Development of Porous Surface Mastic Asphalt Course (POSMAC)

H. Itou, W. Mizuno, Y. Arao, T. Ichioka, Y. Watanabe, T. Shimizu, S. Ohno, T. Ooba, T. Matsumura, K. Asano & H. Tsushima
Technical Study Society of POSMAC, Japan

ABSTRACT: Many recent reports have described the superior performance of porous asphalt pavement in reducing traffic noise, restraining hydroplaning of vehicles in rainwater, and eliminating splashing. The issues unique to this technology have also become more clearly defined with the increase of construction, one issue being the rapid embrittlement of the binder course and lower layers due to water infiltration. Embrittlement causes stripping at the interface between surface and binder course, as well as within the binder course, which can eventually lead to failure of the pavement. To counteract stripping, researchers have created two-layer structures consisting of porous asphalt over an impermeable binder course. However, when reducing work time and costs for rehabilitation is desired, planners prefer more efficient methods depending on the structural soundness of the existing pavement, rather than comprehensive reconstruction including the binder course. From this perspective, the authors developed porous asphalt pavement named Porous Surface Mastic Asphalt Course (POSMAC), which has impermeable layer on the binder course for water protection. This structure preserves good surface drainage as conventional porous asphalt pavement and also provides structurally sound binder course. This paper introduces the characteristics of POSMAC which contribute to prolong the life of porous asphalt pavement. Also, the properties of the improved mixture which protects the existing binder course, as well as the construction results on actual pavement are reported.

KEY WORDS: Impermeability, enhanced adhesion, reflection crack suppression efficacy, stripping resistance.

1 INTRODUCTION

As increasing volumes of porous asphalt pavement come into use, rising numbers of reports are describing cases of premature failure, such as lateral flow and potholes. The causes for these problems are believed to be insufficient adhesion between the surface and binder courses of porous asphalt pavement, as well as water penetration vulnerability in the binder course. These problems allow rain water to infiltrate beneath the binder course and quickly make the asphalt brittle.

A two-layer construction consisting of a drainage course and an impervious binder course is effective against this kind of typical damage to porous asphalt pavements. However, during maintenance, when it is desirable to shorten work time and minimize costs, authorities prefer to use a repair method that takes full advantage of the soundness of the existing pavement, rather than replace the entire pavement, including the binder course. The above reason motivated the Porous Surface Mastic Asphalt Course (POSMAC) Research Committee to initiate development of POSMAC, which is a method for protecting the binder course with a course incorporating a new impervious layer while conserving the functionality of conventional porous asphalt pavements. Other objectives include disseminating and further improving this technology. This report provides an overview of POSMAC, which contributes to improving the durability of porous asphalt pavements, and its characteristics. This report also describes the properties of newly added or improved mixes for protecting pre-existing binder courses and provides some application examples.

2 POROUS SURFACE MASTIC ASPHALT COURSE

2.1 Overview

Large volumes (at least 1.2 ℓ/m^2) of a highly concentrated modified asphalt emulsion using a self-priming asphalt finisher (SPAF) are uniformly sprayed in POSMAC pavements. This causes immediate decomposition and, at the same time, shapes and compacts the porous asphalt mix, thus providing a porous asphalt pavement. In addition to the original purpose of the generously applied emulsion as a tack coat, the emulsion also improves the water impermeability of the binder course by infiltrating and filling the gaps in the lower part of the surface course. This improves the durability of the pavement as a whole. Another function of this portion is to moderate stresses; it can be expected to suppress the formation of reflection cracks from the existing road surface (see Fig. 1).

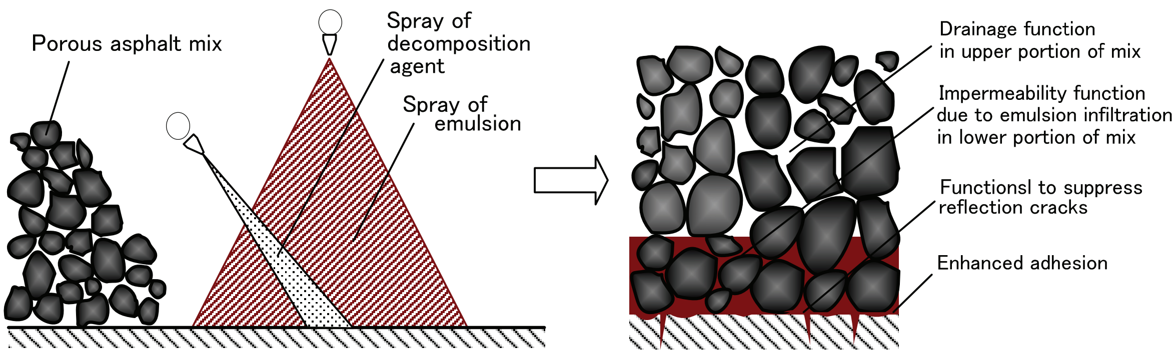


Figure1: Porous surface mastic asphalt course (POSMAC)

