Proceedings of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 671 - 678, 2005

THE IMPROVEMENT OF WATER DRAINAGE FUNCTION AND ABRASION LOSS OF CONVENTIONAL POROUS ASPHALT

HARDIMAN
Ph.D Student
School of Civil Engineering
Universiti Sains Malaysia
14300 Nibong Tebal, Penang
Malaysia
E-mail: cehardi@eng.usm.my

Abstract: Air void content of porous asphalt are very closely relate to the durability and mixture performance. Aggregate factors affecting air voids are gradation, specific gravity and particle shape. This paper investigates the factors that improve of drainage function and abrasion loss of conventional porus asphalt (PA). Three maximum aggregate sizes were tested each made up of 10, 14 and 20 mm for conventional single layer PA. Double layer PA made of 10, and 14 mm top layer maximum aggregate size and thickness of top layer is 15 mm. Base layer made of maximum aggregate size 20 mm. All mixes are prepared using 60/70 grade base bitumen and polymer binder styrene-butadiene-styrene (SBS). The result shows that the coefficient of permeability of SBS mixes is lower compared to base bitumen mixes. However, SBS mixes are found to be more resistant against disintegration compared to base bitumen mixes.

Key Words: Porous asphalt, Water drainage, Abrasion loss, Disintegration, Permeability.

1. INTRODUCTION

Porous asphalt is an innovative road surfacing technology, which allows water to enter in to the asphalt mix through its continuous air voids. It is used in wearing course and always laid on an impervious base course; it is promising and proofs effective in enhancing traffic safety in rainy weather, reducing hydroplaning tendencies and having good skid resistance properties at higher speed. Porous asphalt is also used to reduce noises and glare at night and on wet surfaces. In addition it also has good resistance to permanent deformation.

According to investigation of actual condition about porous asphalt pavement in Japan and also some other countries, it has many problems, such as drainage and scattering. The biggest problem facing by the existing single layer porous asphalt (conventional porous pavement) is a drainage function falls. This phenomenon is caused by clogging of road dust, coming-flying dust and by consolidation of air void (Nakanishi *et al.*, 1995). In Singapore, local residual soils deposited from dirty wheels and vehicles carrying earth has been a major source of materials contributing to clogging of porous asphalt layers (Fwa *et al*, 1999). Kraemer (1990) reported that the initial drainage times of 25-75 s had increased to 80-100 s after 3 years and to 160-400 s after 9 years (Kraemer 1990).

In porous asphalt, the quantity and gradation of coarse aggregate determines porosity, hence permeability and resistance to disintegration. In general, porosity can be increased by increasing the proportion of the coarse mineral aggregate and reducing the amount of fine aggregate fraction. Abdullah, *et al.*, (1998) concluded that increasing void in the mineral aggregates and air voids in the mix by choosing the coarse aggregate gradation for the asphalt mix makes it more porous and water permeable. Hardiman (2004) reported that the porosity and resistance to disintegration have a strongly relationship with the conventional base bitumen content (60/70 penetration), as shown in Figure 1.

