Laboratory and Field Evaluation of Porous Asphalt Concrete

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Abstract: Porous asphalt concrete (PAC) is mainly applied to the surface drainage layer on high-speed trafficked highway pavements. The use of polymer-modified binder was shown to minimize the abrasion loss and enhance the durability of the PAC mixture. Test results indicated that using polymer-modified binders instead of unmodified binder reduced rutting and raveling, with the mixture containing high-viscosity binder showing the best performance in the field. There were indications of drainage improvement by replacement of traditional binders with polymer-modified binders according to measurements in the field. PAC pavement surfaces provided good frictional characteristics once the asphalt binder film was worn from the aggregate.

Keywords: porous asphalt concrete, polymer-modified asphalt, draindown

1. INTRODUCTION

Porous pavement is an infiltration system where storm water runoff is infiltrated into the ground through a permeable layer of pavement or other stabilized permeable surface. These systems can include porous asphalt concrete (PAC), porous concrete, modular perforated concrete block, cobble pavers with porous joints or gaps or reinforced/stabilized turf (Field et al. 1982; Deo1 et al. 2010). Permeable pavement can be used in parking lots, roads and other paved areas and can greatly reduce the amount of runoff and associated pollutants leaving the area. PACs have been used since the 1970s. The initial use of PACs was in Europe. Europeans took the U.S. version of open-graded friction courses developed in the 1930s through the 1970s and, through research, improved the performance of these mixes. Later, Japanese further modified the European method to create another generation of PACs which are widely used in Asian areas. Improvements primarily included the use of modified asphalt binders and fibers. The modified binders and fibers alleviated some of the problems that were encountered with open-graded friction courses in the United States (Kandhal 2002;

Watson et al. 2004; Alvarez et al. 2009).

Benefits realized from the use of PACs are primarily associated with improved safety. PACs have been shown to improve wet weather frictional properties, reduce the potential for hydroplaning, reduce the amount of splash and spray, and improve visibility. Other benefits identified in the literature included resistance to permanent deformation, smoother pavements (and, hence, improved fuel economy), reduced tire/pavement noise levels, and other environmental benefits (McDaniel and Thornton 2005; Vivar et al. 2007; Cooley et al. 2009;).

There are numerous differences between permeable friction course (PFC) and open-graded friction course (OGFC) widely used in Taiwan. PFCs typically contain at least 20 percent more asphalt binder (by volume) than conventional OGFC mixes. They are generally designed to have 18 percent air voids or more, whereas conventional OGFC mixture typically contained between 10 and 15 percent air voids. The void structure of PFC allows the mix to be more permeable than conventional OGFC and less likely to trap water that could freeze. Unlike conventional OGFC, PFCs may contain fibers, polymer-modified asphalt binders, or asphalt-rubber, alone or in combination. Permeable friction courses are typically placed in thicker layers than conventional OGFC (3-5 cm as opposed to 2 cm or less). The thicker, more open void structure allows PFC to drain larger volumes of water off the roadway surface faster than conventional OGFC and keeps the void structure clean longer through the flushing action of high-speed traffic, and therefore, reducing the potential for loss of permeability over time.

These differences have contributed to a longer reported performance life for PFC compared to conventional OGFC. Research on PFC indicates that the mixes typically last between 8 to 12 years, significantly longer than the first generation OGFC mixtures which typically lasted 5 to 7 years. No widespread performance problems with PFC such as raveling have been reported, but concerns remain whether PFC mixes will experience the same performance problems that plagued the first generation OGFC mixes used in freeze-thaw environments. In freeze-thaw environments, the associated inconveniences and increased cost of winter maintenance and the possible related formation of glaze (“black ice”) seem to outweigh the benefits of PFC. While black ice can form on any pavement under the right environmental conditions, there is information that it is likely to form on PFC earlier and last longer than on other HMA surfaces. These concerns are a likely reason that PFC mixes are used predominately in the warmer climates found in the southern and western regions of the United States and are not used widely in areas that experience frequent freeze-thaw cycles. Pavement maintenance issues and snow and ice removal also are cited as obstacles to further increased use of PFCs in colder climates.

Using modified binders and adding additives are the common methods to improve the performance of porous asphalt concrete. However, the effects of all these materials are two-sided: when they improve the mixture’s performance in one aspect, they might decrease its performance in the other aspect. There is a need to investigate the effect of binder types for PAC on the functionality and durability of these mixtures. The main objective of this study focuses on evaluating the engineering properties of PAC mixtures, and assessing PAC performance according to field measurements.

