PERFORMANCE EVALUATION OF THE LOW NOISE DRAINAGE INTERLOCKING BLOCK PAVEMENT SYSTEM APPLIED TO THE DRIVEWAY

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ABSTRACT

As a part of driveway deployment of the interlocking block pavement in Japan, authors develop low noise drainage interlocking block pavement system, and have accumulated basic data. This paper performs performance evaluation of this system on the basis of the analysis of this data.

1.INTRODUCTION

The needs of the society to road pavement have shifted to the time where recent years come and environment and scene nature centering for a man are also thought important, from the time of function. In connection with this, drainage pavement has spread quickly as the road, which is easy by environment in recent years. These market needs are caught, and authors considered as the pavement system, which has drainage asphalt pavement, the drainage and low noise function, which excelled more than equivalent. And authors are performing spread activity from 1997 as a part of driveway deployment of the interchange locking block pavement in Japan.
This paper reports the functional recovery experiment result by a run experiment and the drainage functional recovery vehicle, which used imitation run examination equipment. Furthermore evaluation of Actual service performance which included maintenance nature on the basis of the on-site pursuit investigation result of this system applied to the shopping-center driveway in Hirosima-city.

2. THE OUTLINE OF LOW NOISE DRAINAGE INTERLOCKING BLOCK PAVEMENT SYSTEM

The standard pavement structure of this system is shown in Figure 1. While the drainage interlocking block usually has high intensity (bending intensity 4.9 N/mm^2 or more) equivalent to an interlocking block by addition of special polymer. On the surface of a block, design nature, vehicles noise reduction effect, and a drainage function are raised using the bone material of the diameter of a granule of 2.36 $\sim$ 4.75mm size. Void filling at the time of jointing sand filling is prevented with it. In consideration of void filling prevention of the tabling effect of a block, and a block surface, silica sand of a single particle size with a maximum size of 1.2mm was used for joint sand. It made for a bedding course to use small particle-diameter crushed stone with a maximum size of 5mm for the purpose of the spill by rain water, liquefaction prevention, and the improvement in drainage function. And, this was united with the block layer and it used as the drainage functional layer. Non-permeability layers, such as a dense particle-size asphalt concrete layer, are prepared in

this lower part, and base course and subgrade are constituted by the bottom. Thereby, rain water permeates a drainage layer and is drained by the crossing slope and the vertical-section slope of pavement in the side slot on the road shoulder. [1][2][3]

3. PERFORMANCE EVALUATION FOR ACTUAL SERVICE OF LOW NOISE DRAINAGE INTERLOCKING BLOCK PAVEMENT SYSTEM

3. 1. Performance Evaluation for actual service by Run Experiment Using Load Simulator

(1) Experiment outline

① Experiment equipment

The experiment was performed using the load simulator (imitation run examination equipment) shown in the photo 1. This equipment carries out the both-way run of the pavement way of 16m of width extension of 4m at the 5 km/hr speed whose double ring for large-sized vehicles of fixed surcharge (a setup is possible up to a maximum 7 ton). And the conditions near a run of actual vehicles can estimate the action of the various pavement under a move load condition. Since this equipment is installed on the outdoors, weather conditions change with enforcement time of an experiment.

② Pavement structure etc.

The experiment divided the inside of the wheel run zone of a load simulator into two divisions in the extended direction. One division of them was used as this system, one division of another side was usually considered as interlocking block pavement, and both actual service performance was compared. As shown in Table 1, pavement structure made lower structure the same from non-permeability layer, and considered it as the composition from which the kind of block and the kind of bedding course differ. Pavement structures are the conditions of number of total 5ton conversion 150,000 wheels, and designed design term 10 years and, and the amount of design traffic based on

