Report for the Study on the Stripping of Intermediate Course Mixture Used for Industrial Roads (Interim Report)

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ABSTRACT : With porous pavement, early destruction is observed due to the infiltration of rainwater to the intermediate course which is a unique feature of this type of pavement. Such destruction is said to be attributable to the declined strength of the intermediate course, in turn caused by stripping of the binder in the asphalt mixture, making improvement of the durability of the intermediate course desirable. The present study monitored pavement applied to an extremely busy trunk road, which is an artery for physical distribution and is prominently used by large vehicles, for a period of two years. The study involved various porous paving methods with different levels of water shut-off performance at the intermediate course surface. The study found that the durability of pavement considerably varied based on a different level of water shut-off performance and verified that the water shut-off function at the intermediate course surface was highly effective to reduce the pavement lifecycle cost.

KEY WORDS : Porous pavement, water shut-off, stripping resistance, binder course mixture, pavement repair

1. INTRODUCTION

Porous pavement is capable of preserving the visibility on the road and controlling hydroplaning by means of preventing the splashing and misty scattering of rainwater through drainage via the porous pavement as shown in Figure 1 instead of draining rainwater from the road surface in the case of dense pavement. It is also capable of reducing the contact noise between the tyres and the road surface and its use is growing in Japan.

In recent years, however, there have been many reports of the early destruction of porous pavement due to the decline of the water shut-off function in the layer immediately below the porous pavement (hereinafter referred to as "the intermediate course surface") which is caused by the unique function of this paving method to drain rainwater through voids inside the pavement. The main factor causing such destruction is stripping of the asphalt binder at the intermediate course surface by water passing through the porous pavement.

While the normal relaying cycle of the surface course is approximately 10 years, this destruction may occur within one year of the original paving work. There are cases of the relaying of porous pavement after a much shorter time than the relaying cycle of dense pavement with an impermeable surface course.

Against this background, the present follow-up study was conducted with porous pavement constructed in 2007 at a trunk road characterised by a heavy traffic volume and high level use by large vehicles for the purpose of verifying the effectiveness of the water shut-off function of the intermediate course surface.

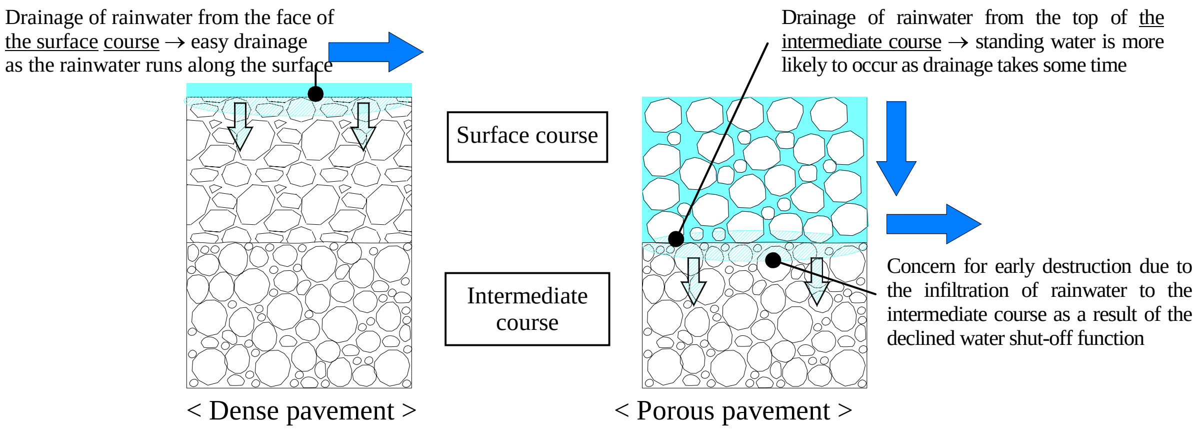


Figure 1 : Different drainage mechanisms of dense pavement and porous pavement

2. OVERVIEW OF THE STUDY SITE

2.1 Characteristics of the Study Site

National Route 23, the subject road of the Study, serves as a physical distribution route for the car industry (Figure 2), which is a major industry in Japan, and experiences high levels of traffic volume and large vehicle ratio. According to the road transport census in 2005, 46,000 vehicles a day used this road with a large vehicle ratio of 30%. When small trucks are included, the ratio is as high as 45% (Photograph 1). The meteorological conditions are a high temperature and high humidity which are standard in Japan. Especially in summer, the pavement is greatly affected by these meteorological conditions as hot and wet conditions continue day after day because of the strong effect of a high pressure system over the Pacific Ocean.