2. MATERIALS

Three types of asphalt binders for PAC pavements in Taiwan were included in this study as follows: conventional asphalt AR-80 (AR), polymer (SBS)-modified asphalt (MA) and high-viscosity asphalt (HV). HV is a specially-designed asphalt binder which is characterized by extremely high absolute viscosity at 60℃. As can be seen in Table 1, the viscosity and the softening point of HV are much higher than those of AR and MA. The mixing and compaction temperatures for the AR binder were selected corresponding to 0.17 Pa.s and 0.28 Pa.s viscosities, respectively. For MA and HV, the manufacturer's recommended temperatures were used.

Table 1 Basic Properties of Asphalt

Properties	AR	MA	HV
Penetration (25°C, 0.1 mm)	54.5	46.7	26.1
Softening point (ºC)	55	63	95
Absolute viscosity (60°C, poise)	3,554	15,872	341,214
Solubility (%)	99.9	99.9	99.7
Residual after RTFOT			
Absolute viscosity (60°C, poise)	8,932	23,546	487,387
Loss of mass (%)	0.02	0.04	0.05
Penetration ratio (25°C, %)	62	72	85

Since porous asphalt concrete has a coarse aggregate skeleton with few fine particles, a thick asphalt film can be formed around the aggregates and the potential for the film to flow off the aggregates, a phenomenon known as draindown, is likely to increase. For this study, cellulose fibers were added at 0.3% of the total mixture mass in porous asphalt concrete to prevent draindown.

The properties of limestone coarse and fine aggregate were summarized in Table 2. Coarse aggregate for a PAC mixture must be strong to carry the imposed loads because coarse aggregate is primarily responsible for carrying the traffic loads in a PAC mix. The LA abrasion value of coarse aggregate should be less than 30% to possess sufficient toughness. In addition, flat and elongated proportions must be limited to be a minimum value, and fracture faces are required to provide a coarse aggregate structure with high internal friction.

Table 2 Physical Properties of Aggregate

Types	Properties		Test results	Specifications
Coarse Aggregate	LA abrasion (%)		18	≤30
	Flat & elongated (%)	3:1	9	≤12
		5:1	3	≤5
	Absorption (%)		1.1	≤2
	Soundness (%)		3.8	≤5
	Fracture faces (%)	one	100	100
		two	97	≥95
Fine Aggregate	Soundness (%)		3.2	≤5
	Sand equivalent value (%)		86	≥50

Based on the field test road selected, master aggregate gradation bands are provided in Table 3. The 19-mm maximum aggregate size gradation is gapped on the 4.75-mm sieve. The percentage of mineral fillers used for PAC mixtures was 5 percent. Open-graded mixtures that are designed to have a minimum of 18 percent air voids are considered PAC. A nominal air-void content of 20 percent was selected for fabricating all PAC specimens in this study. The job mix formula was decided using the Marshall mix design method. Specimens of 100mm diameter and 63.5mm height were prepared by applying 50 blows on each faces. Two properties were utilized to define the range of allowable binder contents: abrasion and draindown tests. The optimum binder content was determined to be 5.0%, 5.1% and 5.0% for AR, MA and HV mixtures, respectively. The mixing and compaction temperatures for AR binder were selected corresponding to 0.17 Pa.s and 0.28 Pa.s viscosities, respectively. For MA and HV binders, the recommended temperatures obtained from the manufacturers were used.

Table 3 Gradation of PAC Mixture

Sieve Size (mm)	19	12.5	4.75	2.36	0.075
Specification	100-95	84-64	31-10	20-10	7-3
Passing %	98	69	20	14	5

3. METHODS FOR LABORATORY EVALUATION

To evaluate the engineering properties of porous asphalt mixes, comprehensive laboratory tests were conducted. These tests include binder draindown test, Cantabro mass loss test, strength test, rutting test, and permeability test. Testing data presented in this paper are the average values of three replicate specimens, and all test specimens were made with the Marshall hammer. The laboratory study centered on the effect produced by the different binders on the following properties:

- Resistance to draindown
- Resistance to disintegration
- Resistance to indirect traction
- Resistance to rutting
- Permeability

3.1 Draindown

At typical production and construction temperatures, the thick film of asphalt binder common to porous asphalt concrete has propensity to drain from the aggregate structure. The basket test was carried out to evaluate the potential of binders draining down from coarse aggregate. The loose mixture was placed in a wire basket that was positioned on a preweighed dry paper plate. The entire apparatus was placed in an over controlled at 165°C for 60 minutes. After that, the basket containing the sample was removed from the oven along with the paper plate, and the paper plate was weighed to determine the amount of draindown that occurred. The percentage draindown was calculated by the following equation:

$$\text{Draindown} = \frac{\text{Final paper weight} - \text{Initial paper weight}}{\text{Initial mixture weight}} \times 100 \tag{1}$$