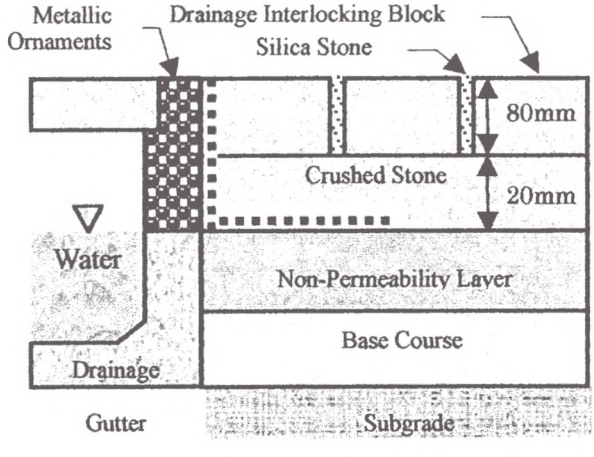


Figure 1 Normal Pavement Structure

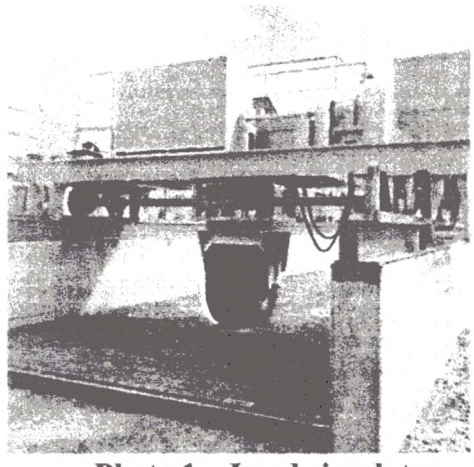


Photo 1 Load simulator

the CBR-TA method. Experiment conditions made it run 150,000 wheels of the wheels of load 5ton, sprinkling water artificially as it is shown in Table 2.

③ An evaluation item and a measuring method

The evaluation item and the measuring method were carried out as it was shown in Table 3.

(2) Experiment result

①The shape of surface nature of pavement

The measurement result of the amount of the maximum rutting on the surface of pavement is shown in Figure 2 as an example of an experiment result. Moreover the measurement result of the support power on the surface of pavement is shown in Figure 3.

After making it run modification of the pavement surface of this system, and 150,000 wheels of support power by 5ton ring load, they was usually almost equivalent to interlocking block pavement. Moreover, the phenomenon that joint sand of this system is spilled out to void of the small particle-diameter aggregate of a bedding course is not seen, and breakage of a block was not produced with both

② Durability of bedding course

5ton wheel load compared the sieving experiment result after 150,000 wheels run examination run before of the smallness particle-diameter aggregate used for the bedding course of this system. Consequently, it checked that both particle size did not change and small particle-diameter aggregate was not formed into a thin grain by traffic load.

③ Value conversion coefficient relative strength of surface (block + joint sand + bedding course)

The surface elastic coefficient was presumed by the multi layer elastic theoretical theory on the basis of the amount of bending of the pavement structure and the pavement surface in both divisions. By value result of computing a value conversion coefficient, it was presumed that both value conversion coefficients are almost 1.

(3) Evaluation

Judging from the run experiment result using the load simulator, it is considered that the surface of the after making it run 150,000 wheels by 5ton wheel load of this system is equal that of normal interlocking block pavement.

