FULL-SCALE DURABILITY EVALUATION TESTING OF INTERLOCKING BLOCK PAVEMENT WITH GEOTEXTILE

Omoto, S.[1], Yoshida, T.[2], and Hata, M.[3]

[1]Chief Researcher, Research Laboratory, Nippon Hodo Co., Ltd.
[2]Road Senior Scientist, Technology Research Group, Public Works Research Institute.
[3]Assistant Research Scientist, Cement and Concrete Technology Center, Laboratory 1, Central Research Development Center, Taiheiyo Cement Corporation.

ABSTRACT

The bedding course plays an important role in determining the serviceability of interlocking block pavement. In Japan, therefore, geotextile is commonly installed between the sand bedding course and the base course, to prevent runoff of cushion sand. The quantity of geotextile used annually has now reached about 1 million m^2. However, there have been few studies on the beneficial effects of geotextile in keeping the bedding and base courses separated from each other and improving the pavement serviceability.

The authors constructed a 30-m-long pavement test site consisting of six pavement zones with different cross-sectional dimensions in the pavement test field (circuit length: 628 m) of the Public Works Research Institute of the Ministry of Land, Infrastructure and Transportation. The pavement zones were constructed with or without geotextile having the fiber area weight of 60 g/m^2 or 130 g/m^2, either on the granular crushed-stone base course or the permeable bituminous stabilized base course. Using a radio-operated no-man loading vehicle, a traffic simulation test of applying a 5-ton equivalent wheel load 90,000 times was performed to examine the separating effects of geotextile and the serviceability of the interlocking block pavement.

The results confirmed that with either base course, geotextile helped prevent the cushion sand from migrating into the base. It was also proved that in zones with the permeable bituminous-stabilized base course, geotextile helped reduce the rutting depth and rate of block breakage, maintaining a good level of pavement serviceability. Because the fiber area weight of geotextile made no difference to the pavement serviceability, geotextile having the fiber area weight of 60 g/m^2 was deemed adequate.

1. INTRODUCTION

The bedding course plays an important role in determining the serviceability of interlocking block pavement (“ILB pavement”). In Japan, therefore, geotextile is commonly installed between the sand bedding course and the base course, to prevent runoff of cushion sand. The quantity of geotextile used annually has now reached about 1 million m^2. However, there have been few studies on the beneficial effects of geotextile in keeping the bedding and base courses separated from each other and improving the pavement serviceability, apart from a report on test pavement work on an actual road site (Saito et al., 1988) and an excavation survey on 2- to 14-year-old ILB pavements (Ando et al., 2001).

The authors constructed six ILB pavement zones with different cross-sectional profiles with or without geotextile, varying the type of geotextile and base configurations, in the pavement test field of the Public Works Research Institute of the Ministry of Land, Infrastructure and Transportation (MLIT). An accelerated traffic simulation test was performed to examine the separating effects of geotextile and the serviceability of the ILB pavement. This paper reports on the results of this full-scale test.

2. OUTLINE OF FULL-SCALE TEST

2.1 Test zone layout

For the full-scale test, a 30-m-long test site was constructed on the inner loop (circuit length: 628 m) of the pavement test field of the Public Works Research Institute of the MLIT. As shown in Figure 1, six pavement zones having the equal area of 4 m wide x 5 m long with different cross-sectional patterns were constructed to identify how the presence and type of geotextile, as well as different base configurations, would affect the serviceability of ILB pavement. Two types of geotextile were used: spunbonded nonwoven fabric having the fiber area weight of 60 g/m^2, and that of 130 g/m^2.