3.2 Cantabro Abrasion Test

The Cantabro abrasion test developed in Spain during the 1980s is a method to evaluate the resistance of PAC mixtures to raveling. The test method entailed compacting a PAC mix 50 blows on each site at the optimum asphalt content, allowing the specimen to cool to a test temperature of 25°C, weighing the specimen to the nearest 0.1 g, and then placing the specimen into a Los Angles Abrasion machine without the charge of steel spheres. The Los Angles Abrasion machine was operated for 300 revolutions at a rate of 30 rpm. After 300 revolutions, the specimen is removed and again weighed to the nearest 0.1g. The mass loss during this process is defined as the Cantabro abrasion value, and is calculated as follows:

$$\text{Weitht Loss} = \frac{\text{Initial specimentweight} - \text{Final specimenweight}}{\text{Initial specimenweight}} \times 100 \tag{2}$$

3.3 Strength Test

The resilient modulus and the indirect tensile tests were conducted to evaluate the strength of the porous asphalt mixtures. The repeated-load indirect tension test for determining the resilient modulus was conducted by applying compressive loads with a haversine waveform according to ASTM D 4123. The load was applied vertically in the vertical diameter plane of a cylindrical specimen of asphalt concrete through a curved loading strip. The resulting horizontal deformation was measured and used to calculate the total resilient modulus (M_r) and the indirect tensile strength (IDT).

3.4 Resistance to Rutting

A wheel-tracking test was performed to evaluate the rutting characteristics of porous asphalt concrete. The porous asphalt slab was rigidly restrained in a 300mm×300mm×50mm steel mould. The wheel driven by a motor and a reciprocating device loaded the slab bi-directionally. At a rate of 42 cycles/min., the wheel covered a loading distance of 230±10mm. The vertical deformation at the middle of the slab was recorded. For the standard test condition, loading pressure was 700kPa at temperature 60°C under dry conditions. The dynamic stability (DS) used to characterize the rutting resistance of each mix is calculated as follows:

$$DS = \frac{t_2 - t_1}{d_2 - d_1} \times N \tag{3}$$

where d_1 = deformation at t_1 minutes (mm), d_2 = deformation at t_2 minutes (mm), and N= speed of the wheel, 42 cycle/mm in this study. Default values of t_1 and t_2 were used in this study, which are at 45 and 60 minutes, respectively.

3.5 Permeability

A falling-head permeability device was used to evaluate the water permeability of water-saturated asphalt samples. Water flowed through a saturated asphalt mixture, and the interval of time taken to reach a known change in head across the specimen was recorded. For each sample, the coefficient of permeability was computed for three runs and averaged. The coefficient of permeability, k, of the asphalt mixture was determined using the following equation:

$$k = \frac{a \cdot L \cdot \ln(h1/h2)}{A \cdot et} \tag{4}$$

where, a = cross section of test tube, L = specimen thickness, A = cross section of specimen , et = elapsed time between h1 and h2, h1 = initial head (cm), and h2 = final head (cm).

4. CONSTRUCTION OF A TEST ROAD

Monitoring in-service pavements is one of the best methods for gaining data on how PAC pavements will perform over time under real environmental and traffic conditions. According to the test results in the laboratory, the Taiwan Freeway Bureau(TAB), thus, started constructing a 4.5-km full-scale pavement test section in 2007. The experimental design was developed by the researchers participating in this project and the TAB field engineers. Pavement sections in the west bound were selected for the field studies as shown in Figure 1.

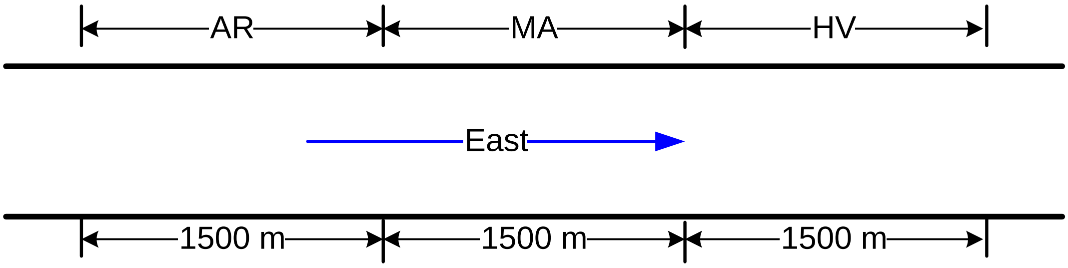

Figure 1 Layout for In-Service Test Road (not to scale)

This freeway has four lanes and an average traffic volume of 15,000 vehicles per day with approximately 16% truck traffic. Each section was consisted of a 3-cm PAC surface course over a 5-cm stone mastic asphalt and a 20-cm bitumen-treated base course. The mix designation and other parameters of mixes listed in Table 4 indicate that all three mixtures have similar gradations, bitumen contents and air voids. The HV mix did not contain fibers, while the other two mixes were added with fibers. Cellulose fiber stabilizing additives were added to the mix as the rate of 0.3 percent by mass of total mix. Distress surveys were conducted on a regular basis on each section during trafficking. The surveys including drainability, friction, rutting and ride quality were performed at a scheduled interval. Following are the in-site evaluation methods used for PAC pavements in this study.

