A Porous Surface Mastic Asphalt Course on the Honshu-Shikoku Bridge Expressway

A. Inoue
TOA ROAD CORPORATION, *Tsukuba, Ibaraki, Japan*
F. Nakamura, Y. Sugimoto
Honshu-Shikoku Bridge Expressway Company Limited, *Naruto, Tokushima, Japan*
M. Nomura, H. Takeuchi
TOA ROAD CORPORATION, *Naniwa, Osaka, Japan*

ABSTRACT: The Honshu-Shikoku Bridge Expressway Company Ltd (HSBE). was established in October 2005 following the privatization of the Honshu-Shikoku Bridge Authority, and placed in charge of the Honshu-Shikoku Bridge Expressway. This expressway consists mainly of a chain of three long span bridges connecting Honshu with the island of Shikoku. It has passed 25 years since its construction and a systematic and effective maintenance program has been carried out on Kobe-Awaji-Naruto route of Honshu-shikoku Bridge Expressway. As a part of the maintenance program, porous surface mastic asphalt was experimentally applied to shorten paving times and provide cost reduction. It is laid with an asphalt finisher in combination with an emulsion sprayer. The equipment sprays a large volume of a newly developed, modified asphalt emulsion with high content that rapidly decomposes to form a single sheet of porous asphalt with an impermeable layer. No additional steps need to be taken to create the impermeable layer and it has proved to be an efficient repair method that can be easily modified depending on the soundness of existing surface, and thus can be employed as an alternative to complete pavement replacement. This report describes the results of the preliminary survey carried out to ascertain the practicality of porous surface mastic asphalt. The results of a follow-up survey performed after the application of this new asphalt will also be presented.

KEY WORDS: impermeability, adhesion improvement, moderation of stress

1 INTRODUCTION

The Honshu-Shikoku Bridge Expressway Co. Ltd. (HSBE) manages and operates the Honshu-Shikoku Bridge Expressways (Fig. 1), which have three routes and consist of the long span bridges connecting the island of Honshu with the island of Shikoku. The HSBE was established in October, 2005, through the privatization of the Honshu-Shikoku Bridge Authority. These expressways have an essential role as main arteries for traffic in the Seto Inland Sea region.

Naruto Operation Center has responsibility for the operation of the Ohnaruto Bridge section (between the Tsuna-Ichinomiya Interchange and the Naruto Interchange; below, “the Ohnaruto section”), an approximately 45-km length of the Kobe-Awaji-Naruto Expressway.

This section has two lanes in each direction and handles a mean cross-sectional daily traffic volume of around 20,000 vehicles, including a rate of heavy vehicles of about 25%. It has been in service for nearly 25 years. Some parts of the roadway have been re-surfaced several times, and others have never been re-surfaced at all. There are concerns about the poor state of the water resistance and water impermeability of the binder course, which has almost never been replaced. Since 2007, the basic procedure for upgrading has been to use polymer-modified Type II asphalt for the binder course and porous asphalt pavement for the surface course. The many cracks, rutting, ridges and other issues in the Ohnaruto section require urgent and widespread treatment. However, budgetary constraints and complaints regarding the restriction of traffic flow for re-paving have plagued attempts to deal with these issues.

In the search for an efficient method that allows adaptation to the structural soundness of the existing pavement and obviates the complete replacement of the pavement, including the binder course, a method was found that takes advantage of sound existing binder course and provides both the competing functions of water drainage as provided by porous asphalt pavements and water impermeability, the Porous Surface Mastic Asphalt Course (POSMAC). This method was used on an experimental basis during FY2007 and FY2008.

This report presents the results of the preliminary survey and the surveys conducted in the test zone just after and two years after installation to examine the pavement condition and performance in terms of drainage. The data provided by these surveys are short-term, but were used to assess the applicability of this pavement construction method and are therefore reported together in this paper.

2 TEST INSTALLATIONS AND OVERVIEW OF SURVEYS

2.1 Scale of test installations

The locations of the test installations are presented in Table 1 and Figure 1. The POSMAC construction method was employed in these installations in 2007 and 2008, and standard porous asphalt pavement (hereafter, normal section) was also installed in a re-paving operation in 2007.