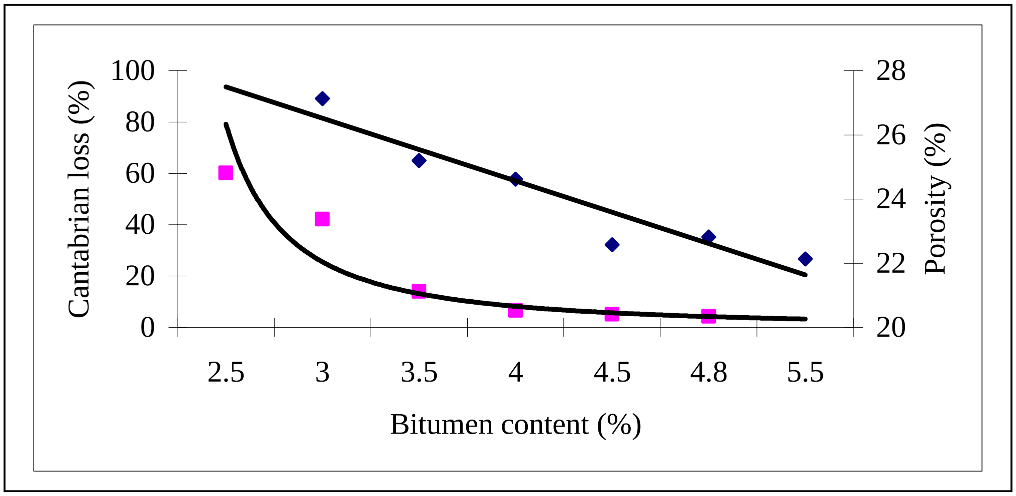

Figure 1. The Relationship between Cantabrian loss, Porosity and Binder Content

The main objective of this research is to improve of drainage function and abrasion loss of conventional porus asphalt. Three maximum aggregate sizes were tested each made up of 10, 14 and 20 mm for single layer (conventional porous asphalt). Double layer PA made of 10, and 14 mm top layer maximum aggregate size, and thickness of top layer is 15 mm. Base layer made of maximum aggregate size 20 mm. All mixes are prepared using 60/70 grade conventional base bitumen and polymer binder styrene-butadiene-styrene (SBS) at design binder content (DBC).

2. METHODOLOGY

2.1 Materials

2.1.1 Aggregates

Crushed aggregates supplied by Kuad Quarry Sdn. Bhd. in Penang were used in this investigation. The aggregates were sieved into their respective size range or fractions. Aggregate grading used in this investigation was developed based on the packing theory (Hardiman and Hamzah, 2003), as shown in Table 1.

Table 1. Aggregate Grading Used in This Investigation

Sieve	Percent passing by weight		
(mm)	Gradation 1	Gradation 2	Gradation 3
20	100	100	100
14	77.9	100	100
10	55.8	74.5	100
5	25	49	59.3
3.35	10	10.5	11.5
0.425	5.5	6	6.5
0.075	4	4	4

2.1.2 Filler

The aggregate gradation indicates a 4.0% filler requirement. It is customary to use hydrated lime as filler in porous mixtures to resist stripping but in quantity not exceeding 2.0%. Hence, the additional 2.0% comprised of ordinary portland cement (OPC).

2.1.3 Binder

Binder used in this research was conventional binder (penetration grade 60/70) and polymer modified binder (SBS). The design binder content used in this investigation was based on the cantabrian and binder drainage tests. From these tests, the design binder contents corresponding to 10, 14 and 20 mm maximum aggregate size equal 5.4%, 5.0%, 4.5% and 5.7%, 5.2%, 4.6% respectively for conventional and SBS binders (Hamzah and Hardiman, 2004a).

2.2 Specimen Preparation

Double layer is made up of the top and base layer. In principle, the preparation of 70 mm thick double layer porous Marshall specimen is similar with the preparation of Marshall specimen for conventional single layer porous asphalt. But, the amount of aggregate for top and base layers were calculated based on the Marshall density of single layer. Knowing the density and volume, the actual amount of mix required can be calculated. The maximum aggregate size for the base layer was 20 mm while two maximum aggregate sizes 14 and 10 mm was used for the top layer. The relative thickness of top and bottom layers (T/B) in a specimen were 0/70(SL) for single layer mixes; and 15/50 mm (DL) for double layer mixes. The structure of conventional and double layers porous asphalt is shown in Figure 2.

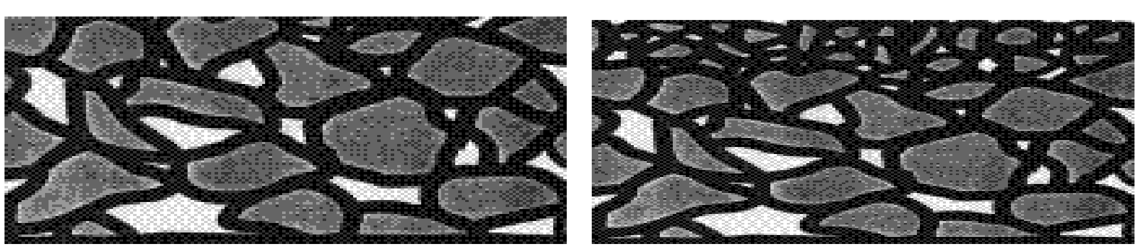

Figure 2. Conventional Single and Double Layer Porous Asphalt

2.2.1 Material preparation

Aggregate and filler were batched in metal container. A 1100 g aggregate would suffice to cast one specimen. The batched aggregates were placed in an oven at the desired mixing temperature for a period of at least 4 hours. The base bitumen 60/70 and SBS binders respectively required at least 2 and 4 hours of pre-heating. The cycle of heating of each binder was kept consistent. The mixing and compaction temperatures for mixes prepared using the two types of binders are outlined in Table 2.