Table 4 Mixtures Employed for Test Road

Sect.	Gradation (mm), % passing					Asphalt	Voids	Fiber
	19	12.5	4.75	2.36	0.075	%	%	%
MA	97	66	17	12	4.5	5.2	20.4	0.3
HV	99	71	21	12	3.5	5.0	19.9	0
AR	98	64	21	12	4.1	5.1	20.9	0.3

5. METHODS FOR FIELD EVALUATION

5.1 Drainability

Detailed examination of drainability is warranted, since drainability is one of the main characteristics of PAC mixtures and closely related to their advantages. A field drainability device made of a Plexiglas cylinder connected to a steel base was used for measuring drainability of the porous asphalt layer as shown in Figure 2. This Plexiglas cylinder has an interior diameter of 50.48 mm and a height of 350 mm. The Plexiglas cylinder contains engraved markings that are 100 ml apart, with the "zero" marking being a height of 600 mm above the pavement surface. Special clay was placed as a 30 mm wide ring on the pavement surface in order to cover the highest aggregate and fill voids at the surface besides an O-ring. Thus the contact zone between the permeameter and the pavement was sealed, and the water was forced to flow through the interior voids of the porous asphalt layer. Permeability of the layer is expressed as the time elapsed between the 100 and the 500 ml line. The downward movement of the water corresponds to an outflow quantity of 400 ml. In cases when the time needed to pass the 400 ml volume is greater than 6.7 sec, the drainability of the porous asphalt layer is considered to be insufficient.

Figure 2 Measurement of in-situ drainability

5.2 Friction

Pavement skid resistance was measured by the British Pendulum Tester according to ASTM E303 and expressed by a British Pendulum number (BPN) as shown in Figure 3. The tests were all adjusted by the exact pavement temperature at measurement to an equivalent BPN value at 20°C.

Figure 3 British Pendulum Tester

5.3 Rut Depth

Rut depth measurements were made for each section using a straightedge according to ASTM E 1703 as shown Figure 4. Three measurements were taken and averaged.

Figure 4 Measurement of permanent deformation

5.4 Pavement Smoothness

Roughness is an important index of pavement performance evaluation, which affects the comfortableness of drivers and passengers. It is an index involving human-vehicle-road interaction, often evaluated by the International Roughness Index (IRI). The ICC Surface Profiler used in this study is a multi-wheeled inclinometer-based system that is pushed by an operator at a walking speed of 1.2 km/h as shown Figure 5.

Figure 5 Measurement of pavement smoothness

6. LABORATORY RESULTS AND DISCUSSION

6.1 Binder Draindown

Figure 6 indicates that the draindown increases with increasing the asphalt content. A maximum draindown of 0.3% by weight of total mix is used as the limiting value for determining acceptable performance. Porous asphalt mixtures without fibers have significantly more draindown. At 0.3% cellulous fibers by weight of mixture, draindown is reduced to be about 0.1% at the asphalt content of 5%. This suggests that fibers help hold the asphalt binder to the aggregate structure of a porous asphalt mix. The amount of binder loss of the MA mix is also lower than that of the AR mix. Reduction in draindown could be attributed to the increase in the viscosity of the MA binder at 165°C. The use of fibers greatly reduces the potential for draindown; more so than does polymer modification as shown in Figure 1. In addition, the HV binder can be used in porous asphalt mixtures with little potential for draindown problems even without the addition of fibers.