Table 1: Scale and date of work

Date of work	December, 2007	December, 2007	March, 2009
section	POSMAC section	Normal section	POSMAC section
A construction area	20,034 m^2	15,932 m^2	19,663 m^2
Construction extension	L = 4714 m	L = 3749 m	L = 4627 m
Mean width	4.25 m	4.25 m	4.25 m

Figure 1: Locations of test installations

2.2 Components of pavement

Cross sections of pavement from a normal section and a POSMAC section are shown in Figure 2. In the POSMAC construction method, large quantities (at least 1.2 l/m^2) of a newly-developed highly concentrated modified asphalt emulsifier (hereafter, “the emulsifier”) are dispersed with an asphalt finisher with an emulsion sprayer installed, along with a decomposition agent to force decomposition of the emulsifier. This combination results in a mix providing a porous asphalt pavement. One of the unique features of this pavement is that the emulsifier-containing asphalt component of the undersurface is impermeable, allowing the pavement to be laid in a single layer.

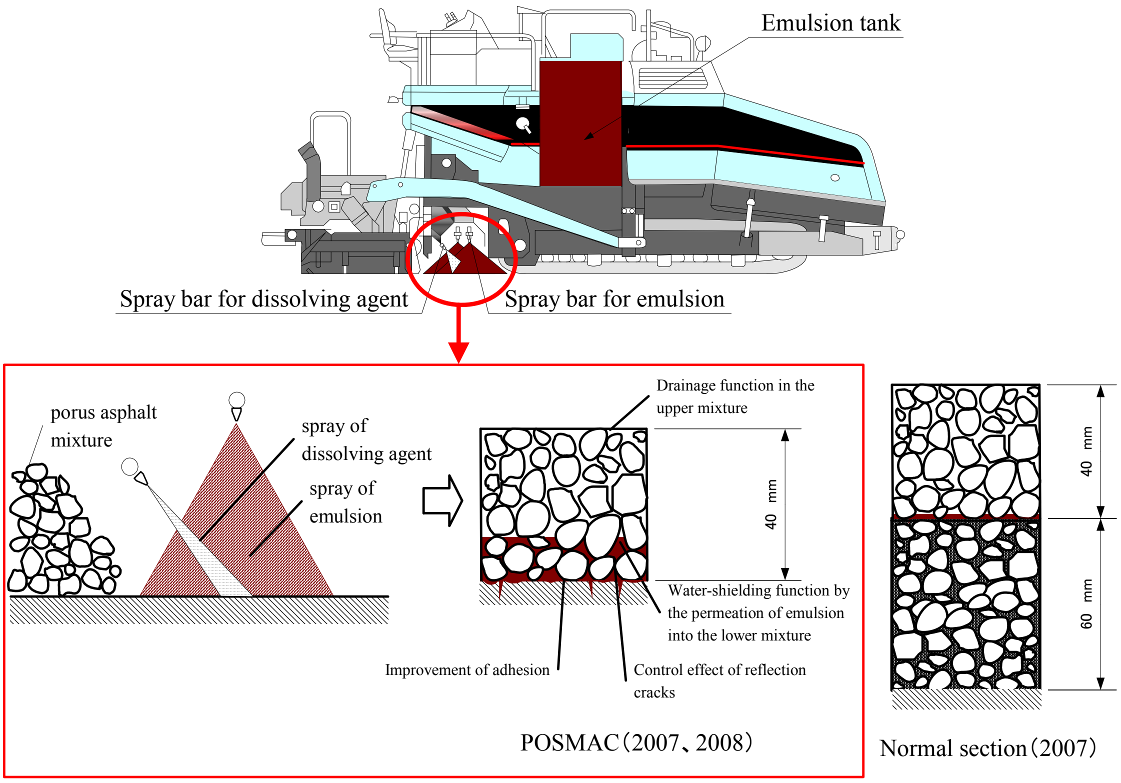

Figure 2: Cross section of pavement

2.3 Objectives of surveys and test descriptions

Surveys were conducted to (1) investigate the effectiveness of the POSMAC construction method, which is expected to reduce costs and improve durability, in addition to fulfilling the functions of conventional porous asphalt pavements, and (2) examine the current serviceability of the existing roadways in terms of their functionality and durability. Specifically, the surveys focused on factors affecting pavement functionality and durability and binder course durability. The test items and the frequency of testing are listed in Table 2.