2.2 Characteristics of POSMAC mix

The performance and workability features of POSMAC are as follows:

<<Performance>>
- Ensures functionality equal to that of conventional porous asphalt pavements

- Increases impermeability of binder course by the infiltration and filling of gaps in lower portion of the surface course by a large volume of sprayed emulsion

- Highly concentrated modified asphalt emulsion improves adhesion to binder course

- Acts to suppress the formation of reflection cracks from the existing road surface

<<Workability>>

- SPAF that allows precise control of high-volume emulsion spray is used

- Forced decomposition mechanisms: A decomposing agent is sprayed together with the emulsion in order to prevent emulsion outflow

- Good workability, no different to that of conventional porous asphalt pavements

- Application in a single process, from emulsion spray to shaping

2.3 Main components

(1) Porous asphalt mix

The components used in conventional porous asphalt pavements are employed in the basic mix for this asphalt.

(2) Highly concentrated modified asphalt emulsion

Table 1 shows the properties of the modified asphalt emulsion used in the POSMAC. This emulsion is highly concentrated, with a percentage of residues by evaporation over 65%, in order to improve impermeability to water and decomposition. It is superior for maintaining mechanical stability as it enhances uniform spray.

Table 1: Properties of the highly concentrated modified asphalt emulsion

Item		Grade
Engler degree (at 25℃)		Max 15
ResidueBretained on sieve (1.18mm)	%	Max 0.3
Electric charge on asphalt particles		Positive
Evaporation residue	%	Min 65
Storage stability (24 hours)	%	Max 1.0

Item			Grade
Evapor-ation residue	Penetration (25℃)	1/10mm	60～100
	Softening point	℃	Min 48
	Toughness (25℃)	N･m	Min 4.0
	Tenacity (25℃)	N･m	Min 2.0

(3) Decomposing agent

An aqueous solution containing a compound hat is also used as a food additive was used as the decomposing agent for the POSMAC. The standard fraction was set at 10% of the sprayed volume of emulsion.

2.4 Main equipment

An SPAF equipped with a mechanism for shaping and compacting the asphalt mix immediately after spray of a determined volume of emulsion was employed as the POSMAC finisher. The SPAF was also modified with the addition of a mechanism for dispersing the decomposing agent, which is sprayed at a high volume to facilitate immediate decomposition of the emulsion (see Fig. 2).

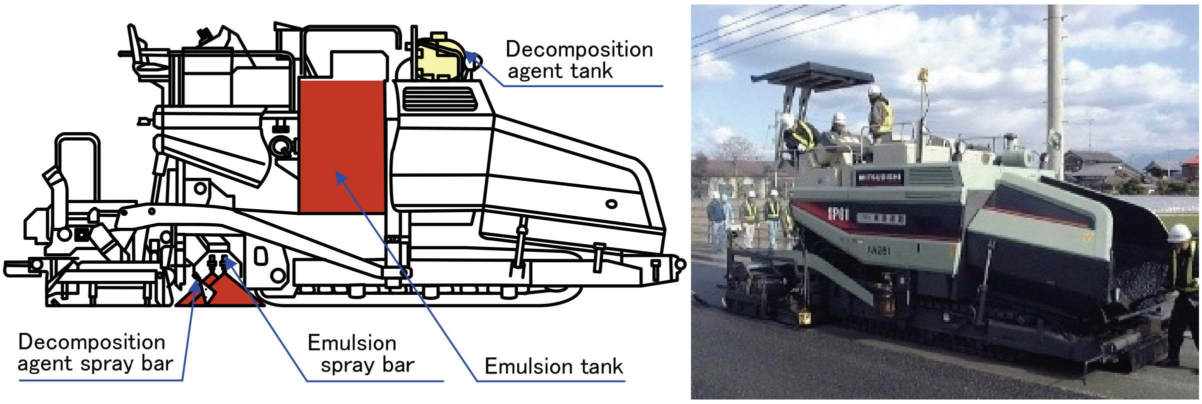


Figure 2: Example of SPAF structure

3 APPLICATION OF POSMAC

Since the POSMAC method applies the pavement in a single layer, a preliminary evaluation of the road surfaces and other structures in the location where POSMAC will be applied should be conducted. It is also desirable to verify the stripping resistance of the course just beneath the pre-existing binder course.