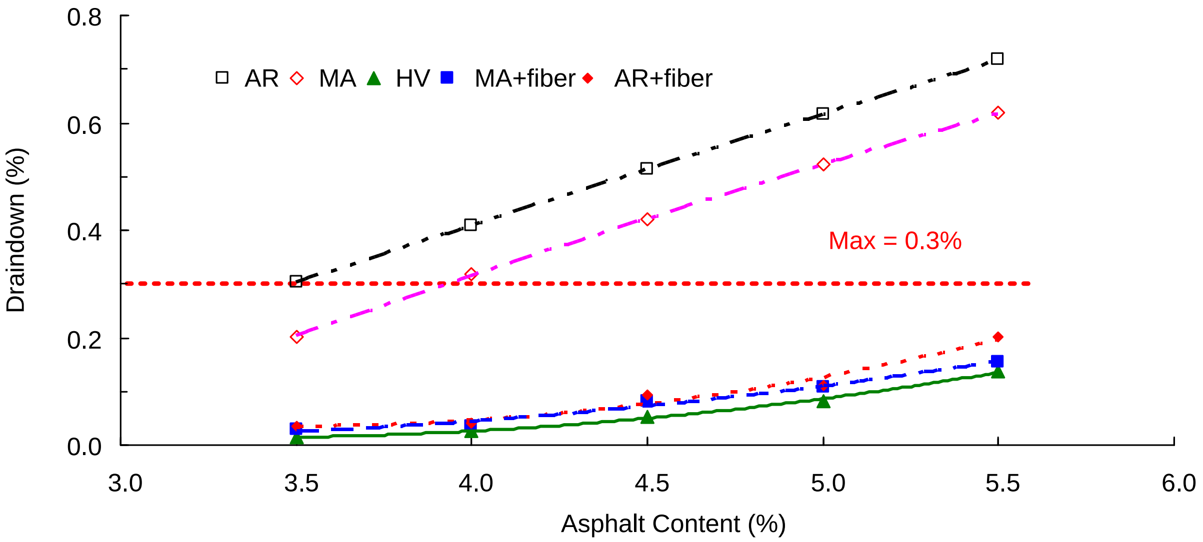

Figure 6 Effect of asphalt content on draindown

6.2 Mixture Abrasion

Figure 7 shows that the AR mix has the highest abrasion loss, and the HV mix has the lowest abrasion loss. The combined use of polymer modified binder and fiber can minimize the abrasion loss and, thus, increase durability of the mixture. Each bar represents the average of three tests with the variation ticks indicating one standard deviation of the tests. A maximum weight loss of 20% is specified for PAC. As compared with the AR binder, the use of the MA binder reduces the weight loss by 2% to 6%, as can be seen in Figure 7. The use of polymer-modified asphalt is shown to make a significant difference in results for the Cantabro weight loss test.

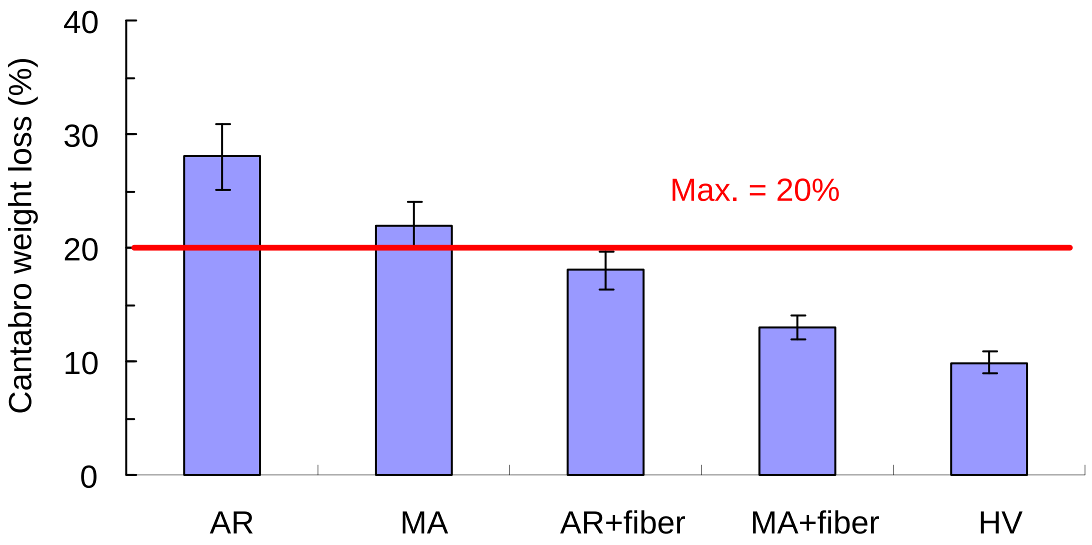

Figure 7 Weight loss during the abrasion test

6.3 Mixture Strength

Figure 8 shows that HV mixes exhibit higher indirect strength and resilient modulus than AR and MA mixes even with the addition of fibers. As listed in Table 1, the kinetic viscosity of HV binder is at least 20 times higher than that of the other two binders. This means that the kinetic viscosity of binder affects the strength of the porous asphalt: a higher viscosity value provided better strength of a PAC mix. As indicated by MA mixes, adding polymers into asphalt increases the indirect strength and the resilient modulus of PAC. In addition, the indirect tensile strength of porous asphalt mixture increases with the addition of fibers because the addition of fibers can stiffen the asphalt binder. It appears that the addition of polymers contributes more to the increase in the indirect tensile strength and the resilient modulus of PAC than that of fibers.