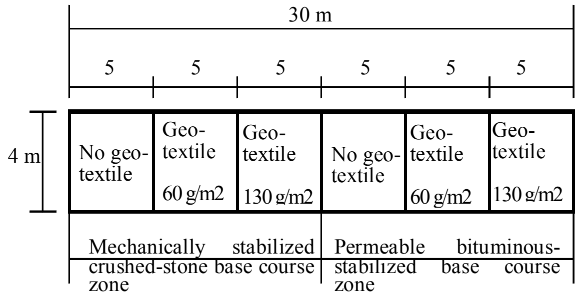

Fig. 1 ILB pavement test zone layout

2.2 Cross-sectional profiles of the pavement zones

In this test, the pavements were constructed as follows: the existing asphalt pavement was removed up to 10 cm deep, and the base course, subbase, geotextile, sand bedding course and interlocking blocks were placed in that order, followed by the application of joint sand.

Table 1. Properties of permeable bituminous stabilized mixture.

Item	Characteristic value
Stability (KN)	2.45 or more
Flow (1/100 cm)	20 to 40
Void (%)	12 or more
Permeability (cm/sec)	1.0 x 10^{-2} or more

Figure 2 shows the pavement profiles constructed for this test. As shown, two types of base course were prepared below the cushion sand: the existing mechanically stabilized crushed-stone base course, and the permeable bituminous-stabilized base course, in which the upper 10-cm section of the existing crushed-stone was replaced with a permeable bituminous-stabilized mixture that had the properties listed in Table 1 (Water and Pavement Research Group, 1997). The permeable bituminous-stabilized base course was used to help drain water smoothly by preventing the stagnation of rainwater that had infiltrated through block joints into the bedding course,

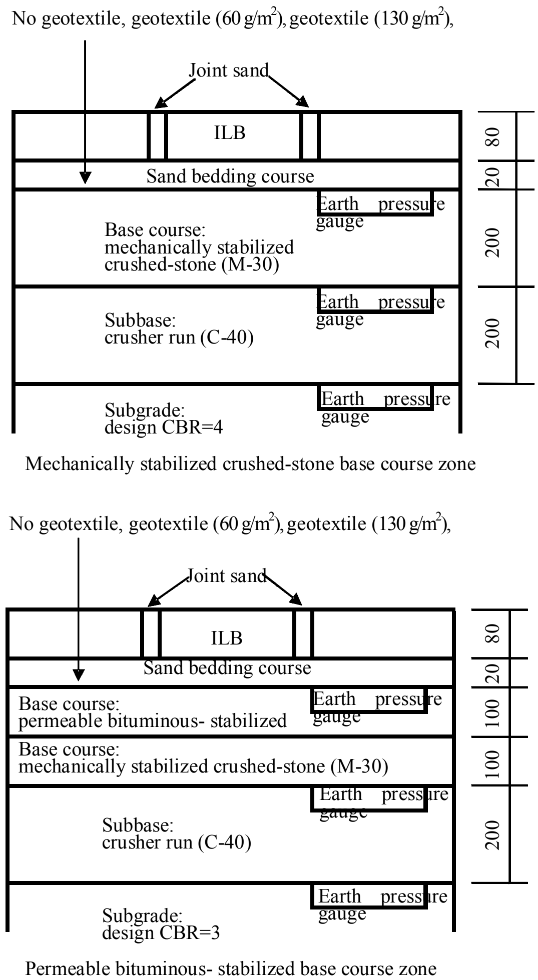

Fig. 2 Cross-sectional profiles of the ILB pavements tested (unit: mm)

which would cause the solidification or migration of sand. A CBR test on a subsoil sample showed that the design CBR of the subgrade was 4% and 3% in the zones with existing mechanically stabilized crushed-stone base course and those with the permeable bituminous-stabilized base course, respectively.

Table 2. Results of quality testing on cushion sand.