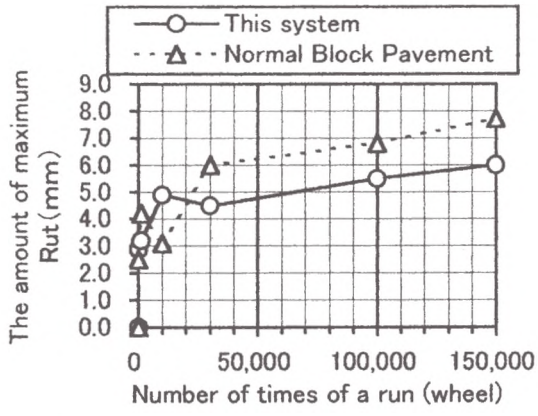


Figure 2 The amount of maximum Rut on the surface of pavement

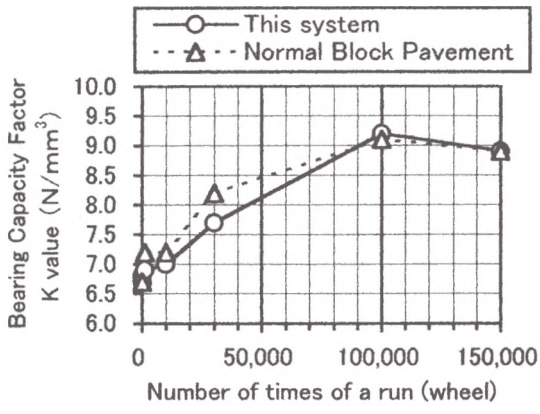


Figure 3 Bearing Power on the Surface of Pavement

Table 1 Pavement structure for a run experiment

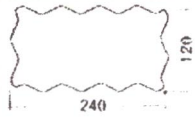
Division			1	2
The kind of pavement			Low Noise Drainage Interlocking Block Pavement System	Normal Interlocking Block Pavement
BLOCK	Kind		Drainage Interlocking Block	Normal Interlocking Block.
	Form		Wave Type Block (mm) 	
	Thickness		80mm	
	Intensity		6. 02N/mm^2 (5 pieces average)	5. 98N/mm^2 (5 pieces average)
	Pattern		Herringbone Bond (90 degree)	
JOINT SAND			Silica Sand (maximum size 1.2mm,FM2.86,75 μ m≦0 21%)	
BEDDING COURSE	Kind		Small particle-diameter crushed stone (the maximum size 5mm, FM4. 58,75 μ m≦4 4 %)	Crushed Sand (the maximum size 2.5mm,FM2.70,75 μ m≦4 1%)
	Thickness		20mm	
Non-PERMEABILITY LAYER	Upper layer	Kind	Dense Particle-size Asphalt Concrete	
		Thickness	30mm	
	Lower layer	Kind	Rough Particle-size Asphalt Concrete	
		Thickness	50mm	
BASE COURSE	Kind		Cement Stabilized Base Course (Unconfined Compression Test σ7= 1.0 N/mm2)	
	Thickness		150mm	
SUBGRADE			Design CBR=3%	
PAVEMENT AREA			Width 4m x Extension 8m	Width 4m x Extension 8m
DESIGN TERM			10 years	
AMOUNT of DESIGN TRAFFIC			150,000 Wheels : Number of total 5ton conversion wheels.	
DESIGNING METHOD			CBR-TA method	

Table 2 Run experiment conditions

WHEEL LOAD		5ton
RIDING TIMES		150,000 Wheels
RIDING POSITION		Carry out the regular distribution of the position of 50 cm of right and left from the direction center line of a width member. It was made to run.
GRADIENT	Crossfall	1%
	Gradient	0.5%
SCATTERED WATER QUANTITY		1,550mm[for-the-year rainfall of Tokyo] *10 years = 15,500mm was artificially scattered suitably within the experiment term
DRAINAGE PROCESSING		Drainage gutter was prepared and drained at the direction end of the transverse.

Table 3 An evaluation item and a measuring method

THE EVALUATION PURPOSE	EVALUATION ITEM	MEASURING METHOD	OBJECT DIVUSION
EVALUATION of SURFACE	Rut depth of the surface	The crossing profile meter method	Both Divisions
	Surface smoothness of pavement	Straight-line ruler method	Both Divisions
	The amount of bending on the surface of pavement	Benchelmans Beam method	Both Divisions
	Bearing power on the surface of pavement	Monotonous load examination	Both Divisions
	Spill of joint sand through into bedding course	Visual check	This System
	Distress of Block	The number of distress is checked.	Both Divisions
EVALUATION of THE DURABILITY of BEDDING COURSE	Formation of a thin grain of bedding course (smallness particle-diameter crushed stone)	Sieve analysis	This System
Presumption of coefficient of strength of surface(Block + joint sand + bedding course)		It analyzes by multi layer elastic theory.	Both Divisions

3. 2. Evaluation of Maintenance by Functional Recovery Experiment Which Used Drainage Functional Recovery Vehicle

As for drainage pavement, a drainage function and vehicles noise reduction effect fall by filling up with voids with a coarse particulate etc. in connection with use. Therefore, a periodical maintenance aiming at recovery of these performances is needed. Authors examined the validity at the time of applying the drainage functional recovery vehicle developed for drainage asphalt pavement as an one side method of a maintenance in this system. [4]

(1) Experiment outline

The drainage functional recovery vehicle used for this experiment is shown in a photo 2. This machine receives the authorization based on construction technical evaluation regulation of the Ministry of Construction as a drainage functional recovery vehicle for asphalt pavement.