Figure 2 : Location of the study site

Photograph 1 : Scene of traffic flow heading towards Nagoya at the study site

The Study features a driving lane which is part of the arrangements for grade separation work at the Anjo Grade Separation Project Site of the Chiryu Bypass of National Route 23 where the original four lanes have been separated to allow work at the central zone as shown in Figure 3.

Even though the pavement of this road site has only been used for two years, partial rutting has already occurred at an intersection (Photograph 2) where the frequency of stopping and starting by large vehicles is very high.

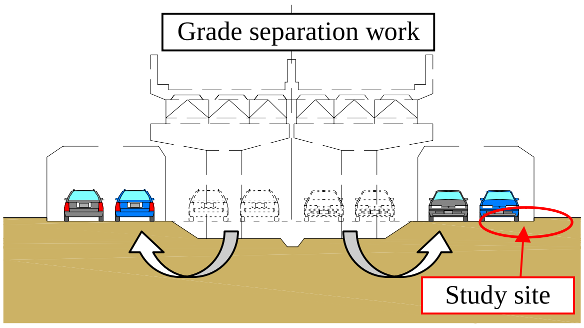
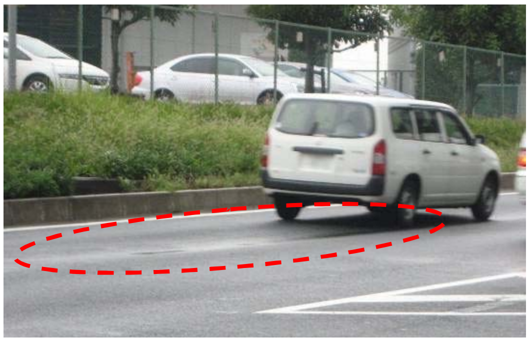


Figure 3 : Road usage at the study site



Photograph 2 : Occurrence of rutting near an intersection

2.2 Pavement Configuration

Table 1, Table 2 and Figure 4 show the design conditions and configuration of the subject pavement of the Study. For the traffic volume category, the highest volume specified by the design standards is employed and the design period is set at six years, taking the period of the temporary use of this road section into consideration.

Two types of surface course are introduced: standard porous asphalt pavement (hereinafter referred to as "standard porous pavement") and water shut-off type porous asphalt pavement (hereinafter referred to as "water shut-off type porous pavement"). Two types of intermediate course mixture are introduced: Type II polymer modified coarse graded asphalt mixture suitable for a heavy traffic volume and coarse graded asphalt mixture with asphalt rubber where rubber grains are added to straight asphalt (the dynamic stability (DS) value of both mixtures is above 5,000 times/mm which is the specified value for a heavy traffic section). The DS value is an indicator of the fluidity resistance and a higher value means a higher level of fluidity resistance.

Of these pavement configurations, water shut-off type porous pavement which is expected to show an excellent performance is briefly explained next.

Table 1 : Pavement design conditions

Item	Value
Design traffic volume for pavement (traffic volume of large vehicles)	≥3,000 vehicles/ day- each way
Design period	6 years
Design CBR	6%

Table 2 : Pavement configuration (surface course and intermediate course)

Pavement Code	Surface Course	Intermediate Course
A-MA	Standard porous pavement	Type II modified polymer
B1-MA	Water shut-off type porous pavement	Type II modified polymer
B2-AR	Water shut-off type porous pavement	Asphalt rubber

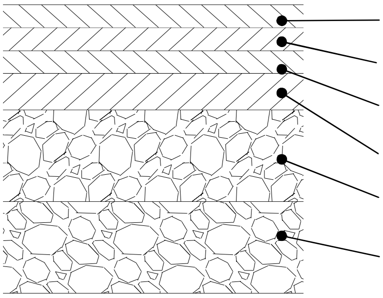


Figure 4 : Configuration of the subject pavement of the Study

2.3 Outline of Water Shut-off Type Porous Pavement

With the water shut-off type porous paving method, porous pavement is created by laying a porous asphalt mixture, while a large quantity (1.2 litres/m^2) of highly concentrated modified asphalt emulsion is uniformly sprayed for immediate decomposition using an asphalt finisher equipped with an emulsion spray system as shown in Figure 5. The application of this method has been increasing in recent years.