Table 2: Test items and frequency of testing

Item	Survey item	Frequency	Evaluation item
Investigation concerning pavement performance	Skid resistance	6（Part / section） OWP,BWP,IWP	Skid resistance (BPN = 60 +)
	Flowing amount of 15second	6（Part / section） OWP,BWP,IWP	Flowing amount of 15second (within 6 seconds)
Investigation concerning durability of pavement	deflection	OWP 10m interval	structurally sound
	Crack ratio	All aspects	Surface characteristic
	Rutting	2（Part / section）	Surface characteristic
	Surface smoothness	Each section OWP	Surface characteristic
Investigation of factor that influences durability of binder-course	Split strengeth	3(Times / section) OWP	Stripping Resistance
	Permeability coefficient of existing binder course	3(Times / section) IWP	Sealing Performance
	Tensile strength	3(Times / section) IWP	Coating Performance

2.4 Survey locations

The locations of the POSMAC sections and the normal sections laid in 2007 and 2008 are shown in Figure 3.

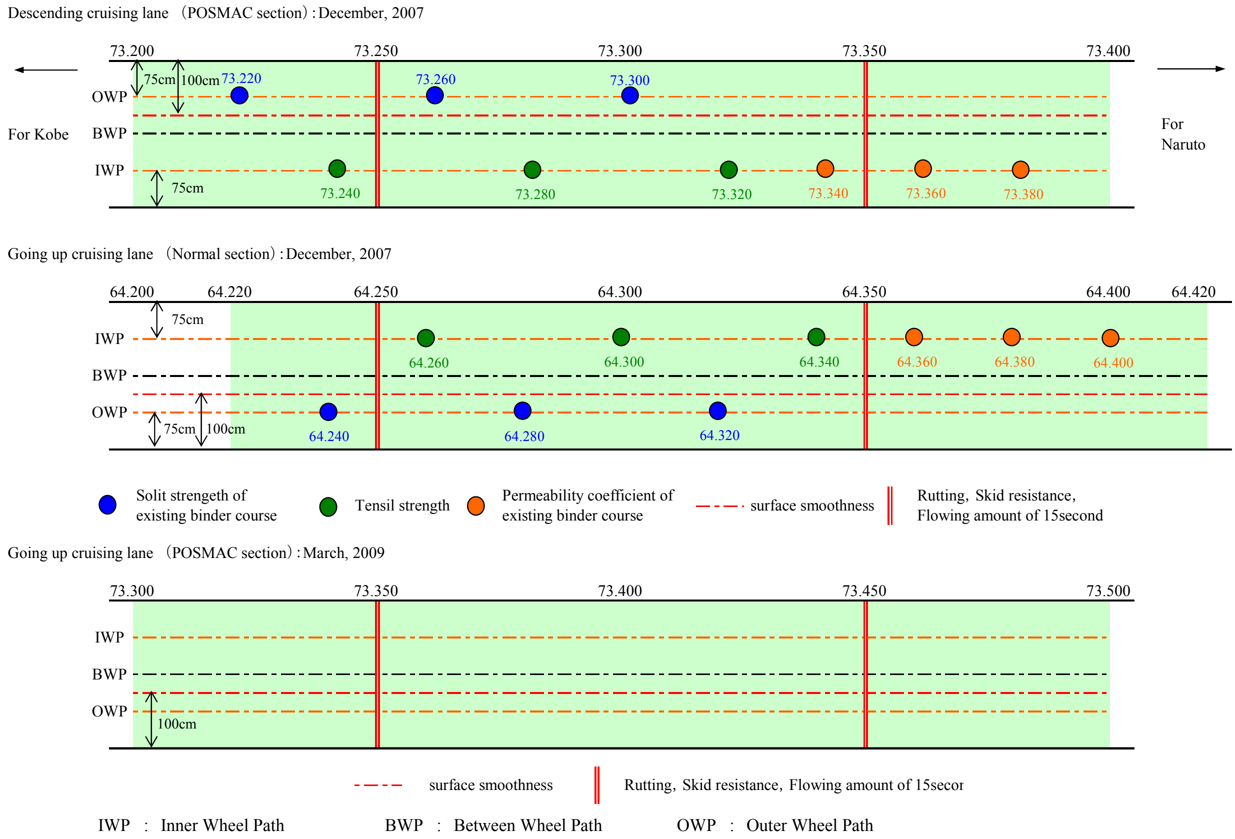

Figure 3: Survey locations

3 SURVEY RESULTS

3.1 Survey of pavement functionality

The skid resistance and water seepage volume per distance marker were measured one year (at the sites paved in 2008) and two years (at the sites paved in 2007) after paving, and were expressed for rutted (IWP, OWP) and non-rutted portions (BWP) of the roadway.