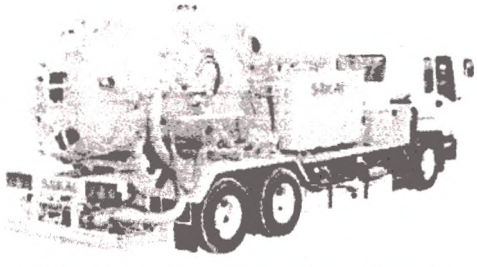


Photo 2 Drainage functional recovery vehicle

The mechanism of this drainage functional recovery vehicle reproduces voids by spraying of high-pressure water and suction of sludge water . The specification of this drainage functional recovery vehicle is shown in Table 4. Experiment conditions are shown in Table 5. Drainage asphalt pavement was put side by side in the examination yard with this system, and comparison evaluation of both maintenance was carried out. It experimented in the reappearance accompanied by use got blocked voids by sprinkling muddy water at an examination yard artificially, and carrying out natural dryness of this. Evaluation of the condition of a maintenance was mainly performed about the following matters.

■Voids -- getting blocked -- how much a drainage functional recovery vehicle recovers the drainage function and the vehicles noise reduction effect of having fallen

■Does "Joint Sand" disappear by washing work of a drainage functional recovery vehicle, and doesn't the support power of a block layer decline?

Table 4 Specimen of a drainage functional recovery vehicle

Weight	The vehicles total weight	19,500kg
	Vehicles weight	17,390kg
	The amount of the maximum loading	2,000kg
Size	Full length	9,800mm
	Full	2,490mm
	All Height	3,550mm
Work many's equipment	The washing method	High-pressure Spraying and Sludge-water suction method
	Work width	2,000mm
	Right-and-left shift width	700mm each of right and left
	Work speed	0～30m/min
	Washing water tank capacity	2,000 ℓ

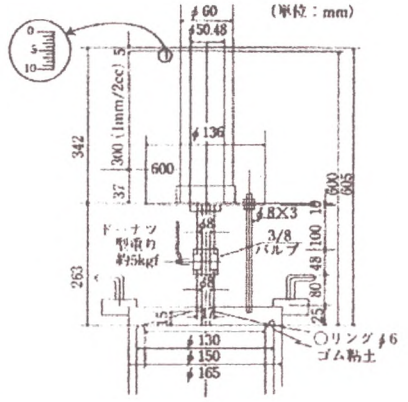


Figure 4 On-site permeability test machine

Table 5 Functional recovery experiment conditions

TRIAL YARD	**This System**	■Construction Area = Width x Extension =4m x 12 5m=50m^2 ■Block Form: Straight type Vertical x Horizontal x Thickness =198x98x80mm ■Laying Pattern: Herringbone Bond (90degree) ■Air Void of Surface course: Total air void 28.4%, Continuation air void 20 8% ■Air Void of Binder course: Total air void23.6%, continuation air void 16 8%
	Drainage Asphalt Pavement	■Construction area = Width x Extension =4m x 12 5m=50m^2 ■Pavement Structure: Drainage asphalt mixtures 50mm, ■Aggregate-particle-size of Drainage Asphalt Mixture :13-0mm ■Air Void of Drainage Asphalt Mixture: Total air void 20.0%, Continuation air void 14 6% ■ Kind of asphalt: High viscoelastic improved asphalt
THE REAPPEARANCE METHOD OF VOID FLLING		■Sprinked muddy water[water: black soil =15:1 (specific gravity under oven dry condition ratio)]12kg/m^2,and carried out natural dryness.
THE WORK CONDITIONS OF DRAINAGE FUNCTIONL RECOVERY VEHICLE		■Washing water pressure: 8N/mm^2 ■Work speed: 24m/min
MEASURING METHOD OF DRAINAGE FUNCTION		■ It measured with the on-site permeability test shown in Figure 5.
MEASURING METHOD OF VEHICLES NOISE		■It was based on the Japanese Automobile Tire Association Standard (JASO C 606). (Noise meter position: 7.5m from vehicles center, height 1 2m) ■Test Vehicle: Passenger car 1600cc/ Gasoline engine /Radial-tire