Item	Particle size Max.	Amount of materials passing the 0.075 mm sieve (%)	Fineness modulus	Pulverization resistance test
Test result	1.2	1.0	1.70	0.9%
Standard	4.75 or less	5 or less	1.55 to 5.5	Increase in the amount of materials passing the 0.075 mm sieve before and after the compaction test is 1% or less

2.3 Specifications of interlocking blocks, joint sand and cushion sand

The interlocking blocks used here had a rectangular wave-sided shape with spacer nibs shown in Figure 3, which were supposed to ensure the good interlocking effects. The herringbone bond pattern (45 degrees) shown in Figure 4 was adopted in the pavement layout. The interlocking blocks, joint sand and cushion sand materials were all selected in compliance with the quality standard (Japan Interlocking Block Pavement Engineering Association, 2000). The properties and the particle size of cushion sand are shown in Table 2 and Figure 5, respectively.

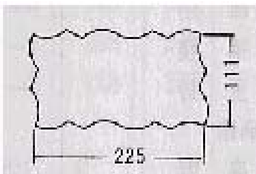

Figure 3. Dimensions of interlocking blocks (with spacer nibs) (mm).

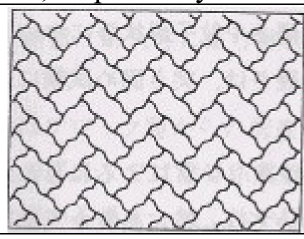

Figure 4. Herringbone bond pattern (45 degrees).

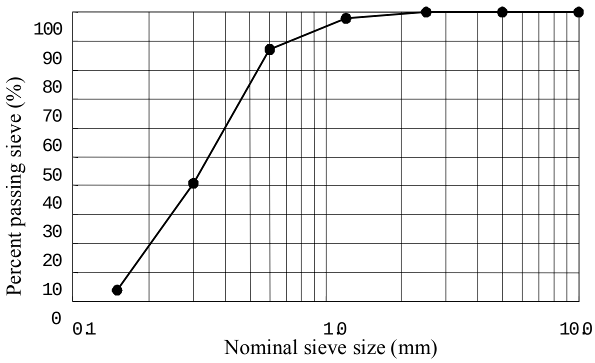

Fig. 5 Particle size curve of cushion sand

2.4 Accelerated traffic simulation test

The accelerated traffic simulation test was performed using a radio-operated no-man loading vehicle (wheel load: 59 kN) to apply a 5-ton equivalent wheel load 90,000 times.

The survey was broadly divided into three stages: a preliminary survey conducted during the pavement construction, a follow-up survey conducted according to the required wheel load applications, and an excavation survey conducted after the accelerated traffic simulation test. The contents and timing of these surveys are shown in Table 3.

Table 3. Items and timing of surveys.

Test	Test item	Method	Measurement point/line	Inspected				
				Initial construction	0 wheel load	Wheel load 13,450	Wheel load 30,000	Wheel load 90,000
Preliminary survey	Bearing capacity of subsoil	Laboratory CBR test	2 points	Yes				
	Reference level of base course	Leveling string	2 lines/cross-section	Yes				
	Bearing capacity of base course	HFWD, FWD	2 points/cross-section	Yes				
		Dynamic plate loading test						
	In-situ transmissivity of base course	In-situ Permeability test of permeable asphalt pavement	2 lines/cross-section	Yes				
Follow-up survey	Damage conditions of geotextile	Visual observation	2 points/cross-section			Yes	Yes	Yes
	Bearing capacity	HFWD, FWD	2 to 4 points/cross-section		Yes	Yes	Yes	Yes
		Dynamic plate loading test						
	Rutting	Transverse profile	2 lines/cross-section		Yes	Yes	Yes	Yes
	Regularity	Cross-sectional profile	2 lines/cross-section		Yes	Yes	Yes	Yes
	Block breakage	Sketch	$16.8m^2$ lines/cross-section		Yes	Yes	Yes	Yes
	Joint width	Vernier calipers	2 lines/cross-section		Yes	Yes	Yes	Yes
	Displacement	Leveling string	2 lines/cross-section		Yes	Yes	Yes	Yes
	Lost joint sand	Scale and sketch	$16.8m^2$ lines/cross-section		Yes	Yes	Yes	Yes
	Load distribution effect of each layer	Earth pressure gauge	1 point/cross-section		Yes	Yes	Yes	Yes
Excavation survey	Migration of cushion sand into the base course	Visual observation	2 points/cross-section					Yes
	Property of geotextile	Tensile strength, tensile strain Tear strength, coefficient of permeability	2 points/cross-section					Yes
	In-situ transmissivity	In-situ Permeability test of permeable asphalt pavement	2 points/cross-section					Yes
	Property of cushion sand	Sieving test, Decantation test	2 points/cross-section					Yes
	Property of base course material	Sieving test (mechanically stabilized crushed-stone) Asphalt extraction test	2 points/cross-section					Yes