1) Skid resistance
The results of measurements of the skid resistance (BPN) of the road surface taken with a pendulum skid resistance tester are shown in Figure 4. Results indicate that the non-rutted portions have a higher skid resistance, which is the typical finding.

2) Water seepage volume
The results of measurements of the water seepage volume taken with an *in situ* permeability tester are shown in Figure 5. This was slightly higher in the non-rutted portions than in the rutted portions of all of the sections, but there were no large differences. All of the test locations were found to be in good condition after at least a year following installation,

achieving rates of at least 1000 (ml/15 s).

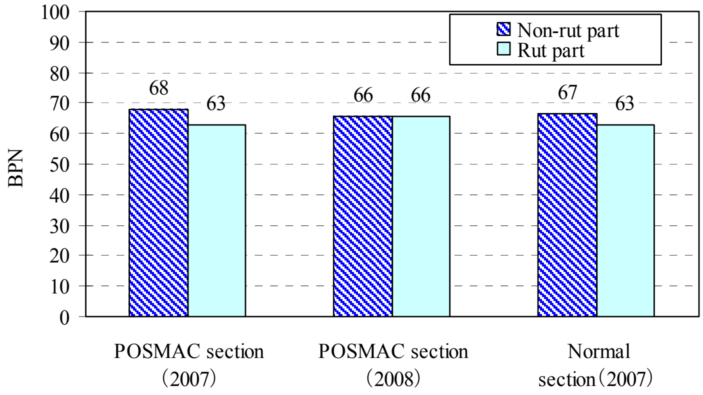

Figure 4: Skid resistance

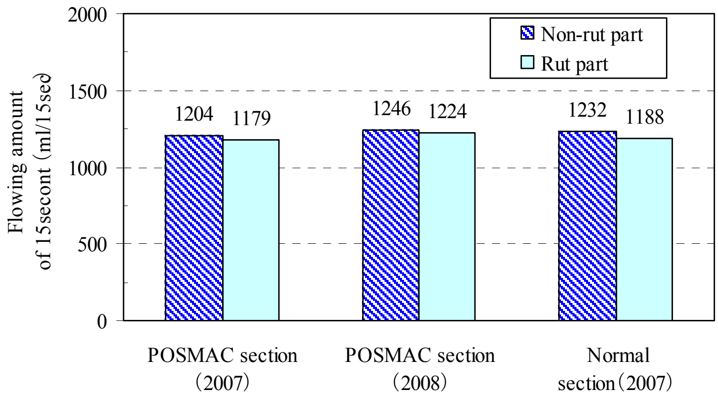

Figure 5: Water seepage volume

3.2 Survey of pavement durability

Measures of pavement durability were calculated using the mean values for each section, and showed changes from year to year.

1) Pavement surface deflection
The maximum, minimum and mean±standard deviation of the pavement surface deflection (D0) before and after installation, obtained by Falling Weight Deflectometer (FWD), are shown in Figure 6. Large fluctuations in deflection were not seen following installation, and the surfaces were in good condition.

2) Surface condition (cracking ratio, rutting, surface smoothness)
The results of rutting and surface smoothness measurements of the road surface are presented in Table 3. No notable differences were found between the normal sections and the POSMAC sections, and the surfaces were in good condition.

