The Performance of Porous Asphalt by using Modified Binder

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ABSTRACT

The application of porous asphalt on traffic safety grounds in Malaysia is relatively new. Encouragement on use of porous asphalt to mitigate road accidents has been spelt out in a Highway Planning Unit report to the Economic Planning Unit (HPU, 1998). However, it is generally accepted that porous asphalt is not as long-lasting as asphaltic concrete. This paper present the result of a laboratory investigation to evaluate performance of porous mixes by using Styrene Butadiene Styrene (SBS) modified mixes compared to conventional 60/70 pen bitumen. Samples using these binder were prepared in the form of Marshall specimen. The specimens are then subjected to a series of performance testing. The results indicate an improvement in mix properties with SBS modified mixes.

Keywords : *Binder, porous asphalt, SBS*

Introduction

The most commonly used surfacing material for roads in Malaysia is asphaltic concrete. Other materials used include macadams, stone mastic asphalt, porous asphalt and surface dressing or chip seals. Unlike asphaltic concrete, porous asphalt is relatively new in the Malaysian context. Porous asphalt was developed in the 1950's on British airport runways to improve the safety of fast moving aircraft traffic. The material later found its usage for roads on similar traffic safety grounds. In Malaysia, porous asphalt was first applied about 14 years ago and took place along Jalan Cheras-Beranang. In 1996 there were 16 locations along the Federal Routes that had been resurfaced with porous asphalt and another 25 locations in 1997 that had been identified for implementation. These efforts are to ensure rainwater do not form puddles on road surface and guarantee improved riding comfort to road users (HPU, 1998).

Thermoplastic Rubber

Thermoplastic rubbers may be regarded as a group name or description for a number of polymers or copolymers used in the modification of bitumen. A copolymer is a polymer that has more than one type of molecule incorporated in the polymer. These polymers are made up of many thousands of individual monomers or molecules built up chains by the various polymerisation processes developed by the large chemical industries. According to Poulsen et al. (1985) and Dinnen (1985), the styrene butadiene styrene (SBS) is also a thermoplastic rubber which is also referred to as a second generation polymers which combine both elastic and plastic properties. SBS is a copolymer and it was originally developed for use in the production of tyres and shoes soles but is suitable for the modification of bitumen. In the field of modified binders, the most commonly used thermoplastic material is SBS. The materials are characterized by softening on heating, hardening on cooling and can be heated to a liquid state.

Objectives

The main objective of this laboratory investigation is to evaluate performance of a porous mix by using the SBS modified compared to conventional mixes.

Scope of Work

The scope of work focuses on porous asphalt performance prepared at varying percentages of binder. The aggregate grading used was a modification to the gradation used in Korea. The basic tests on aggregates and binder were initially conducted to ensure conformity to the specifications. The binders used were a conventional bitumen grade 60/70 and SBS modified binder while the aggregates used were from the granitic group. The design binder content was determined based on the Cantabrian and binder drainage tests. Material characterization tests conducted at the design binder content include Marshall stability and resilient modulus.

Methodology

Binder Type Designation

Throughout this investigation, a 60/70 pen base bitumen and SBS modified binder were used. Both bitumens were supplied by Shell Ltd. In Malaysia, the typical bitumen used is grade 80/100. However, this bitumen will be too soft for porous asphalt. Another justification for using 60/70 pen bitumen was to make the mix comparable with the Korean mixes. The binders are designated in accordance with Table 1.

Table 1: Binder Designation

Binder Type	Designation
Base Bitumen 60/70	70P
SBS Modified	SBS

Preparation of Bitumen

The bitumen that arrived in bulk was subjected to two cycles of heating. Sufficient quantity of bitumen during one laboratory session was placed in the oven at the required mixing temperature until it was fully liquefied for mixing with the aggregates. The SBS and 70P respectively required at least 4 and 2 hours of pre-heating. The cycle of heating of each bitumen was kept consistent. The mixing and compaction temperatures are dependent on binder viscosity. The guidelines from Darin Tech (2000) provides information on mixing and the range of compaction temperatures for base and rubberized mixes as shown in Table 2. Following the recommendations given in Table 2, the chosen mixing and compaction temperatures for mixes prepared using the three types of bitumen are outlined in Table 3.

Table 2: Mixing and Compaction Temperatures According to Darin Tech (2000)

Binder Type	Mixing Temperature	Compaction Temperature
Base Bitumen	150°C	130°C
SBS Modified	185°C	140°C

Table 3: Mixing and Compaction Temperatures Adopted in this Investigation

Binder Type	Mixing Temperature	Compaction Temperature
70P	140°C	130°C
SBS	180°C	165°C

Preparation of Moulds

A typical 101.6 mm inner diameter steel Marshall moulds were used in conjunction with the Marshall hammer. In addition, moulds for the Marshall hammer must be fitted with a collar. Both steel moulds and their corresponding base plates were placed in the oven together with the aggregates.