(1) Results in actual applications

About 1,000,000 m^2 of POSMAC had been laid by the end of fiscal year (FY) 2009. This was mainly cut and overlay (thickness 3.5 – 6 cm). See Fig. 3.

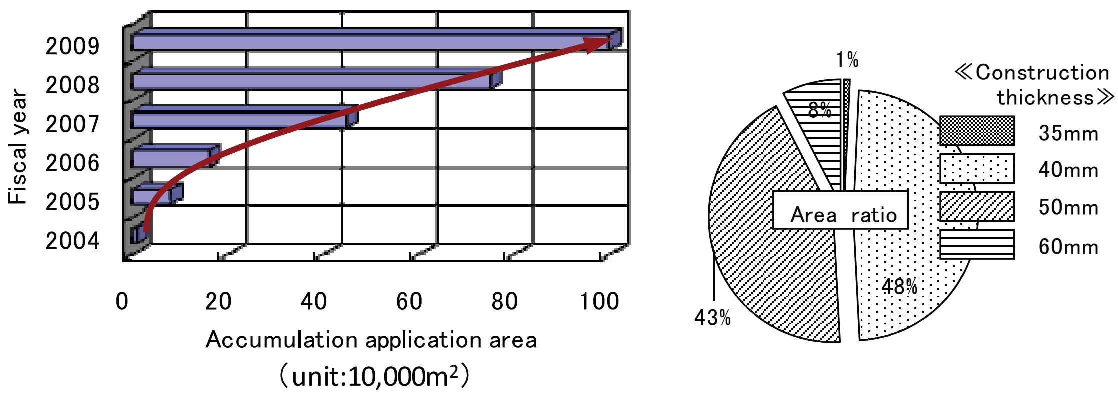


Figure3: Status of POSMAC application

(2) Application in specialist locations and conditions

Here are some examples of specific locations and conditions where POSMAC was applied:

- Bridge girder (steel plate deck) POSMAC was applied on top of pre-existing Guss asphalt on a steel plate deck. No cracks were found after about 3 years of service.

- Bridge girder (concrete deck)

- Overlay atop a new concrete pavement

- Application with a large volume of sprayed emulsion (1.4, 1.6, 1.8 ℓ/m^2)

- Steep grade: Application on an 8.58% slope

【Application on steel plate deck】

【Application on concrete pavement】 【Application on steep grade】

Photo1: Examples of installations under specific conditions

4 PROPERTIES OF POSMAC MIXES

The main properties of POSMAC mixes are shown below. POSMAC mixes incorporate large volumes of sprayed highly concentrated modified asphalt emulsion (at least 1.2 ℓ/m^2) and are simultaneously decomposed and shaped into a porous asphalt mix that is then compacted.

4.1 Volume of emulsion improving impermeability performance

Figure 4 shows how the results of a pressurized water permeability test varied with the volume of sprayed highly concentrated modified asphalt emulsion. The specimens consisted of two layers, POSMAC mix and coarse-graded asphalt mix. The volume of emulsion resulting in equilibrium in upgrading performance in impermeability is at the inflection point (minimum value) of 1.2 ℓ/m^2. The experimental conditions for the pressurized water permeability test were as follows:

- After exposure to 150 kPa of pressure for 24 hours, the permeability coefficients were calculated from the amount of water dripping off the sample in a fixed time frame.

- When no permeating water was observed even after exposure to 150 kPa of pressure for 24 hours, the test was repeated for 24 hours at 500 kPa.