The porous pavement created by this method has such functions as enhanced water shut-off and improved binding with the intermediate course in addition to the conventional functions of porous pavement as shown in Figure 6.

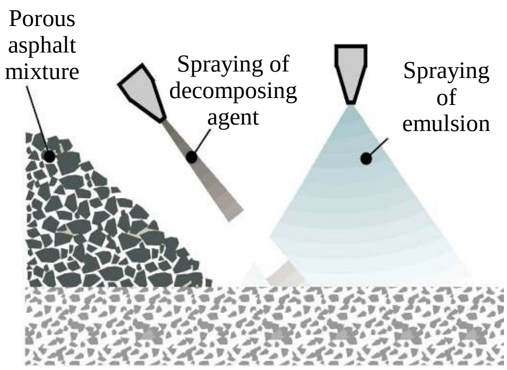


Figure 5 : Rough working drawing of water shut-off type porous pavement

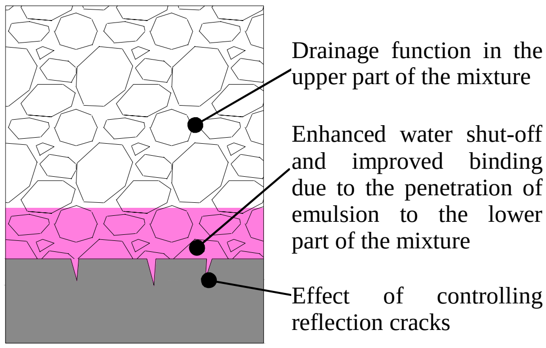


Figure 6 : Characteristics of water shut-off type porous pavement

3. STUDY RESULTS

3.1 Study Items

The items studied or tested are listed in Table 3.

Table 3 : List of Study / Test Items

Item	Purpose
Visual observation	Visual observation of the state of the road surface
Measuring of degree of deflection (FWD)	Confirmation of the bearing strength of the pavement body (secular changes)
Binding strength test	Confirmation of the binding performance between the surface course and intermediate course
Pressurised permeation test	Confirmation of the impermeability of the intermediate course
Pressurised stripping acceleration test (Motomatsu et al. 2004)	Visual observation of the future prospect of stripping (facilitation of stripping) by means of facilitating the degradation (stripping) of the asphalt
Compression splitting test	Judgement on the applicability of porous pavement as the intermediate course by means of calculating the ratio between the residual pressurised tensile strength in the pressurised stripping facilitation test and the standard pressurised tensile strength prior to the facilitation of stripping

3.2 Visual Observation

The visual observation of the present state of the pavement did not find stripping even though rutting was observed at an intersection where the traffic conditions are severe. The investigation to check the state of the pavement below the surface course using cut out specimens found similar rutting with the intermediate course, indicating that the subsidence of this course in the form of rutting manifested in the surface course (see Figure 7).