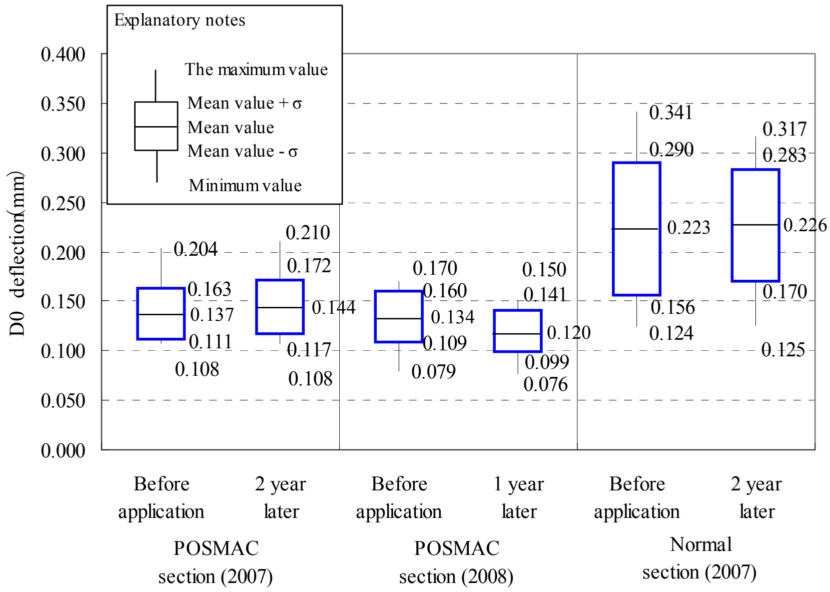

Figure 6: Pavement surface deflection (D0) found by FWD (maximum, minimum, mean, mean±standard deviation)

Table 3 Results of rutting and surface smoothness tests

Investigation time	rutting (mm)			surface smoothness (mm)		
	POSMAC section (2007) *	POSMAC section (2008)*	Normal section (2007)*	POSMAC section (2007)*	POSMAC section (2008)*	Normal section (2007)*
Immediately after application	-	-	-	0.82	0.63	0.70
1 year later	-	4.5	-	-	0.87	-
2 year later	5.2		6.0	0.87		0.87

* ( ): construction year.

3.3 Survey of factors affecting durability of binder course

Tests of factors affecting durability of the binder course were conducted in the laboratory on core specimens collected on site. Yearly changes were calculated for each section, and the results are presented as means for the corresponding measurement location.

1) Split strength
The results of the split strength tests are shown in Figure 7. Both the POSMAC section and the normal section tended to decline in split strength with the length of service, but both retained strengths above 1.0 (MPa), and were in generally good condition.

2) Permeability coefficient
The findings from a pressurized permeability test on sample cores that had been cut to a specified length (existing binder course, 4 cm; POSMAC, 4 cm) are listed in Table 4. From these results, it was confirmed that POSMAC remained impervious two years after installation, showing a high value for impermeability.

3) Tensile strength

The results of laboratory tests of tensile strength are shown in Figure 8. The tensile strength tended to rise just after installation and the tensile strength of POSMAC remained above 1.0 (MPa) after two years of service. Both pavements remained in good condition.