Table 2. Mixing and Compaction Temperatures

Binder types	Temperature (°C)	
	Mixing	Compaction
Conventional binder (60/70 pen.)	140	130
SBS binder	180	160

2.2.2 Mixing

An electrically heated vertical paddle mixer was used to blend the aggregates and bitumen. The mixing process started with firstly feeding the hot aggregates into the mixer and then mixed dry for 1 minute. This step ensured uniformity and homogeneity of the aggregate blend. The correct quantity of bitumen was added into the blended aggregates and mixing continued. The mixing process ceased as soon as all of the aggregate was thoroughly coated with bitumen which normally required less than 1 minute of mixing time. Once the temperature of the unsegregated mix had dropped uniformly to the required compaction temperature, an approximately 1100 g of the material was transferred in to the hot mould. Using a metallic rod, the sample was tamped 15 times around the circumference and 5 times in the centre to ensure uniformity of mix. The partially compacted sample was then ready for full compaction at 2x50 blows.

2.2.3 Compaction Procedure for Double Layer Specimens

An investigation by Richter in 1995 has developed a method for two layer asphalt pavements in one single layer for some time and called as compact asphalt method. With the compact asphalt, the binder layer and wearing course are laid using the surfacing method “hot on hot” that means that both layers are immediately and successfully build in hot condition and are commonly compacted. The bonding of the layers is made of a conglutination and deep interlocking. The wearing course is reduced to a thickness of 1.5-2.5 cm. The early cooling of the thin wearing course can be prevented by a constant temperature balance between the hot core zones of the binder and the outside areas of the wearing course (Schafer, 2004). Next, Hamzah and Hardiman (2004b) reported that Marshall stability and permeability values for double layer porous asphalt compacted using Methods 2 steps and 3 steps do not differ significantly. Compaction procedure for each method is described in Figures 3 and 4.

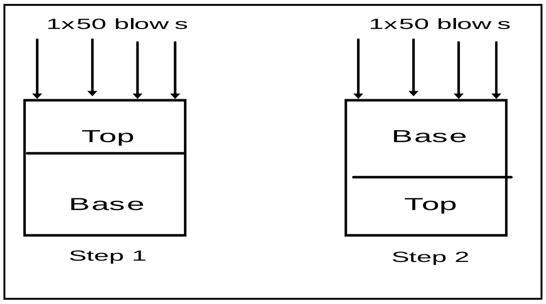

Figure 3. Compaction Procedures in Accordance with Method 2 Steps

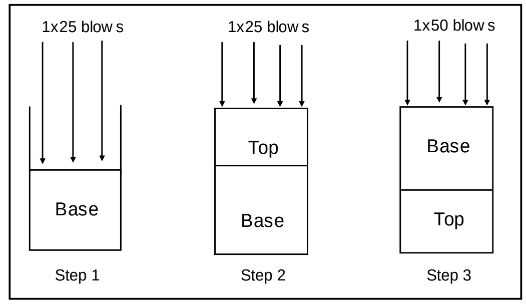

Figure 4. Compaction Procedures in Accordance with Method 3 Steps

For this investigation, compaction was carried out in 2 steps at 2x50 blows. The compaction procedure was as follows:

(i) The base layer mix ingredients were prepared for mixing. The required quantity of mix was placed inside the Marshall mould and the whole assembly was then transferred into the oven which was earlier set at the destined compaction temperature.

(ii) For the next step, the porous mix for the top layer was prepared. Once ready, the calculated amount of mix was then transferred into the Marshall mould and placed on top of the base layer mix.

(iii) The mix was then compacted at 1x50 blows each face.

2.3 Test for Porous Asphalt at DBC

2.3.1 Permeability Test

The equipment used for determining permeability in this investigation is a specially designed water permeameter which was designed based on the Leeds Water Permeameter. The coefficient of permeability of the specimen k was computed from Equation (1).

$$k = 2.3\ [a.L/At]\ [\log (h1/h2)] \qquad (1)$$

Where: k = coefficient of permeability (cm/s)
a = the cross sectional area standpipe (cm2)
t = time taken for water in the standpipe to fall from h1 to h2 (s)
A = cross sectional area specimens (cm2)
L = height of specimens (cm)
h1, h2 =water level at t1 and t2 (cm)

2.3.2 Resistance to Disintegration

To determine the loss of aggregate from porous asphalt specimen, the cantabrian test was carried out. In this test, a Marshall sample was subjected to 300 drum rotations in the Los Angeles drum. The abrasion loss was expressed in terms of the percentage mass loss compared to the original mass as illustrated in Equation (2).

$$P = \frac{P1 - P2}{P1} \times 100 \qquad (2)$$

Where P is the abrasion loss (%), P_1 and P_2 are respectively the initial and final specimen mass in grams.