3. RESULTS OF ACCELERATED TRAFFIC SIMULATION TEST

Table 4 shows the main results obtained after applying the wheel load 90,000 times. The following sections discuss these results.

3.1 Migration of cushion sand into the base course

A block sample was extracted after the wheel load had been applied 90,000 times and was visually examined for signs of cushion sand migrating into the base course.

Table 4. Results of major items after 90 thousand applications.

Base course structure		Mechanically stabilized crushed-stone (M-30)						Permeable bituminous-stabilized					
Geotextile (weight)		No geotextile		60g/m²		130g/m²		No geotextile		60g/m²		130g/m²	
Traffic lane/non traffic lane		Traffic lane	non traffic lane	Traffic lane	non traffic lane	Traffic lane	non traffic lane	Traffic lane	non traffic lane	Traffic lane	non traffic lane	Traffic lane	non traffic lane
Physical proper-ties of geotex-tile	Damage con-ditions(visual)	-	-	*3	*2	*3	*1	-	-	*4	*2	*4	*1
	Tensile strength (N/5cm)	-	-	37.3	63.7	68.0	56.3	-	-	NA	20.7	NA	142.5
	Tensile strain (%)	-	-	57.2	52	NA	48.3	-	-	NA	55.0	NA	49.9
	Apparent den-sity (g/cm^3)	-	-	0.081	0.079	0.106	0.089	-	-	0.072	0.077	0.102	0.095
	IVf (absolute viscosity)	-	-	0.627	0.617	0.627	0.617	-	-	0.624	0.634	0.621	0.629
	Fiber diameter retention (%)	-	-	103	97	97	96	-	-	104	100	100	99
FWD (mm)		1.708		1.899		1.768		1.558		1.185		1.276	
HFWD (mm)		0.259		0.357		0.369		0.124		0.179		0.219	
Rutting (mm)		36.5		35.5		51.0		27.0		21.5		17.5	
Surface regularity (mm)		8.12		4.07		9.05		8.48		6.55		5.20	
Joint width, average (mm)		3.85		3.68		3.77		3.65		3.82		3.76	
Displacement, average (mm)		56.7		52.1		36.0		12.7		21.1		26.8	
Lost joint sand (%)		12.1		18.7		20.7		5.3		5.4		5.9	
Block breakage (%)		1.61		0.94		1.88		1.88		0.16		0.31	
MCI_0 rank		4.54		4.87		3.47		5.16		6.56		6.71	
		(C)		(C)		(D)		(C)		(B)		(B)	
Earth pres-sure (MPa)	Subgrade	0.087		0.119		0.043		0.180		0.132		0.167	
	Subbase	0.169		0.203		0.064		0.212		0.255		0.265	
	Base course	0.328		0.555		0.375		0.389		0.606		0.575	

*1: No clear difference is seen compared to the initial construction. *2: Minimum damage. Geotextile has entered between the aggregates. *3: Minor damage. Geotextile has entered between the aggregates. *4: Major damage. Geotextile has entered between the aggregates. NA: Measurement was not applicable.

In the pavement zones without geotextile, cushion sand was found to have partially migrated into the base course at the loading positions and other locations alike, regardless of the type of base course. On the other hand, the cushion sand in the pavement zones with geotextile had hardly migrated into the base course at any position. It was thus proved that geotextile had a separating effect, preventing cushion sand from migrating into the base course.