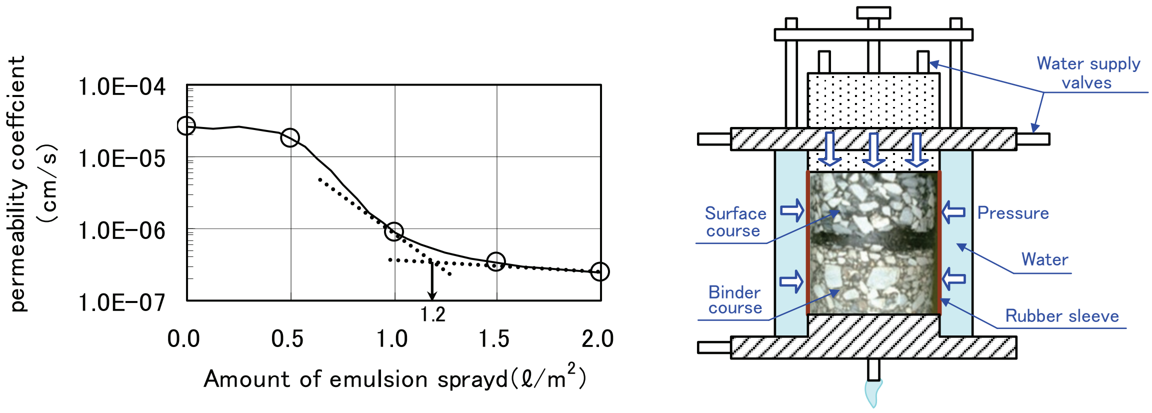


Figure4: Improvement effect of emulsion volume

4.2 Effectiveness in improving stripping resistance of binder course

Specimens consisting of two layers, a POSMAC mix and a coarse-graded asphalt mix were employed in immersed wheel tracking tests to determine the stripping resistance of the binder course when using POSMAC. The results are shown in Table 2 and Photo 2.

When POSMAC was used (with the highly concentrated modified asphalt emulsion at 1.2 ℓ/m^2), the stripping rate in the binder course was smaller than when compared with conventional porous asphalt pavement (emulsified rubberized asphalt: 0.4 ℓ/m^2), and the part of the binder course that is directly exposed to rain and other sources of water was noted to show a significant improvement in stripping resistance. The experimental conditions differed from the "Manual of Pavement surveys and tests" as follows:

- An asphalt mix for binder courses was laid beneath the test specimen

- The lower surface of the specimen (two-layer structure) was sealed in order to limit water exposure to infiltration from the surface

- A non-porous sheet was laid in the frame floor

- The water level was maintained 1 cm above the specimen surface

Table 2: Results of Simplified water immersion wheel tracking test

Condition (Asphalt emulsion on binder course)	Stripping rate (%)	
	No.1	No.2
Porous asphalt pavement (no spray of emulsion)	9.7	34.5
Porous asphalt pavement (emulsified rubberized asphalt: 0.4ℓ/m^2)	4.4	27.6
POSMAC (highly concentrated modified asphalt emulsion: 1.2ℓ/m^2)	1.9	4.0

	No.1	No.2
Binder course surface	with not cut	with cut
Binder course aggregate	large stripping resistance	small stripping resistance
Thickness binder course surface course	 50mm 50mm	 60mm 40mm

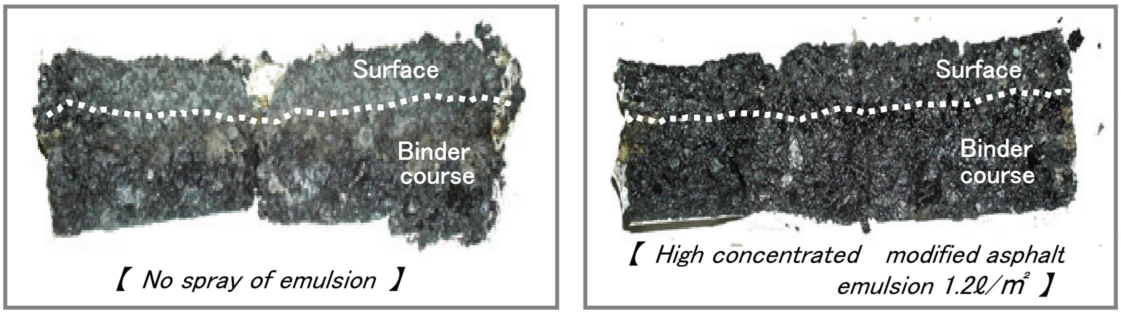


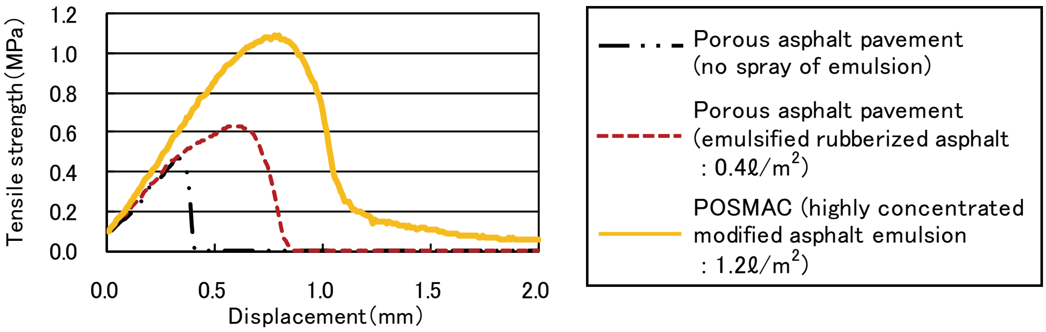
Photo2: State of stripping at conclusion test (No.2)