Mixing

An electrically heated paddle mixer was used to blend the aggregates and bitumen. The mixer was first calibrated and then set to the required mixing temperature. Mixing of dry aggregates was accomplished in less than 30 seconds. Then, the correct amount of binder was poured onto the dry mixed aggregate and the wet mixing continued for a further 1 minute. The amount of bitumen required was calculated as a percentage of the total mix. Temperatures of the mix immediately prior to compaction shall be within the limits of the specified compaction temperature. Full compaction was then carried out using the Marshall hammer once the mix temperature dropped to the desired compaction temperature.

Compaction of Marshall Specimen

Impact specimens were compacted using an automatic Marshall compaction apparatus. The compaction hammer had a flat circular tamping face and a 4536 g sliding weight with a free fall of 457.2 mm. The mould holder was mounted on the compaction pedestal so as to center the compaction mould over the center of the post. It held the compaction mould, collar and base plate securely in position during compaction of the specimen. The entire batch was placed in a previously prepared mold assembly and the mixture vigorously spaded with a heated spatula or trowel. A heated rod was then used to tamp the mix 15 times around the perimeter and 10 times over the interior. Temperatures of the mix immediately prior to compaction shall be within the limits of the specified compaction temperature.

Two filter papers were placed on the surface of the mix and replaced the mold collar. The mold assembly was placed on the compaction pedestal in the mold holder and unless otherwise specified, applies 50 blows with the compaction hammer. The motor was switched on caused the hammers to apply about 50 blows per face and the compacter was run automatically. The base plate and collar were removed and the mould was reversed and reassembled. The reverse specimen was applied to the same number of compaction blows to the face of specimen. When compaction was completed, the sample was allowed to cool to room temperature overnight and later extruded from the compaction mould. Specimen was then carefully transferred to a smooth, flat surface and allowed it to cool to ambient temperature before testing.

The Marshall Test

In the stability test, the specimens were prepared with the specified temperature by immersing in a water bath at a temperature of 60°C ± 1°C for a period of 45 minutes. It was then placed in the Marshall stability testing machine and loaded at a constant rate of deformation of 50.8 mm/minute until the maximum load was reached. The stability result was recorded on the Marshall testing machine in kN. The total time elapsed between removing the specimen from the bath and completion of the test was not more than 30 seconds.

The Resilient Modulus Test

The resilient modulus test was conducted using the Universal Testing Machine, MATTA. The test was carried out according to the ASTM test method D4123 (ASTM, 1999). Each specimen was tested at 25°C after 4 hour-conditioning. A 1200 N peak load was applied along the vertical diameter of the sample. With a fixed level of applied peak force, the test sequence consists of a 5 count of conditioning pulses followed by 5 loading pulses where data acquisition takes place. The conditioning pulses ensured that the loading platens were seated onto the specimen so that consistent results were obtained. The pulse period and pulse width were respectively 3000 ms and 100 ms while the rise time was 50 ms. Pulse width specifies the width of the loading pulse whereas the pulse period specifies the total cycles of loading and resting time. The rise time was measured at the points of 10 % and 90 % of peak force and force pulse diagram is shown in Figure 1.

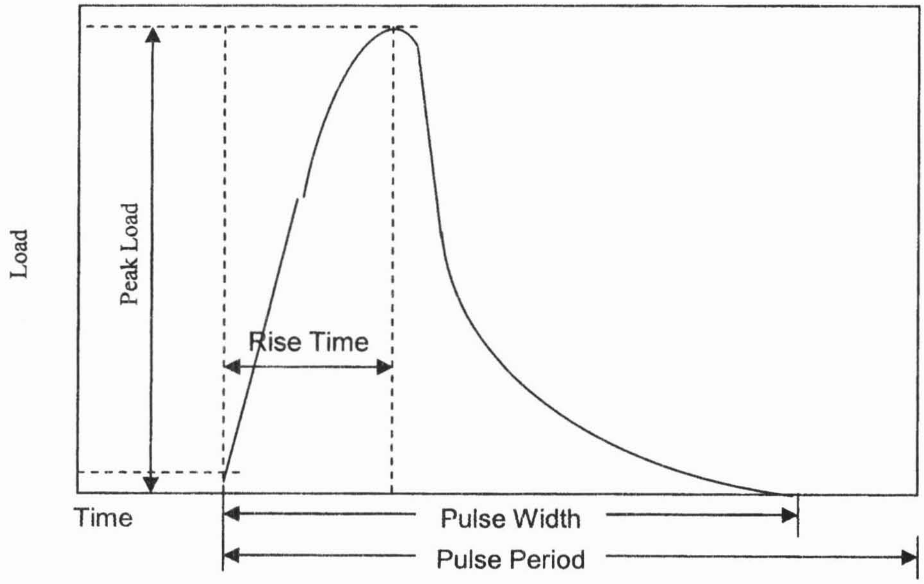

Figure 1: The Force Pulse Level and Timing Diagram (BSI, 1993)

Results and Discussion

Marshall Stability Test Results

For dense mixes, it is possible to optimize the binder content from the Marshall stability results when the stability increases with increment in bitumen content up to a peak value beyond which further addition of bitumen will cause a general drop in stability. For porous mixes, as shown in Figure 2, this form of definite relationship is inconsistent. The variation in stability with binder content is small and indicates that the stability is not sensitive to variations in binder content. This is one of the reasons why the Marshall stability method could not be used to design porous mixes.