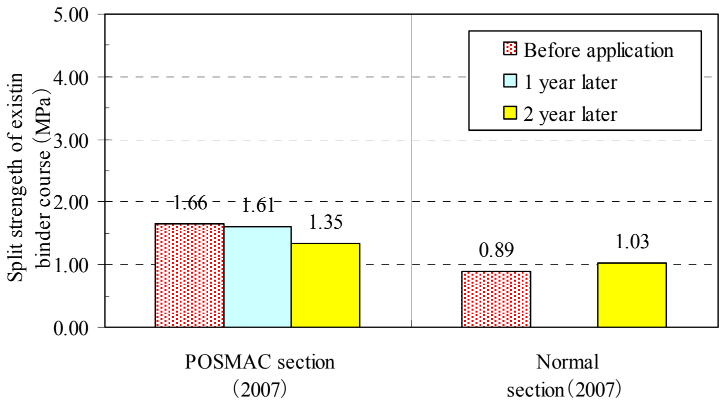

Figure 7: Split test

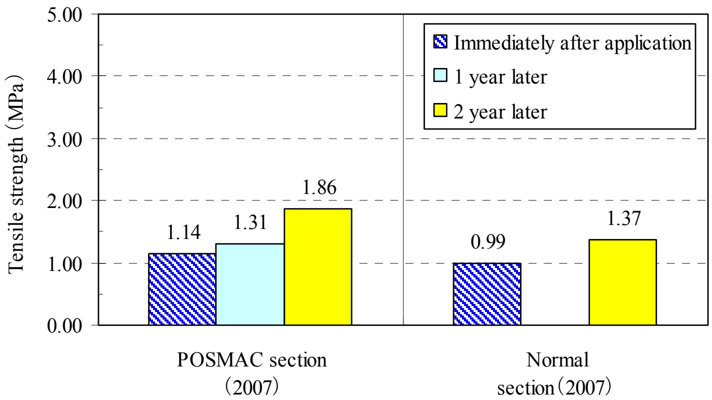

Figure 8: Tensile test

Table 4: Pressurized permeability test

Section	No	Before application	Immediately after application	1 year later	2 year later
POSMAC section (2007)	1	6.16E-07	Impermeable	Impermeable	Impermeable
	2	5.97E-07	Impermeable	Impermeable	Impermeable
	3	Impermeable	Impermeable	Impermeable	Impermeable
Normal section (2007)	1	2.11E-07	-	-	Impermeable
	2	9.45E-07	-	-	5.45E-07
	3	5.46E-07	-	-	6.93E-07

Units: (cm/s)

4 SUMMARY

The following are the results of the surveys conducted over two years after the pavements had been installed.

4.1 Survey of pavement functionality

- Comparison of skid resistance between the POSMAC section and the normal section two years after installation did not show any difference. One year after installation, the skid resistance of the POSMAC section was over 60, indicating it had remained in good condition.

- The two sections showed water seepage rates of around 1200 ml/15 s. No marked difference between the sections was found.

These results indicate that no deterioration in functionality due to the passage of time was present, and the pavements remained in good condition.

4.2 Survey of pavement durability

- Comparison of the pavement surface deflection before installation and one or two years after installation showed no large changes in either the POSMAC section or the normal section. Generally, the pavements retained good load-bearing capacities.

- Measurements of surface conditions (cracking ratio, rutting, and surface smoothness) indicated the following. Rutting was within 10 mm in both sections. The surface smoothness tended to be slightly higher than just after installation, but was still within 0.9 mm; indicating good surface condition. No cracking had occurred in either of the sections.

Thus, it is not currently possible to judge whether POSMAC has better or worse durability than the normal pavement. Both sections remain in good condition from the viewpoint of durability.

4.3 Survey of factors affecting durability of the binder course

- A tendency for split tensile strength to decrease was found in the results of tests performed on the POSMAC section and the normal section. The POSMAC section, however, exhibited a split tensile strength of 1.35 (MPa), in comparison to the 1.03 (MPa) found in the normal section, a factor of about 1.3 in favor of the POSMAC section.

- From the results of the pressurized permeability test, the POSMAC section showed higher imperviousness regarding the pre-existing binder course than the normal section, even after two years. Thus, we can expect to achieve an improvement in impermeability using POSMAC.

- The tensile strength tests indicated a tendency for the strength to increase with time, remaining above 1.0 (MPa), but the normal section showed only about 70% of the strength of the POSMAC section.

The survey of factors influencing durability of the binder course thus indicates an additional point of superiority for POSMAC; however, both sections remain in good condition, and additional follow-up surveys will be necessary.

5 CONCLUSION

The present surveys conducted in the test sections provided results for only two years following installation of the pavements; however, no notable changes in pavement conditions occurred. As for the impermeability capacity required from the POSMAC construction method, the results were satisfactory. We must wait, however, for future surveys to see whether POSMAC suppresses reflection cracks from the pre-existing pavement, which is one of the issues attributed to this method. If the POSMAC method comes into practical use, it will allow the company to offer a more comfortable roadway experience, shortening the times for restricting traffic flow, as well as reducing construction costs and increasing the area of roadway that can be paved in a single day. It also offers an environmental advantage, a reduction in the volume of roadway construction material waste.

The present results were gathered two years after installation of this pavement, and cannot be considered an assessment based on long-term service. Follow-up surveys will be needed to observe changes over a longer time course. The serviceability of this construction method will be verified with long-term data, and its range of applications will also be determined. We look forward to the frank reviews of our readers.

REFERRENCES

S. Motomatsu, et al., 2004. *Research on method of evaluating stripping resistance of existing base-course* , Journal of Pavement Engineering, JSCE, Vol.9, pp.73-79, Japan.

East Nippon Expressway Company Limited, et al.,Volume 2 Method of asphalt pavement relation examination, (2008.8)

Japan road association, Manual of pavement surveys and tests, (2007.6)