3.2 Rut depth

Figure 6 shows the relationship between the rut depth measured with a transverse profilemeter and the number of loading vehicle applications (number of equivalent 59-kN wheel loads applied). According to Figure 6 and Table 4, the presence of geotextile had no apparent impact on the rut depth after 90,000 applications in the mechanically stabilized crushed-stone base course. In the case of the permeable bituminous-stabilized base course on the other hand, the pavement zones with geotextile showed a smaller rut depth than the pavement zone without geotextile, regardless of the fiber area weight.

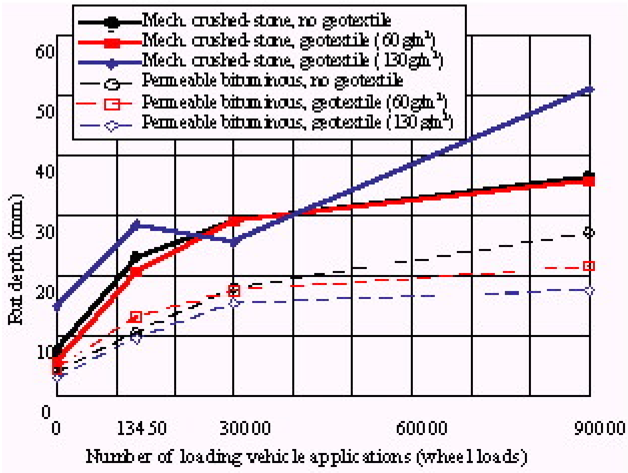

Figure 6. Time history of rut depth.

These results suggest that geotextile helped prevent the rutting of pavement with the permeable bituminous-stabilized base course, but not with the mechanically stabilized crushed-stone base course. The rutting of a road surface occurs by deformation of the bedding course as well as deformation of the base course and all layers below it. Thus, the presence of geotextile could hardly affect the rut depth in pavements with the mechanically stabilized crushed-stone base course due to the large amount of deformation in the base course and all layers below it. On the other hand, according to the deflection measured with a falling-weight deflectometer and other results in Table 4, the permeable bituminous-stabilized base course had a greater bearing capacity and the layers below it experienced smaller deflections than the crushed-stone base course. Also, as the separating effect of geotextile prevented cushion sand from migrating into the base course, deformation of the bedding course was presumably restrained in the permeable bituminous-stabilized base course. This is supposed to be the reason for the shallower ruts in pavements with the permeable bituminous-stabilized base course and geotextile.

3.3 Block breakage

Figure 7 shows the relationship between block breakage and the number of wheel load applications. Note that block breakage is defined as the ratio of the number of broken blocks to the total number of blocks in the pavement zone surveyed.

According to Figure 7 and Table 4, the presence of geotextile had no apparent impact on the block breakage rate after 90,000 applications in pavements with the mechanically stabilized crushed-stone base course. In the case of permeable bituminous-stabilized base course on the other hand, the pavement zones with geotextile had a smaller breakage rate than the pavement zone without geotextile, regardless of the fiber area weight.

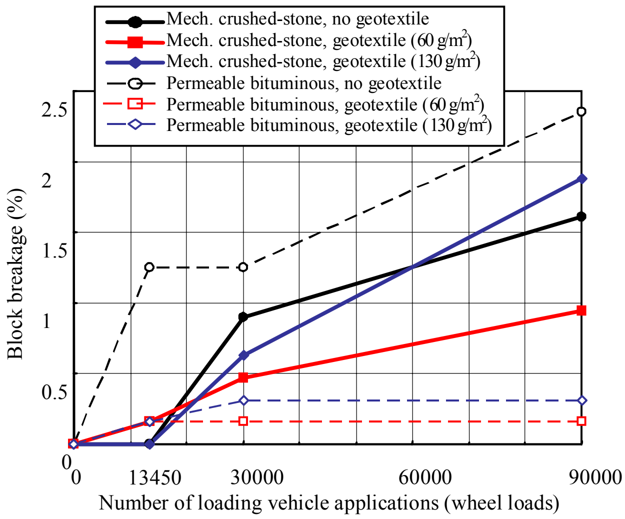

Figure 7. Time history of block breakage.