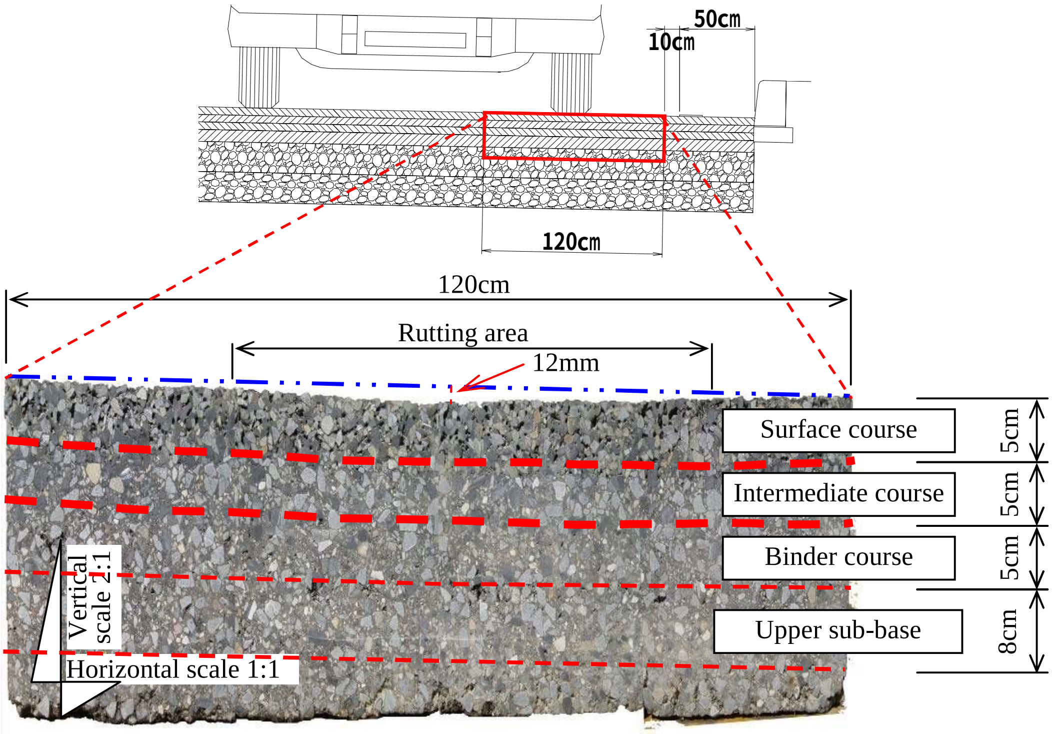


Figure 7 : Example of cross-section of the pavement at the study site (B2-AR)

3.3 Measuring of the Amount of Deflection (FWD)

The measuring results of the amount of deflection are shown in Figure 8.

The amount of deflection has increased by 10% for standard porous pavement (A-MA) and by 2% - 4% for water shut-off type porous pavement (B1-MA and B2-AR), suggesting that the degradation of pavement has progressed faster with standard porous pavement that water shut-off type porous pavement.

3.4 Binding Strength Test

The binding strength test was conducted to establish the degree of degradation of the intermediate course due to the declined bearing strength between the surface course and intermediate course and the results are shown in Figure 9.

In the case of standard porous pavement, a some 40% decline of the binding strength is observed with both non-rutting and rutting areas. When core specimens were taken, some of the specimens did not even have bound surface and intermediate courses. As this suggests the existence of areas where the surface course and intermediate course is not properly bound, the actual binding situation is judged to vary much more extensively than the test values indicate.

In the case of water shut-off type porous pavement, the decline of the binding strength is 20% with non-rutting areas and 30% with rutting areas, registering a smaller rate of decline than standard porous pavement. The value of the binding strength was water shut-off type porous pavement ranges from 160% to 290% of the corresponding value with standard porous pavement. The fact that the surface course and intermediate course are perfectly bound with all of the specimens collected suggests a long duration of uniform binding strength with this type of pavement.