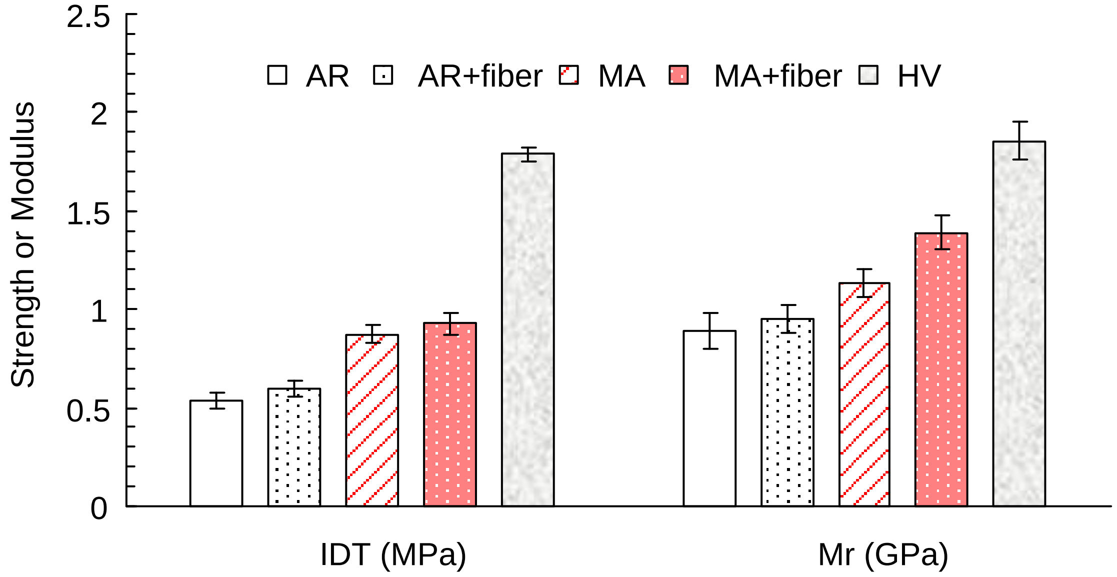

Figure 8 Test results of indirect tensile (IDT) and resilient modulus (Mr)

6.4 Permanent Deformation

Figure 9 represents the average rut depth curve of each mix from the wheel-tracking test. The rut depth of the porous asphalt mix appears to be sensitive to the binder type as shown in Figure 9. The rut depths at 6,000 cycles were less than 5 mm for all mixes, and were considered acceptable. With the use of polymer-modified asphalt, there is greater resistance to permanent deformation than the mix fabricated with ordinary bitumen AR. Figure 9 shows that AR has a rut depth curve similar to that of AR+fiber, indicating that the addition of fibers did not significantly improve the resistance of PAC mixtures to rutting. On the other hand, the resistance of PAC to rut depth improves with the addition of polymers. The most significant reduction on rutting occurs at the addition of the HV binder. The dynamic stability (DS) value is 1559, 1592, 2281, 2312 and 3182 cycle/mm for AR80, AR80+fiber, MA, MA+fiber and HV mixtures, respectively. The dynamic stability greater than 1500 cycle/mm is recommended for a porous asphalt mix. This observation corresponds well with the test results obtained from the indirect tensile strength and resilient modulus.