This result shows that geotextile restrained block breakage in pavements with the permeable bituminous-stabilized base course, but not in those with the mechanically stabilized crushed-stone base course. The fact that similar results were obtained in the examination of rut depth suggests that the rut-induced surface deformations caused friction between adjacent blocks, leading to breakage.

Note that about 80% of the breakages observed in this test was minor corner breakage that would not require block replacement.

3.4 Maintenance Control Index (MCI_0)

The Maintenance Control Index ("MCI_0") given in formula (1) below is used in the maintenance of ILB pavement in Japan (Japan Interlocking Block Pavement Engineering Association, 2000).

$$MCI_0 = 10 - 1.51\, C^{0.3} - 0.30\, D^{0.7} \qquad [1]$$

where,
C: Block breakage rate (%)
D: Average rut depth (mm)

The serviceability of the pavements was evaluated according to this index. Table 5 and Figure 8 show the results. The presence of geotextile had no apparent impact on the MCI_0 of the pavement with the mechanically stabilized crushed-stone base course after 90,000 applications.

In the case of the bituminous stabilized base course on the other hand, the MCI_0 of the pavement without geotextile was about 5.0, while those of the pavements with geotextile of 60 g/m^2 and 130 g/m^2 were about 6.6 and 6.7, respectively. The pavements with geotextile thus had greater MCI_0 than the pavement without geotextile, regardless of the fiber area weight. In terms of the MCI_0 rating shown in Table 6, the MCI_0 of the pavements without geotextile are categorized as "Rank C" because of the greater degree of rutting and block breakage. On the other hand, those of the pavements with geotextile of either fiber area weight are evaluated one rank higher, namely "Rank B (Regarded good despite some deficiencies)".

The above results confirmed that geotextile did not significantly contribute to the serviceability of ILB pavement with the mechanically stabilized crushed-stone base course, but it certainly did in the case of the permeable bituminous-stabilized base course.

3.5 Properties of geotextile

A series of performance evaluation tests was carried out on geotextile samples extracted after 90,000 applications. Table 7 compares the results with the properties before the test.

Table 5. Results of MCI_0 evaluation.

Base course structure	Geotextile (weight: g/m^2)	0 wheel load	Wheel load 13,450	Wheel load 30,000	Wheel load 90,000
Mechanically stabilized crushed-stone	Nil	8.77	7.31	5.37	4.54
	60	9.01	6.64	5.63	4.87
	130	8.00	6.87	5.79	3.47
Permeable bituminous-stabilized	Nil	9.21	6.83	6.33	5.04
	60	9.14	7.32	6.90	6.56
	130	9.35	7.68	6.89	6.71

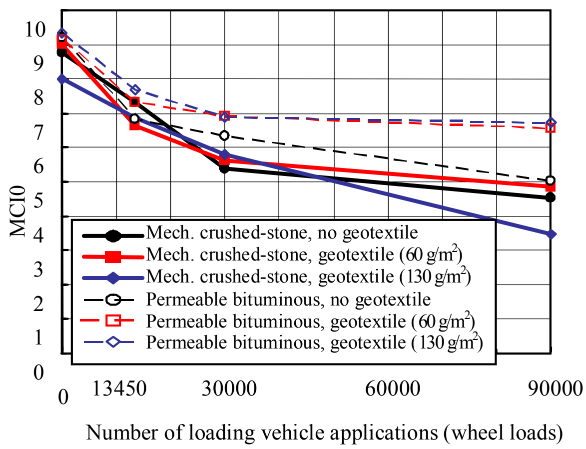

Fig. 8 Time history of MCI_0

Table 6. MCI_0 classification.