(2) Experiment result

An example of an experiment result is shown in Figure 5 and Figure 6. The drainage function of these results to this system and vehicles noise reduction effect are considered to be very equivalent to drainage nature asphalt pavement by actual from early stages of for actual service. Voids -- getting blocked -- even when these functions fall, it is considered that it is recoverable using the drainage functional recovery vehicle for drainage asphalt pavement according to the condition.

Moreover, the disappearance depth of joint sand by washing work of a drainage functional recovery vehicle is about 15mm from the block surface, and even when it carries out traffic opening immediately

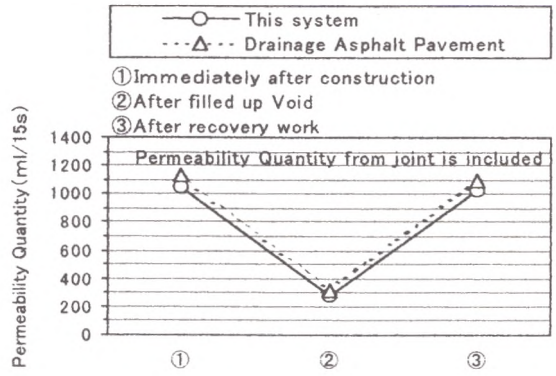


Figure 5 Drainage Functional Measurement Results

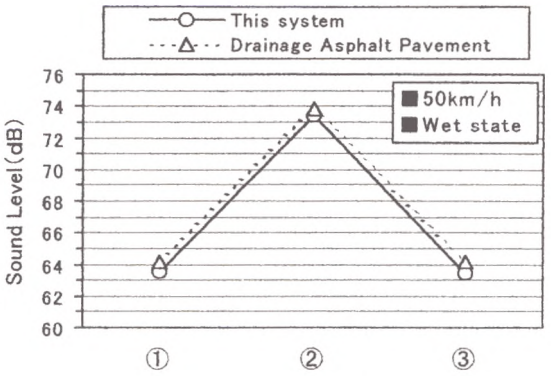


Figure 6 Noise Measurement Results

(3) Evaluation

This system has possible and effective application of the functional recovery vehicle for drainage asphalt as the recovery measure, when drainage function and noise reduction effect fall increased.

3. 3 Performance Evaluation by On-site Pursuit Investigation

Authors are carrying out pursuit investigation of the spot for this system constructed on the driveway of the Hiroshima-shi Yokogawa shopping center in June, 1997 for the purpose of the evaluation of pursuit investigation.

(1) An on-site outline

An on-site situation is shown in a photo 3. The on-site outline including pavement structure is as being shown in Table 6.

(2) Investigation schedule

Five investigations are planned in 5 years from use start . It is in the stage which the investigation for the 1st year has ended after the present use.

(3) Investigation item

Investigation carried out about seven items shown in Table 7.



Photo 3 The Hiroshima-shi Yokogawa shopping center

(4) Investigation result

① Drainage function

The result of on-site Permeability examination is shown in Figure 7 Permeability volume was immediately after construction 466ml per 15 seconds, and was 150 ml per 15 seconds from use start at the time of 1 year progress. However, this numerical value is permeability volume only from the block surface, and it from joint does not contain. Now, the on-site drainage examination method of the interlocking block pavement in Japan is not established. When the on-site permeability test method specified by drainage nature asphalt pavement is applied as it was for the reason, since joint sand

flows out at the time of an examination, there is a problem that examination. Therefore, after performing a joint portion provisionally waterproofing processing to 5mm depth, the permeability function only from the block surface was evaluated. As compared with the permeability (900ml per 15 seconds or more recommended) immediately after construction of the drainage asphalt pavement with common permeability volume. However, the drainage function of the surface (block + joint sand) of this system including permeability volume from joint is considered being almost equivalent to drainage asphalt pavement over long-term use from immediately after construction.