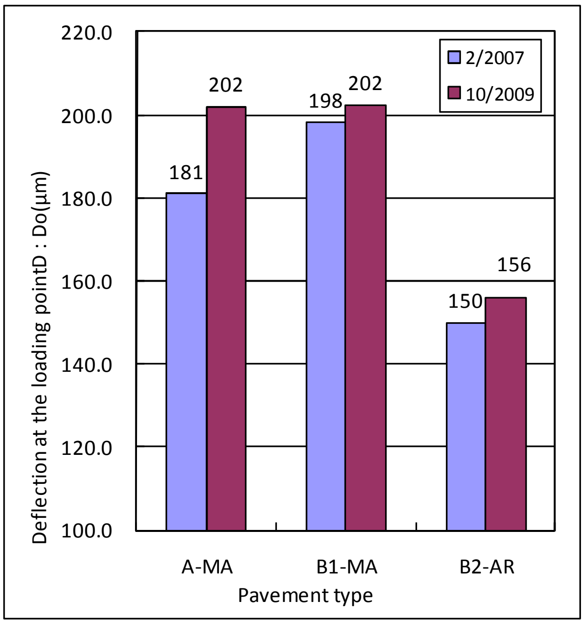


Figure 8 : FWD survey results

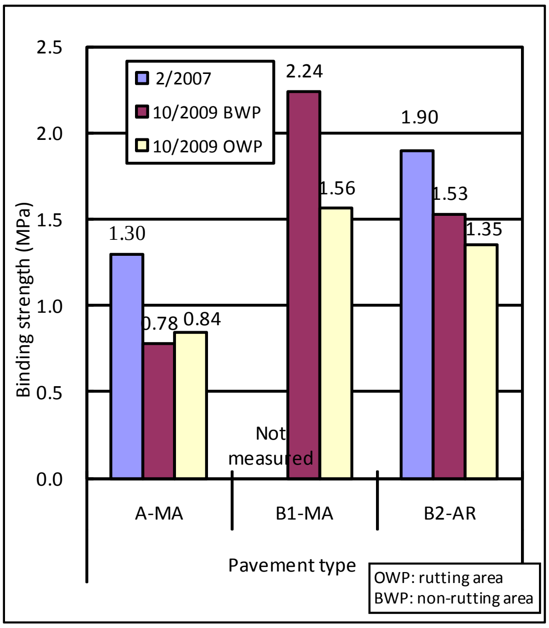


Figure 9 : Binding strength test results

3.5 Pressurised Permeation Test

The pressurised permeation test was conducted to confirm the impermeability of the intermediate course and the test results are shown in Table 4. With all types of pavement, the impermeability improved with the passing of time. While the water shut-off type porous pavement shows impermeability of 1.00×10^{-10} or lower, standard porous pavement shows a value of $4 \sim 7 \times 10^{-7}$.

Table 4 : Pressurised permeation test results

Sampling Time and location	Pavement type		
	A-MA	B1-MA	B2-AR
Feb., 2007	7.10E-05	1.30E-07	Impermeable
Oct., 2009 BWP (Rutting Area)	6.95E-07	Impermeable	Impermeable
Oct., 2009 OWP (Non-Rutting Area)	3.84E-07	Impermeable	Impermeable

3.6 Pressurised Stripping Acceleration Test and Compression Splitting Test

The pressurised stripping acceleration test was conducted for the visual checking of stripping and the residual tensile strength and standard tensile strength prior to the acceleration test were calculated based on the compression splitting test so that the future possibility of stripping could be inferred through their comparison. The outline and results of these tests are described next.

The results of the pressurised stripping acceleration test which explores the future possibility of asphalt stripping, are shown in Table 5. This test was originally proposed in the past study by Motomatsu and others (Motomatsu et al. 2004) and is characterised by the fact that the tensile strength test can be performed using specimens which have undergone the pressurised permeation test. Judgement on the test results is based on the visual observation of the state of stripping.

The tests under the Study found a high level of stripping with standard porous pavement and a relatively low level of stripping with water shut-off type porous pavement. Stripping in the case of standard porous pavement in particular was visible prior to the test and was greatly aggravated after the test, confirming the effectiveness of the water shut-off function at the surface of the intermediate course.

Table 5 : Results of the pressurised stripping acceleration test

Indicator		Pavement type	Oct., 2009 BWP (Rutting Area)	Oct., 2009 OWP (Non-Rutting Area)
			Specimens 1 & 2	Specimens 1 & 2
State of stripping	Standard	A-MA	None, low	Low, low
		B1-MA	None, none	None, none
		B2-AR	None, none	Low, low
	Residual	A-MA	Small, small	High, high
		B1-MA	None, small	None, none
		B2-AR	None, small	Low, medium

Legend for the level of stripping

High	:	Stripping is observed with most of the coarse aggregates.
Medium	:	Stripping is observed with approximately half of the coarse aggregates.
Low	:	Slight stripping is observed with the coarse aggregates.
None	:	No stripping is observed with the coarse aggregates.

The compression splitting test was conducted next to judge the applicability of porous pavement as an intermediate course by means of calculating the ratio between the residual tensile strength after the pressurised stripping acceleration test and the standard tensile strength before the said acceleration test. The results are shown in Figure 10 and Table 6.

Both types of water shut-off type porous pavement (B1-MA and B2-AR) are judged to be excellent in terms of the tensile strength ratio as the decline of this ratio is small for both. In the case of standard permeability pavement (A-MA), both the rutting area and non-rutting area fall in areas where caution is required for the application of porous pavement (hereinafter referred to as "area requiring caution"). At the rutting area, the residual tensile strength ratio falls below the 50% level, indicating a major progression of pavement degradation in the coming years.

An area requiring caution corresponds to the evaluation criterion established on the basis of those specimens with which stripping was observed in a past study (Motomatsu et al. 2004)