Rank	Description	Point
A	Good. No deficiency is found	10
B	Good despite some deficiencies	8
C	No maintenance is needed despite many deficiencies	6
D	Needs minor maintenance.	4

Note that the geotextile in pavements with the permeable bituminous-stabilized base course had been firmly buried between the base course materials, and could not be sampled without incurring damage at the loading positions. Therefore, the mechanical properties such as the tensile strength, elongation and tear strength of geotextile could not be evaluated for the pavements with this base course. Also, it was not possible to perform a comparison with the properties of geotextile in the pavements with the mechanically stabilized crushed-stone base course.

According to Table 7, the post-test apparent density was reduced for the 60 g/m^2 geotextile but increased for the 130 g/m^2 geotextile, regardless of the base course material and location. This is supposed to have been largely affected by the on-site sampling procedures, such as the sampling itself and the sample adjustment cleaning. The intrinsic viscosity factor (IVF), which is one of the indexes of polymer material deterioration, showed the excellent retention rate of between 98 and 100%. This suggests that the fibers of the geotextile hardly deteriorated even after the traffic simulation test.

Table 7. Geotextile property.

Base course structure	Item	Geotextile（60g/m^2）					Geotextile（130g/m^2）					Test method
		Test	Traffic lane		Non traffic lane		Test	Traffic lane		Non traffic lane		
		Before testing	Measurement point	Retention (%)	Measurement point	Retention(%)	Before testing	Measurement point	Retention (%)	Measurement point	Retention (%)	
Mechanically stabilized base course	Weight (g/m^2)	70	70	—	70	—	132	132	—	132	—	JIS L 1908
	Thickness（mm）	0.72 (n=5)	0.86 (n=5)	—	0.89 (n=5)	—	1.48 (n=5)	1.25 (n=5)	—	1.49 (n=5)	—	JIS L 1906
	Apparent dentistry (g/cm^3)	0.097	0.081	—	0.079	—	0.089	0.106	—	0.089	—	(weight/thickness)
	IVf (absolute viscosity)	0.631	0.627	99	0.617	100	0.631	0.627	99	0.617	98	Viscometric molecular weight
Permeable bituminous- stabilized base course zone	Weight (g/m^2)	70	70	—	70	—	132	132	—	132	—	JIS L 1908
	Thickness（mm）	0.72 (n=5)	0.97 (n=5)	—	0.91 (n=5)	—	1.48 (n=5)	1.29 (n=5)	—	1.39 (n=5)	—	JIS L 1906
	Apparent dentistry (g/cm^3)	0.097	0.072	—	0.077	—	0.089	0.102	—	0.095	—	(weight/thickness)
	IVf (absolute viscosity)	0.631	0.624	99	0.634	100	0.631	0.621	98	0.629	100	Viscometric molecular weight

The fiber diameter and decitex (the weight in grams of 10000 m of yarn; unit: dtex) of the geotextile samples extracted after 90,000 applications were obtained by taking photographs with a scanning electron microscope (SEM). Table 8 compares the results with the pre-testing properties. While the photographs showed that geotextile had been partly crushed or cut by the base course material, there was no reduction in the fiber diameter based on the diameter retention rate shown in Table 8.

Table 8. Measurement results with SEM photographs.

Base course structure	Geotextile	Traffic lane/non traffic lane	Fiber dia.	Fineness	Fiber dia. retention (%)
	Weight (g/m^2)		(um)	(dtex)	
Mechanically stabilized base course	60	Traffic lane	19.6	4.1	103
		Non traffic lane	18.5	3.7	97
	130	Traffic lane	18.3	3.7	97
		Non traffic lane	18.2	3.6	96
Permeable bituminous-stabilized base course zone	60	Traffic lane	19.9	4.3	104
		Non traffic lane	19.1	4.0	100
	130	Traffic lane	19.1	4.0	100
		non traffic lane	19.0	3.9	99
Physical properties before testing			19.1	4.0	—

Therefore, the fibers in geotextile themselves were not damaged after the traffic simulation test.