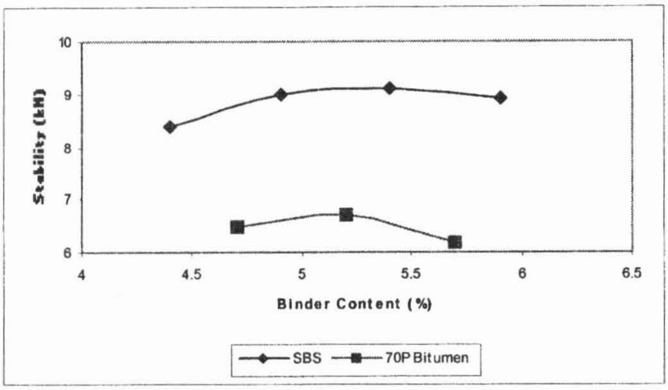

Figure 2: Stability Test Results

The effect of SBS modified mixes on stability is also shown in Figure 2. Clearly, the trend is quite inconsistent for majority of mixes. However, using modified bitumen has the positive effect of increasing stability. Generally, the SBS mixes exhibit the highest stability compared to conventional mixes. Nevertheless, all mixes indicated stability values more than the required 5kN stipulated in the Korean specification (Darin Tech, 2001). The average stability of conventional porous mix is 6.3kN. However, with the SBS mixes, the stability value can increase by as much as up to 1.4 times compared to conventional mixes. Nevertheless, the stability remains insensitive to binder content variations.

In this study, the Marshall stability values range between 6.2kN to 8.9kN for 70P bitumen and SBS mixes, respectively. The increasing of bitumen content does not show any constant trend in the stability result. This is because, a unique correlation between stability and bitumen content does not exist.

Resilient Modulus Test Results

The results of the resilient modulus test for mixes prepared at varying binder contents are shown in Figure 3. For all mixes, modified and unmodified bitumen exhibits similar pattern. Table 4 shows the mean resilient modulus of five pulse with the various binder types and binder contents. Each value is the average reading of two samples. Figure 3 exhibits a distinct peak beyond which further addition of modified binder will cause a drop in modulus except 70P bitumen. At 4.9% binder content, the SBS mixes give the value of modulus, which is 5160 MPa. Nevertheless, the resilient modulus of the SBS mixes is twice that of the 70P mixes.

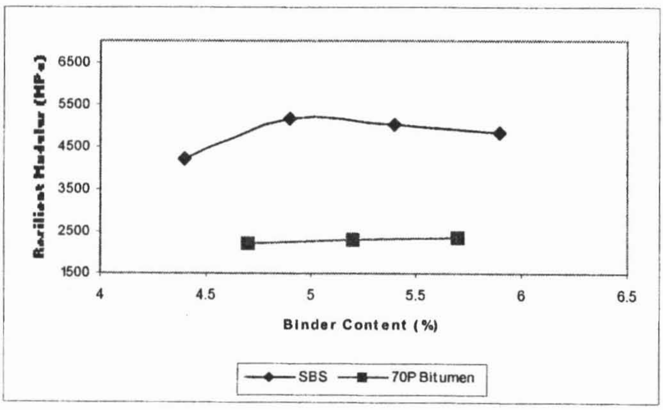

Figure 3: Resilient Modulus Test Results

Table 4 : Mean Resilient Modulus For Types of Binder

Types of Binder	Binder Content (%)	Mean Resilient Modulus at Pulse Number (MPa)					Mean RM* per Sample (MPa)
		1	2	3	4	5	
70P	4.7	2110	2237	2246	2140	2217	2190
	5.2	2118	2256	2430	2360	2421	2317
	5.7	2460	2268	2478	2412	2242	2372
SBS	4.4	4212	4109	4256	4115	4218	4182
	4.9	5210	5120	5170	5220	5080	5160
	5.4	5087	4990	4960	5012	5001	5010
	5.9	4760	4790	4880	4814	4856	4820

In this study, the resilient modulus mixes incorporating 4.4% modified and 4.7% unmodified binder were 4182 MPa and 2190 MPa, respectively. The mixes using modified binder achieved 48% more stability than mixes using unmodified binder and the result shows the same trend for other bitumen contents.

Conclusions

From the Marshall stability test, the variation in stability with binder content is small and indicates that the stability is not sensitive to changes in binder content. This is one of the reasons why the Marshall mix design method could not be used to design porous mixes. Generally, the SBS mixes exhibit the highest stability compared to conventional mixes. From the resilient modulus tests, the incorporation of SBS modified binder causes an increase of resilent modulus by two times compared to conventional mixes.

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