Table 6 On-Site Outline

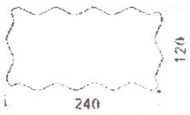
TOTAL LENGTHN		345m
CONSTRUCTION AREA		About 2,000 m^2
BLOCK	**Form**	Wave type block  (mm)
	Thickness	80mm
	Laying Pattern	Herringbone Bond (45degree)
JOINT SAND		Silica Sand (Maximum size 2.5mm,FM4.21,75 μ m≦0 18%)
BEDDING COURSE	**Kind**	Small particle-diameter crushed stone (Maximum size 5mm, FM4.58, 75 μ m≦4.4%)
	Thickness	20mm
Non-PERMEABILITY LAYER	**Kind**	Dense Particle-Size Asphalt Concrete
	Thickness	40mm
BASE COURSE	**Kind**	Rough particle-size asphalt concrete
	Thickness	100mm
SUBGRADE		Design CBR=6%
DESIGN TERM		10 years
AMOUNT OF DESIGN TRAFFIC		1,000,000 wheels as total 5ton conversion wheels.
DESIGNING METHOD		CBR-TA Method

Table 7 Investigation item

INVESTIGATION PURPOSE	INVESTIGATION ITEM	MEASURING METHOD AND MEASURMENT APPARATUS
EVALUA-TION OF DRAINAGE FUNCTION	Permeability quantity	On-site Permeability Test Machine Method
	Existence of a surface outflow	Visual observation at the time of heavy rain
NOISE REDUCTION EFFECT EVALUA-TION	Vehicles Noise	It is based on the Japanese Automobile Tire Association Standard (JASO C 606). (Noise Meter position: 7.5m from vehicles center, height 1 2m)
SURFACE EVALUA-TION	Rutting depth on the surface of pavement	Crossing Profile Meter method
	Surface regularity of pavement	3m Vertical-section Profile Meter method
	Skidding Resistance	Dynamic Friction Tester method
		It is based on "ASTM E303: Measurement of the slide resistance, Portable Skid Resistance Tester.
	Distress of Block	Distress form and the number of distress are viewing-observed about all numbers.

Table 8 Existence of Rain and Surface Puddle

Date	The term for actual service	24 hour rainfall (mm) *	A maximum of 1 hour Rain (mm) *	For a maximum of 10 minutes Rain (mm) *	Existence of surface puddle
1997.28 Jun.	Soon after construct-ion	136.5	24.0	8.5	Nothing
1998.22 July	1 year and 1 month	53.5	38.5	22.0	Nothing
1999.21 Sep.	2 years and 3 months	62.0	46.0	16.5	Nothing

The Hiroshima Local Meteorological Observatories observation

Next, the observation result of the existence of surface pool in rain data and this system at the time of the heavy rain in the spot is shown in Table 8. Even when this system passed 2-year 3 months from use start, it checked maintaining the drainage function of not having generated the puddle to the surface but having excelled very much at the time of rain. The function of the drainage layer (block + joint sand + bedding course) which guessed from this result and the past research result, and included the bedding course of this system is beyond drainage asphalt pavement.