4. CONCLUSIONS

The test results are summarized as follows.

(1) The visual observation confirmed that geotextile served to prevent cushion sand from migrating into the base course, in pavements either with the mechanically stabilized crushed-stone base course or the permeable bituminous-stabilized base course.

(2) When geotextile was installed between the sand bedding course and the permeable bituminous-stabilized base course, the degree of rutting and block breakage were smaller than that without geotextile. Therefore, the serviceability of pavements with geotextile was evaluated one rank higher than those without geotextile in terms of MCI_0 even after applying a 5-ton equivalent wheel load 90,000 times. This proved that geotextile helps maintain good pavement serviceability when the permeable bituminous-stabilized base course is used in ILB pavement.

(3) Geotextile having the fiber area weight of 60 g/m^2 and that of the 130 g/m^2 type showed similar damage conditions, physical properties and MCI_0 in pavements with the permeable bituminous-stabilized base course. Therefore, it can be concluded that geotextile having the fiber area weight of 60 g/m^2 is adequate.

(4) When geotextile was used in pavements with the mechanically stabilized crushed-stone base course, geotextile provided a separating effect as mentioned in (2) above. However, the presence of geotextile did not affect pavement serviceability. Therefore, the beneficial effects of geotextile on the serviceability of ILB pavement were not confirmed in pavements with the mechanically stabilized crushed-stone base course.

5. CONCLUDING REMARKS

As a result of full-scale tests, it was confirmed that when the permeable bituminous-stabilized base course is used in ILB pavement, installation of geotextile between the base course and sand bedding course would prevent cushion sand from migrating into the base course and would restrain deformation of the sand bedding course, thereby reducing the degree of rutting and block breakage. The serviceability of ILB pavement was found to be better maintained with geotextile than without, proving the beneficial effects of geotextile in pavements with the permeable bituminous-stabilized base course.

This study was carried out as part of research in the International Standard Development Project for New Industries Promotion, “Standardization of Performance Evaluation Criteria for Fiber Materials Used in Block Pavements” by the New Energy and Industrial Technology Development

Organization (NEDO). The authors sincerely thank all those who provided valuable assistance and cooperation.

6. REFERENCES

Y. Ando, E. Noda, K. Yaginuma, 2001, Report on Excavation Surveys on Interlocking Block Pavements with Geotextile, Proc., The 24th Japan Road Conference, Vol. C, pp.162-163

Japan Interlocking Block Pavement Engineering Association, 2000, Interlocking Block Pavement Engineering Design and Build Guidelines

Water and Pavement Research Group, 1997, Permeable Pavement Made Simpler, Sankaido Publishers.

T. Saito, Y. Maruyama, T. Kawano, Y. Miura, 1988, Effects of Geotextile on the Deformation Behaviour of Concrete Block Pavement, Pavement, pp.49-52

FULL-SCALE DURABILITY EVALUATION TESTING OF INTERLOCKING BLOCK PAVEMENT WITH GEOTEXTILE

Omoto, S.[1], Yoshida, T.[2], and Hata, M.[3]

[1]Chief Researcher, Research Laboratory, Nippon Hodo Co., Ltd.
[2]Road Senior Scientist, Technology Research Group, Public Works Research Institute.
[3]Assistant Research Scientist, Cement and Concrete Technology Center, Laboratory 1, Central Research Development Center, Taiheiyo Cement Corporation.

A BRIEF RESUME OF MINORU HATA

Engaged in research and development of interlocking block for 20 years since he entered Taiheiyo Cement Corporation.

Engaged mainly in evaluation of interlocking block applied to motorways, development of composite interlocking block using tile and natural stone, development of high strength permeable interlocking block for motorways and development of water retentive interlocking block..