4.3 Improvement of adhesion performance due to large-volume spray of emulsion

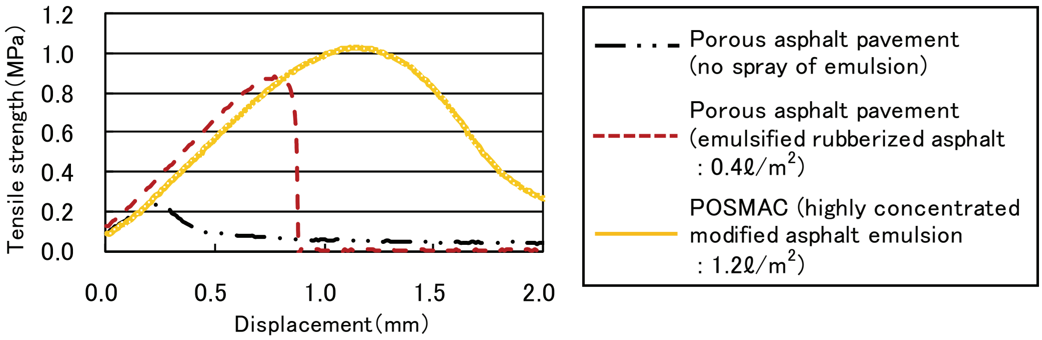
Two types of two-layer specimens, one consisting of POSMAC and dense asphalt mix and the other consisting of POSMAC and concrete slabs, were subjected to tensile testing. The test results are shown in Fig. 5.

When POSMAC was applied (with 1.2 ℓ/m^2 of highly concentrated modified asphalt emulsion), it showed adhesion performance that was different from that of the existing surface laid with conventional porous asphalt (emulsified rubberized asphalt: 0.4 ℓ/m^2). Additionally, the large volume of emulsion resulted in an improvement in adhesion energy. The adhesion between the surface and binder courses was tested with a direct tensile test (based on JEAAT-5) under the following experimental conditions:

- Tensile strain rate: 60 mm/min, - Specimen temperature: 20ºC



(1) Binder course :Asphalt mix



(2) Binder course :Concrete slab

Figure5: Results of tensile test

4.4 Reflection crack suppression efficacy

Figure 6 shows the results of cyclic loading tests of two-layer specimens made of POSMAC and dense graded asphalt. A wheel tracking test machine was used. A 3 mm wide cut joint was created in the lower course mix (5 cm thick) to simulate a crack and the number of wheel passages was counted until the crack propagated to the upper layer of the surface course. The figure also shows the number of wheel passages set as the standard in conventional porous asphalt pavements.

When POSMAC was applied (with 1.2 ℓ/m^2 of highly concentrated modified asphalt emulsion), it showed similar levels of crack suppression to those seen when a geogrid to suppress reflection cracking is laid beneath conventional porous asphalt. The test conditions differed from those in the "Manual of Pavement surveys and tests" as follows:

- Load: 1079 N, Specimen temp: 20ºC

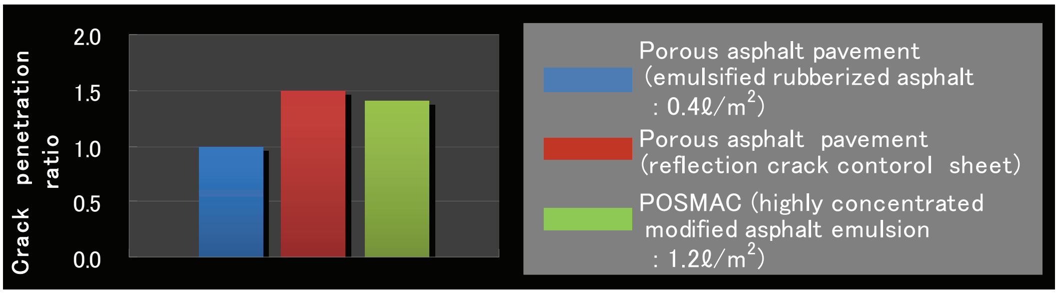
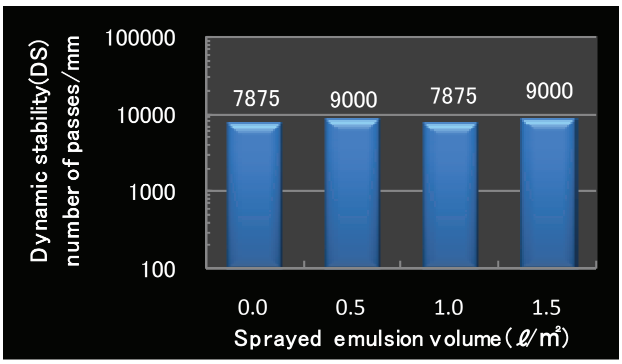