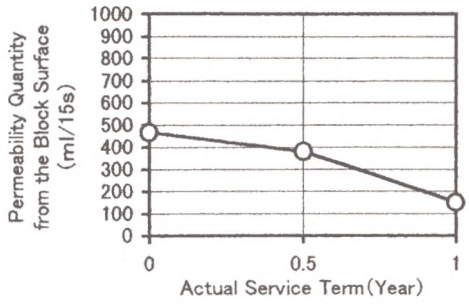


Figure 7 On-site permeability test results

② Noise reduction effect

The measurement result of traffic noise is shown in Fig 8. The vehicles noise level in the dry state in this spot is 70.7 (dB) in the time of being immediately after construction and passing from 68.4 (dB) and use in 1 year. And it checked that there was noise reduction effect as compared with the traffic noise level(73～79dB) in the dryness state immediately after construction of general dense particle-size asphalt pavement.[5]

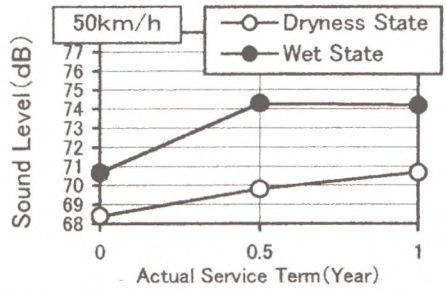


Figure 8 Noise Measurement Result

③ The shape of surface nature

Almost all the "amounts of Rut" when passing after use in 1 year are zero, and its flat nature is also good. Moreover, when measuring slide resistance with a portable skid resistance tester at the time of after use 1 year progress, it is 56.8 BPN (wet). And the dynamic friction coefficient value by the dynamic friction value tester, it is 0.57 μ m. It is shown that this has slide resistance bigger than general dense particle-size asphalt pavement. Furthermore, even when it will pass in 1 year, it is not generated at all and breakage of a block has not produced the spill of joint sand, either. From the above result, it was judged that the shape of good road-surface nature was maintained to run vehicles.

④ Others

When passing from use start in 1 year, as a result of performing listening comprehension investigation about this system to a road user, or along-the-line residents and also road administrators, such. Compared with the dense particle-size asphalt pavement before modification, the town became bright. The water shuttlecock by vehicles is lost and it becomes easy to walk along a sidewalk. The noise which vehicles generate became small. The brake of a vehicle came to be effective. A hand does not start maintenance management. High evaluation was obtained.

(5) Evaluation

It is considered that the shape of a drainage function, noise reduction effect, and road-surface nature is good, and can be applied to the driveway of designed traffic to number of total 5ton conversion wheels 1,000,000 wheels.

4. CONCLUSION

When this system applied to the driveway of the amount of design traffic to number of total 5 ton conversion 1,000,000 wheels judging from the run experiment result using a load simulator. It was judged that this system was a system, which can provide effective street space in "preservation of the life environment" and "reservation of safety" which can be expressed with the improvement

5. A FUTURE EXAMINATION SUBJECT

It is based on a series of experiment result so far and an on-site pursuit investigation result, and the subjects which should be examined from now on are described below.

① Since it has a bedding course by the thing which this system has that void filling by mobilization of summer is not generated, and joint, and small particle-diameter crushed stone, drainage asphalt pavement excels. However, although the on-site permeability test method in drainage asphalt pavement has diverted provisionally as the evaluation method of the drainage function in the realizing space of this system. Therefore, it is considered that the evaluation method suitable from now on needs to be examined.

② Validity at the time of applying the drainage functional recovery vehicle in this system developed for drainage asphalt pavement as the maintenance method of drainage and a noise reduction function. However, realizing space can consider that a difference arises in recovery effect by functional recovery work time. Examination about functional recovery work time is due to be carried out from now on. It is due furthermore, to check also about the validity of a simple functional recovery machine from now on.

③ It is under examination also about the system by waste recycling from the viewpoint of "earth-environment preservation". For example, the system which used city refuse slag and sewer sludge slag as substitution of bone material. The system which used “Ecological Cement” which manufactured city refuse incineration ashes and sewer sludge made as mane materials.

④ It is under examination to expand application to the permeable pavement with the function of “Heat Island” control and regulating underground water.

6. CONCLUSION

"Low noise drainage interlocking block pavement system" are establishing positioning as one technology of the drainage nature pavement using the interlocking block, and further future spread is expected. Authors advance accumulation of various data further focusing on an on-site pursuit investigation or an on-site experiment, and want to aim at establishment of the design and construction / management

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