3. RESULTS AND DISCUSSION

3.1 Permeability

Figure 5 shows the permeability results of all mixes tested. The coefficient of permeability of SBS mixes is lower compared to conventional mixes. Permeability of SBS mixes are on average 2.2%, 6.0% and 10.1% lower than conventional mix respectively for top layer made of maximum aggregate sizes 14 mm, 10 mm and single layer mixes. The decrease in permeability of single layer porous asphalt made with maximum aggregate size 10 mm is about 36.1% when compared with mixes made with maximum aggregate size of 20 mm. The highest permeability for double layer is 0.147 cm/s was measured for mix made of 15 cm top layer thickness and 10 mm maximum aggregate size. The average permeability of double layer mix is higher compared to 14 and 10 mm single layer mix but not single layer 20 mm. However, in terms of maximum aggregate size, the permeability of SBS and conventional mixes are not significantly different. Increasing the maximum aggregate size and decreasing the DBC increases the porosity. Higher porosity generally leads to higher permeability which is a valuable property of porous asphalt. However, this must be trade-off with specimen strength and durability.

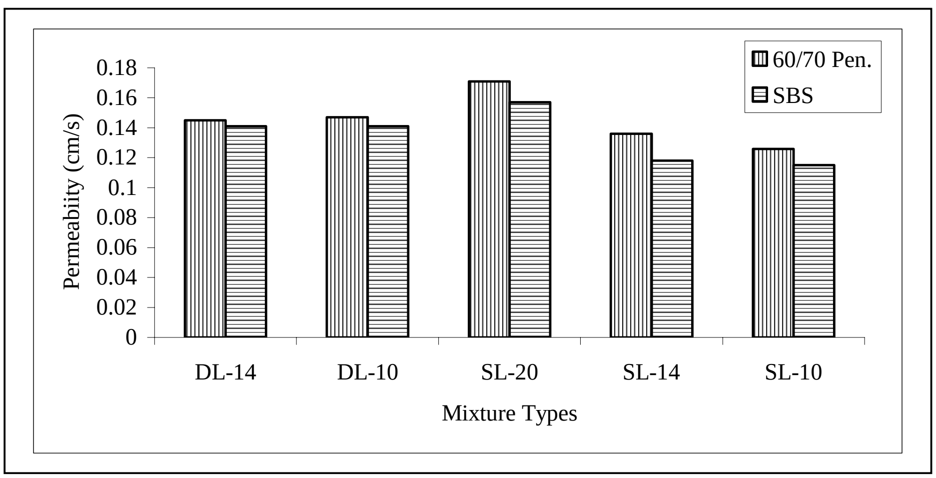

Figure 5. Permeability of Porous Asphalt Made with Conventional and SBS Binder

3.2 Resistance to Disintegration

The resistance to disintegration of porous asphalt is evaluated in terms of its abrasion loss and the results are shown in Figure 6. SBS mixes are found to be more resistant to disintegration compared to conventional mixes. Incorporation of SBS binder in a porous mixture can cause the resistance to disintegration to increase by an average of 51.1%, 55.3% and 148.6% when compared with the conventional mixes respectively for top layer made of maximum aggregate size 14 mm, 10 mm and conventional single layer mixes. This may be attributed to more superior inter-particle adhesion of such mixes. Other factors that appear to influence the resistance to disintegration include maximum aggregate size, design binder content and binder type. However, mixes prepared using 10 mm maximum aggregate size, SBS binder and 30 cm top layer thickness records the highest resistance to disintegration. The abrasion loss of all mixes prepared using SBS and base binders respectively experienced 1.4 to 4.5% and 5.7 to 7.76% abrasion loss. An improvement in resistance to disintegration is noticeable by increasing the binder content and decreasing the maximum aggregate size. For instance, the resistance to disintegration increases by up to 75.9% when porous asphalt are made with SBS binder and compared to base bitumen at top thickness layer 30 cm. While the resistance to disintegration for single layer mix made with the maximum aggregate size 10 mm increase by up 155.2% when compared to maximum aggregate size 20 mm. From figures shows that the resistance to disintegration for porous asphalt made of maximum aggregate size 10 mm is better than 14 and 20 mm. Double layer prepared using 10 and 14 mm maximum aggregate sizes exhibits abrasion higher than all 14 and 10 mm single layer with the exception of 20 mm single layer mix. The 20 mm single layer is the least resistant to disintegration.