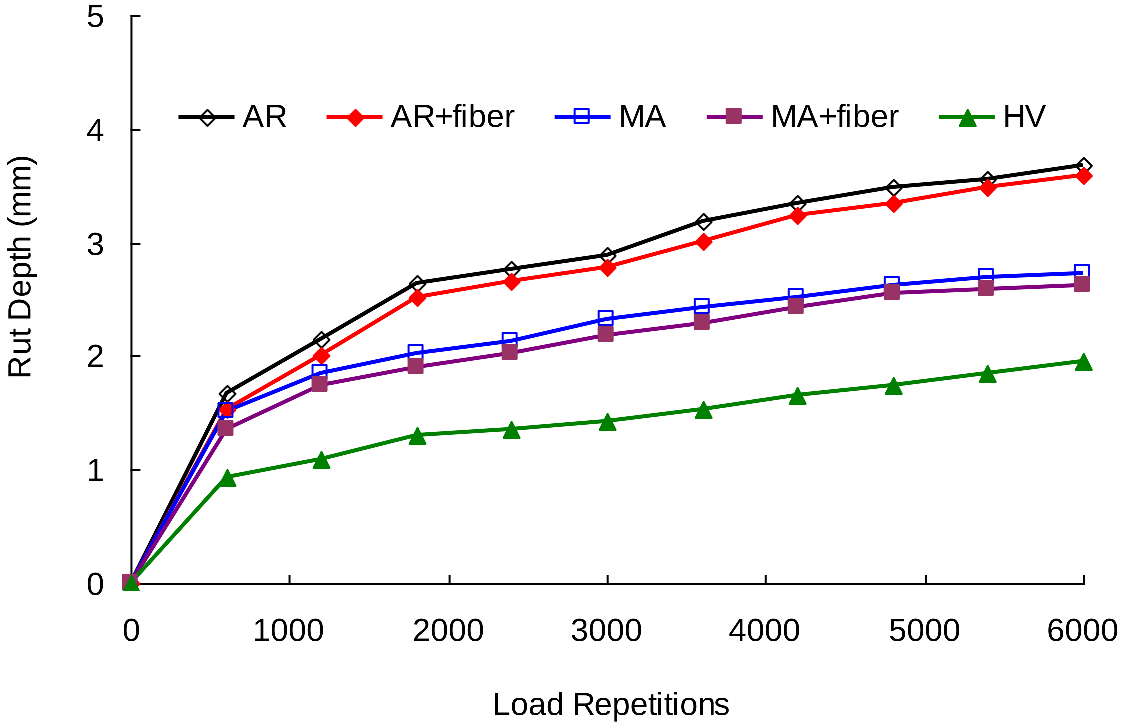

Figure 9 Load repetitions versus rut depth without submersion

6.5 Mixture Permeability

Figure 10 shows that all PAC mixtures prepared at air voids of 20 percent have good permeability values, which are higher than the minimum permeability of 0.01 cm/s. The minimum permeability of 0.01 cm/s is considered to be the starting point where connected voids become effective to provide good drainage in an asphalt mixture. There seems to be no significant difference in permeability among AR, MA or HV mixes. As shown in Figure 10, the existence of fibers appears to reduce drainage by filling pores inside PAC mixtures, although the addition of fibers improves the durability of PAC mixtures by providing a thicker binder film.

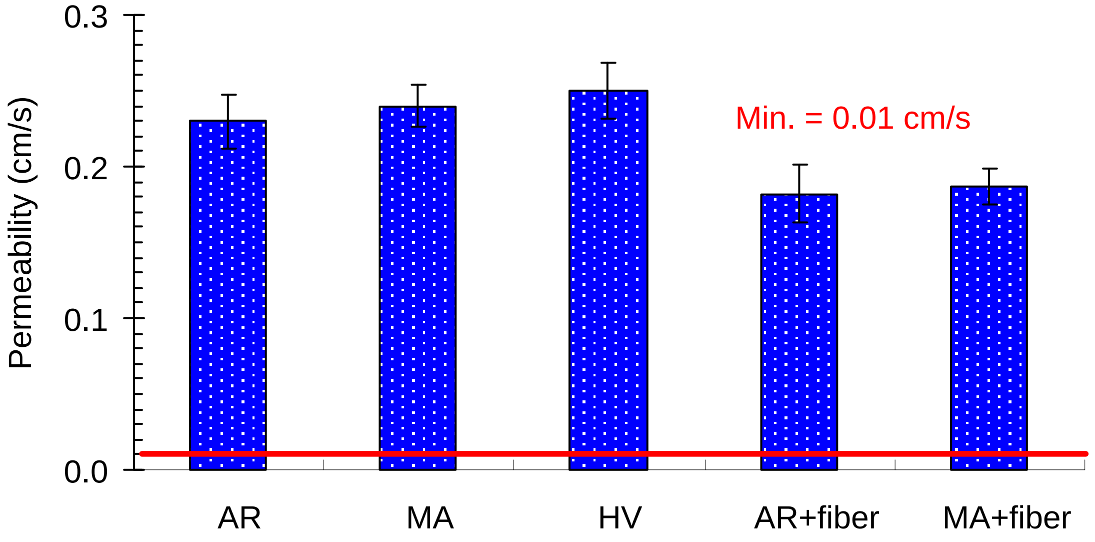

Figure 10 Effect of binder types on permeability of PAC mixtures

7. FIELD PERFORMANCE

7.1 PAC Drainability

As listed in Table 5, the drainability of the porous asphalt wearing course is almost the same in the beginning, but decreases over time in general. The drainability right after construction is well correlated to the test results of permeability in the laboratory. The reduction rate appears to be binder specific with the HV section having the best drainability. After more than two years of service, a slight filling up of the PAC layer occurred for both MA and HV sections. The water evacuation time measured with the field permeameter had gone from 4.24 to 5.29 seconds for the HV section. The slight reduction had no appreciable effects on the efficient of water draining and the avoidance of splashing.

However, after one year in service, there existed an increase in drainability for both MA and HV sections. Self cleaning seems to enhance the drainability because of the pumping and suction of the tires of numerous fast move vehicles on the PAC surface. The drainability of both MA and HV sections met the requirement of less than 6.7 sec after 2.5 years of service.

The drainability of the AR section decreases faster than that of the other two sections. The AR section had a drainability value of 8.96 sec that was significantly higher than MA and AR sections. A great densification of the AR porous asphalt layer is likely to occur due to heavy traffic loadings, thus leading to reduction in drainability. With a low viscosity value, the AR mix holds the void structure worse than MA and HV mixes. With time, more dust and debris also accumulate within the AR pavement structure and slowly clog up the voids, thus reducing the drainability of the pavement structure. Clogging of AR pavement pores occurs due to operational and consolidation problems.