Figure6: Result of cycle loading test

4.5 Resistance to plastic deformation

In order to verify the resistance of the POSMAC mix to plastic deformation, the volume of highly concentrated modified asphalt emulsion was varied and the results of wheel tracking tests were examined (see Fig. 7).

The dynamic stability (DS) was constant, showing little variation with the volume of sprayed emulsion. No effect of the large volumes of emulsion on DS could be identified. The depths of the ruts "dug" by the wheels in the rotating pavement tester were compared with those found in another test. The use of POSMAC mix (with 1.2 ℓ/m^2 of highly concentrated modified asphalt emulsion) provided favorable resistance to plastic deformation.



Specimen Manufacturing Conditions	
Asphalt applied	Polymer-modified Type H asphalt
Asphalt fraction	4.8%
Maximum particle diameter	13mm
Void ratio	20%
Thickness	50mm

Figure7: Volume of emulsion and dynamic stability

5 FOLLOW-UP SURVEYS

It has been five years since POSMAC use commenced on actual roadways. In addition to the performance surveys conducted immediately following installation, follow-up surveys were performed in six locations to observe long-term serviceability. These follow-ups were all performed by earthmoving and involved cut and overlay sites, where the surface course had been replaced with porous asphalt pavement.

Table 3 shows examples of the results of the follow-up. According to a preliminary survey performed with a falling weight deflectometer (deflection D_0), these locations had sufficient levels of structural soundness. The surface conditions and performance indices (impermeability, adhesion, permeability, etc.) were all acceptable after three years of service.

Table 3: Result of the follow-up survey

Survey items		Job-site A					Job-site B		
		Befor application	Immediately after application	3 months later	1 year later	3 years later	Befor application	Immediately after application	1 year later
Traffic volume class		N_5					N_7		
Date of work		Sept.27,2004					Sept.27,2005		
Application thickness		50mm					40mm		
Spray volume of emulsion		1.2ℓ/㎡					1.2ℓ/㎡		
Porous asphalt mixture void ratio		20%					20%		
Crack ratio(total)	(%)	18.9	0.0	0.0	0.0	0.0	2.3	0.0	0.0
Crack ratio(local)	(%)	31.3	0.0	0.0	0.0	0.0	—	—	—
Roughness	(mm)	1.50	1.31	1.37	1.46	1.48	1.20	0.82	0.94
Rutting	(mm)	2.4	1.6	1.4	2.2	3.5	7.0	3.2	4.8
Deflection of pavement sueface(D_0)	(mm)	0.40	—	—	—	—	0.10	—	—
Tire/Road noise	(dB)	93.1	89.4	88.8	89.0	90.8	—	—	—
Permeability coefficient of existing binder course	(cm/s)	1.89×10^{-6}	Impermeable	Impermeable	Impermeable	Impermeable	3.70×10^{-7}	Impermeable	Impermeable
Split strengeth of existing binder course (standard-cured)	(MPa)	—	—	—	—	1.48	—	—	1.28
Tensile strength(interface of surface course and binder course)	(MPa)	—	1.10	1.20	1.00	1.00	—	1.36	1.54
Flowing amount of 15second	(ml/15s)	—	1307	1280	1296	1154	—	1277	1224
Note : there was a control zone at Job-site B									

6 SUMMARY

The porous surface mastic asphalt course (POSMAC) is a method for protecting the binder course that contributes to improving the durability of porous asphalt pavements, which draws rainwater below the road surface. It is anticipated to come into much wider use as a construction method offering substantial cost effectiveness, especially when re-paving by the cut and overlay (single course) method. The Technical Study Society of POSMAC will continue gathering data on a variety of application conditions and locations, carrying out continuous follow-up surveys, and announcing new findings as they come in the future.

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