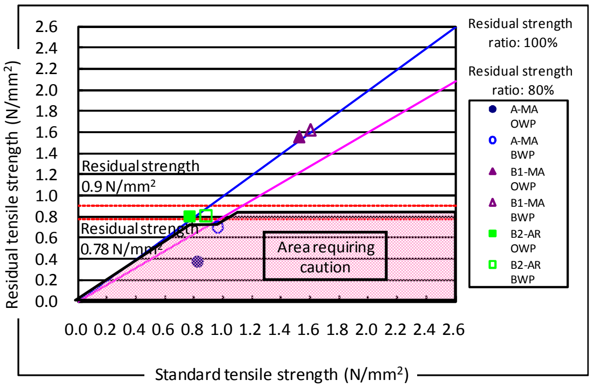


Figure 10 : Calculation of the residual strength ratio

Table 6 : Compression splitting test results

Pavement type	Tensile strength		Residual tensile strength ratio	Judgement
	Standard	Residual		
A-MA OWP	0.823	0.376	45.7%	Caution required
A-MA BWP	0.963	0.701	72.8%	Caution required
B1-MA OWP	1.525	1.556	102.0%	Good
B1-MA BWP	1.603	1.620	101.1%	Good
B2-AR OWP	0.771	0.800	103.8%	Good
B2-AR BWP	0.883	0.807	91.4%	Good

OWP: rutting area BWP: non-rutting area

3.7 Laboratory Test Results

The laboratory test results are shown in Table 7 and these test results have revealed the following facts.

(1) There is a great difference in the state of pavement degradation depending on the existence or non-existence of a water shut-off layer above the surface of the intermediate course.

(2) In the case of standard porous pavement, the results of various tests suggest that asphalt degradation has started at the surface of the intermediate course. In particular, the amount of FWD deflection and decline of the binding strength are larger than those of water shut-off type porous pavement, indicating a decline of the durability. The pressurised stripping acceleration test results indicate the prospect of major degradation of pavement in the coming years.

(3) The binding strength test, pressurised stripping acceleration test and compression splitting test have confirmed that water shut-off type porous pavement maintains high levels of durability and water shut-off performance.

Table 7 : Changes since the time of construction

Item	A-MA	B1-MA	B2-AR
Rutting	↘	↘	↘
FWD deflection	↘	→	→
Binding strength	↓↓	-	↓
Pressurised permeation	→	→	→
Pressurised stripping (strength ratio)	↓↓	→	↘
State of stripping	High	None	Small

Legend : → unchanged; ↓ decline; ↓↓ major decline; ↘ slight decline

4. KEY FINDINGS

Rutting of the surface course of porous pavement originates from rutting (fluidisation) of the intermediate course. Rutting of the intermediate course not only accelerates stripping of the asphalt through its accumulation of rainwater on the surface but also damages the strength of the intermediate layer. This situation then leads to the premature functional decline of porous pavement and deterioration of the road surface properties, eventually resulting in destruction of the pavement.

What is crucial to maintain porous pavement in a sound state is (i) preservation of the soundness of the surface layer through improved durability of the intermediate course to contain the occurrence of rutting and (ii) preservation of the soundness of the pavement with the intermediate course and below through an improved water shut-off performance at the surface of the intermediate course to prevent the infiltration of rainwater to the intermediate course and below. The findings of the Study clearly suggest that the types of improvement mentioned above prolong the service life of pavement.

5. CONCLUSION

The results of tests conducted for the Study show that the state of pavement can differ for different types of pavement even after only two years and that such difference may further widen with the passing of time. The superiority of water shut-off type porous pavement with its excellent function of preventing water permeation to the intermediate course indicates that the water shut-off performance at the intermediate course surface affects the durability of the entire pavement. As standing water in the rutting area of the intermediate course surface accelerates stripping of the asphalt, containment of the occurrence of rutting through the construction of an intermediate layer with a high level of fluidity resistance should prove effective for the improvement of pavement durability.

The above findings indicate that the preservation of a sound intermediate course through an improved water shut-off performance and durability can prolong the service life of pavement. Reduction of the repair frequency and need to only repair the service course mean a shorter period of traffic control necessitated by repair work, reducing economic loss. Moreover, reduction of the overall maintenance cost helps reduce the lifecycle cost of pavement.

At the study site, the road section in question will continue to function as part of a trunk road serving a heavy traffic volume. As such, further progression of the deformation of the pavement is predicted to take place. It is, therefore, necessary to conduct a continuous study to check the water shut-off performance and durability of the intermediate course with a view to verifying that the soundness of the intermediate course has a major implication for the service life of porous pavement. It is hoped that global standards for porous pavement will eventually be developed through such study.

REFERENCE

Motomatsu , S., Kamiya , K., Matsumoto , D.and Yamada , Y., 2004. *Evaluation of Stripping Resistance for Existing Binder Course Mixture*. Collection of Pavement Engineering Papers Vol. 9, Japan Society of Civil Engineers.