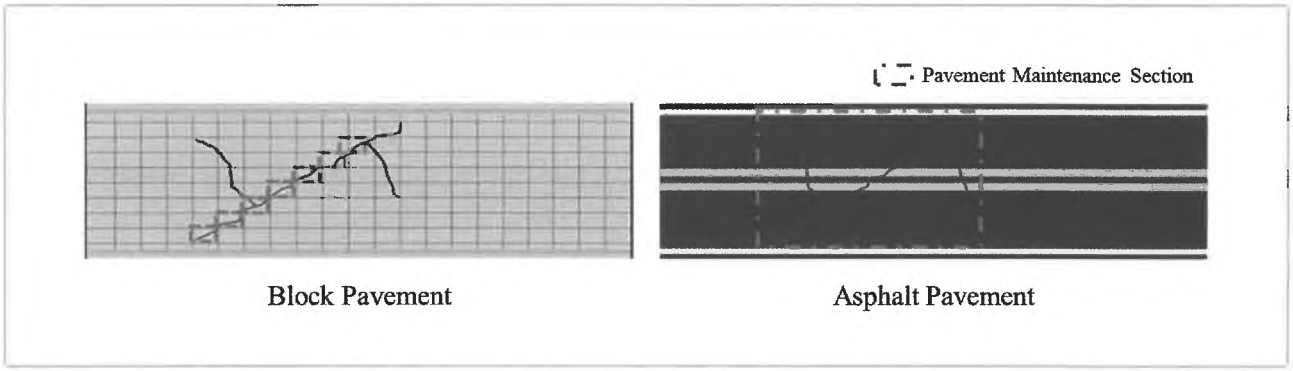


Figure 16. Comparsion of pavement maintenance section of Block and Asphalt

4) Surface Temperature

Since the cost of Asphalt Pavement is 40,000 won per square meter, the total cost is 28 million won for $700m^2$

In addition, to install two-way of street trees for 100m, the total cost is 10 million won. Therefore, to construct Asphalt pavementand street trees, total cost of 38 million won. However, the construction of block pavement is 50,000 won per square meter. To construct block pavement for 700 square meter can cost 35 million won.

Therefore, in case of Block pavement construction instead of street treets in 700 square meter, the expected benefit is three million won. However, given the additional temperature reduction effect, the difference in temperature reduction results in an expected benefit of More than 3 million won.

5) Suspended dust

In the case of ultrafine dust, the cost of health damage is calculated from the environmental costs of air pollution, which is estimated at about 45,742 won per person per year if increased with in $1\mu g/m^3$ (Ministy of Environment, 2013). This results in health-related cost benefits of about 180,000 won per person per year as the average ultrafine reduction in Block pavment is 4 $\mu g/m^3$ in this study. In addition, in the case of mortality, An so eun(2016) studied an annual 2.3% increase in mortality with an average concentration of $9.2\mu g/m^3$. When these figures are applied to study values, the mortality rate is estimated to decrease by about 1% per year. Finally, the benefit of reducing the concentration of suspended dust in the air by $1\mu g/m^3$ is estimated to be about 183.4 billion won in the calculation(Cho Yong sung.2004). This assumption yields a benefit of approximately 733.6 billion won in Block pavement.

6. Conclusion

This study was conducted to demonstrate validity of application of low speed and sustainable Roads through evaluation of the performance and effectiveness of Block pavement to present quantitative values. A five factors (Noise level, Speed, Brokenage, Temperature and Dust) were selected for the evaluation of the performance in 5 section of Block pavement. Summary and contents of this study are as follows.

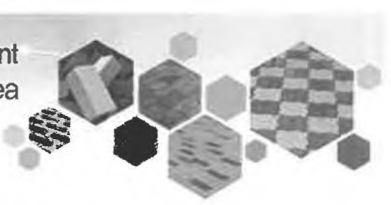
1. The noise measured by CPX method in Road Block pavement was found to be approximately 0.9 dB(A) lower on average than in Asphalt pavement at speeds of 10 km/h, 30 km/h and 40 km/h. At 20 km/h it was shown to be approximately 0.3 dB(A) high, but the difference was small and the high frequency area felt sensitive by humans (1,000 - 4,000 Hz) for well-maintained Block pavement.
2. Speed analysis shows that the driver noticed the Block pavement at 100 meters before entering the Block pavementand started slowing down, and that the Block pavement had a speed reduction of about 4 km/h compared to Asphalt pavement.
3. According to the visual inspection of the Block pavement, edge broken corresponding to material damage were found to be the main cause, and the average brokenage of Block pavement section was 0.0024%.
4. Comparing the surface temperature of the pavement between the Block pavement and the Asphalt pavement, the surface temperature of the Block pavement was measured on average 3.3°C lower than that of the Asphalt pavement.
5. Measurement of Ultrafine dust generated by the Roadshowed that the concentration of Ultrafine dust increased as the rainfall day of passes. It is estimated that there is more Ultrafine dust accumulated on the Roads after rain. This means that The concentration of Ultrafineparticles generated by the Road of section E was 4.5($\mu g/m^3$) on average, and the concentration of Ultrafine measured by section F was 2.6($\mu g/m^3$).

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