Table 5 Drainability (second)

Section	Service time				
	0 month	1 month	6 month	1 year	2.5 yrs.
MA	4.50	4.85	5.89	5.22	5.58
HV	4.34	4.74	5.11	4.81	5.29
AR	4.49	5.39	6.64	7.49	8.96

7.2 Surface Friction

he tests were all adjusted by the exact pavement temperature at measurement to an equivalent BPN value at 20°C, as listed in Table 6. The measurement of the friction showed an initial BPN of 63 to 64. Skid resistance was relatively low just after construction because of asphalt binder film coating the aggregate at the pavement surface. As a consequence of the disappearance of the binder film covering the surface of the aggregate, skid resistance was improved after PAC open to traffic. After one month, it was already 66 and after six month 70. A BPN of 50 to 55 is considered sufficient and safe for highway pavements (13). According to test results listed in Table 6, porous asphalt layers provide good wet weather friction. The BPN value does not appear to be correlated with the binder type of the PAC mixture.

Table 6 Friction Characteristics - BPN value

Section	Service time				
	0 month	1 month	6 month	1 year	2.5 yrs.
MA	64.2	66.5	70.5	71.8	71.6
HV	64.3	66.7	70.7	71.3	71.7
AR	63.7	66.9	70.9	71.2	71.8

7.3 Pavement Rutting

As listed in Table 7, rutting depth increased with increasing service time. The low rutting values indicate that the PAC layer possesses good resistance to plastic deformation since PAC has a coarse gradation that results in stone-on-stone contact. Rut depth ranged from 2 mm for the HV section to 8 mm for the AR section after 2.5 years in service. The rutting depth of AR was highest among the three binder types, that of HV the lowest, and that of MA in between. In the HV section, high-viscosity modified bitumen was used to improve the rutting resistance of PAC mixtures. The field measurements on rutting are in good agreement with the results of the wheel tracking test. The polymer-modified binder effectively reduced the rutting in use.

Table 7 Rut Depth (mm)

Section	Service time				
	0 month	1 month	6 month	1 year	2.5 yrs.
MA	0	1	2	3	4
HV	0	1	1	2	2
AR	0	2	4	6	8

7.4 Changes in Smoothness

Roughness is an important index of pavement performance evaluation, which affects the comfortableness of drivers and passengers. It is an index involving human-vehicle-road interaction, often evaluated by the International Roughness Index (IRI). The ICC Surface Profiler used in this study is a multi-wheeled inclinometer-based system that is pushed by an operator at a walking speed of 1.2 km/h. For these sections, the IRI value expressed by m/km increased with time as listed in Table 8. The IRI value of AR was the lowest immediate after construction, while the roughness of HV was slightly larger than that of MA. Through investigation, short compaction time was the main reason of highest IRI of HV; however, the HV section can maintain ride quality well in the long run.

Table 8 International Roughness Index (m/km)

Section	Service time				
	0 month	1 month	6 month	1 year	2.5 yrs.
MA	2.3	2.4	2.5	2.6	2.7
HV	2.7	2.7	2.9	2.9	2.9
AR	1.2	1.5	2.1	2.8	3.0

8. CONCLUSIONS

This paper is to evaluate the engineering properties of porous asphalt concrete in laboratory, and compare field performance of PAC pavements constructed using three different types of asphalt. These three binders were traditional asphalt AR, and polymer-modified asphalt MA and HV. Following conclusions can be made according to test results:

- Mixtures without fibers or polymers showed greater draindown than those with additives. The use of fibers greatly reduced the potential for draindown; more so than did polymer modification. The use of polymeric bitumen made it easier to obtain a greater resistance to draindown, particularly for the HV mix.

- The wear losses in the Cantabro test were lower when using polymeric bitumen compared with a pure binder. The combined use of polymer modified binder and fiber minimized the abrasion loss and, thus, increased durability of the mixture.
- The HV mix had the highest strength and the best resistance to permanent deformation, since the viscosity of HV binder was much higher than that of the other two binders. The increase in viscosity of polymer-modified asphalt helped provide better indirect strength and resilient modulus for a PAC mix.
- The drainability of the MA and HV sections was higher than that of the AR section. Both MA and HV mixes maintained the efficiency of water draining and the avoidance of splashing after 2.5 years in service.
- Clogging of pavement pores in the AR section occurred and resulted in the reduction in drainability.
- PAC pavement surfaces provided good wet weather friction resistance once the asphalt binder film worn from the aggregate. It took about 6 months for the binder film to wear from the aggregate at the surface of the PAC layer.
- The test results obtained from laboratory and field made clear the advantage of using bitumen modified with polymers in the properties and characteristics of the porous asphalt mixes.

ACKNOWLEDGEMENTS

The authors are very grateful for the National Science Council (NSC97-2211-E-006-185-MY3) providing financial supports to make the completion of this project possible.

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