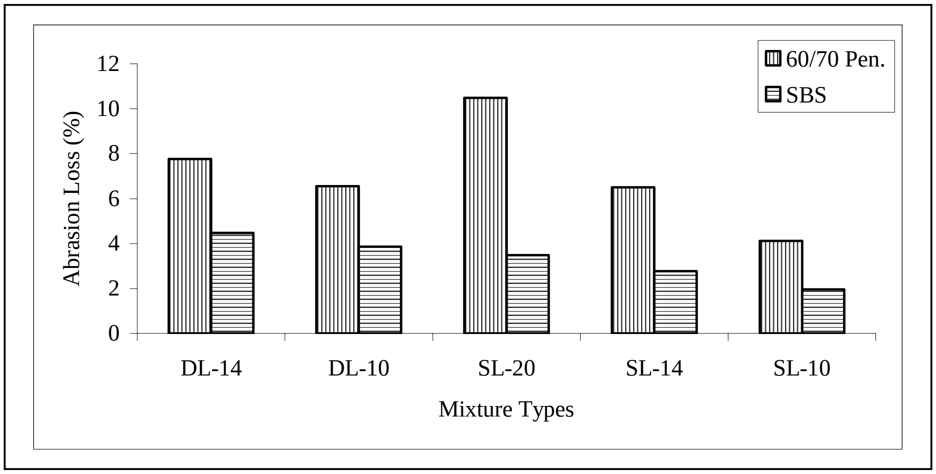

Figure 6. Permeability of Porous Asphalt Made with Conventional and SBS Binder

4. CONCLUSIONS

1. Addition of SBS modified binder can improve the resistance to disintegration of porous asphalt, but permeability is lower slightly compared to conventional base binder mix.
2. The properties of porous asphalt such as permeability, and resistance to abrasion loss decreases when the maximum aggregate sizes in porous asphalt decreases.
3. Permeability and abrasion loss of double layer porous asphalt is generally higher in comparison with 14 and 10 mm single layer porous asphalts. However, the 20 mm single layer exhibits higher permeability and abrasion loss compared to all double layer mixes.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Malaysian Ministry of Science, Technology and Innovation that has funded this research grant through the Intensified Research in Prioritised Area Grant (IRPA) program that enables this paper to be written. Finally, many thanks are also due to technicians of the Highway Engineering Laboratory at the Universiti Sains Malaysia for their support, assistance and encouragement.

REFERENCES

Abdullah, W.S., Obaidat, M.T. and Abu-Sa'da, N.M. (1998) Influence of aggregate type and gradation on voids of asphalt concrete pavements, **Journal of Materials in Civil Engineering, Vol. 10, No. 2.**

Fwa, T.F., Tan, S.A. and Guwe, Y.K. (1999) Laboratory evaluation of clogging potential of porous asphalt mixtures, **Journal of the Transportation Research Board (TRB), No. 1681,** 43-49.

Hamzah, M.O. and Hardiman (2004a) Effect of maximum aggregate size on single layer porous asphalt properties and a proposal for double layer to resist clogging. **Proceedings of the 6th Malaysian Road Conference**, Malaysia, 16-18 August 2004.

Hamzah, M.O. and Hardiman (2004b) Proposed impact compaction procedure for double layer porous asphalt specimens. **Malaysian Universities Transport Research Forum Conference 2004,** Universiti Teknologi Mara, Malaysia, 1-2 December 2004.

Hardiman and Hamzah, M.O. (2003) Grading design of double layer porous asphalt. **Proceedings of Malaysian Science and Technology Congress (MSTC) 2003,** Kuala Lumpur, 23-25 September 2003.

Hardiman (2004) Peran gradasi dan bahan pengikat dalam perbaikan campuran aspal porus. **Proceeding of Forum Studi Transportasi antar Perguruan Tinggi (FSTPT) 2004,** Parahyangan University, Bandung, Indonesia, 11 September 2004.

Kraemer, C. (1990) Porous asphalt surfacing in Spain. **International Symposium on Highway Surfacing,** University of Ulster.

Mallick, R. B., Kandhal, P.S., Cooley, L.A. and Watson, D.E. (2000) Design, construction and performance of new generation open-graded friction course**, Journal of the Association of Asphalt Paving Technologist, Vol. 69,** 391-423.

Nakanishi, H., Takei, S. and Goto, K. (1995) Suggestion to the improvement in durability of the function of porous asphalt pavements, **Road Construction,** Japan, August 1995.

Schafer, V. (2004) Compact asphalt and twin-layer porous asphalt laid by the compact module paver. **Proceedings of the 3rd Euroasphalt and Eurobitume Congress 2004**, Vienna, 12-14 May 2004.