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BINDER DRAINAGE TEST FOR POROUS MIXTURES MADE BY VARYING THE MAXIMUM AGGREGATE SIZES

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ABSTRACT

Binder drainage occurs with mixes of small aggregate surface area particularly porous asphalt. The binder drainage test, developed by the Transport Research Laboratory, UK, is commonly used to set an upper limit on the acceptable binder content for a porous mix. This paper presents the results of a laboratory investigation to determine the effects of different binder types on the binder drainage characteristics of porous mix made of various maximum aggregate sizes 20, 14 and 10 mm. Two types of binder were used, conventional 60/70 pen bitumen, and styrene butadiene styrene (SBS) modified bitumen. The amount of binder lost through drainage after three hours at the maximum mixing temperature were measured in duplicate for mixes of different maximum sizes and binder contents. The maximum mixing temperature adopted depends on the types of binder used. The retained binder is plotted against the initial mixed binder content, together with the line of equality where the retained binder equals the mixed binder content. The results indicate the significant contribution of using SBS modified bitumen to increase the target bitumen binder content. Their significance is discussed in terms of target binder content, the critical binder content, the maximum mixed binder content and the maximum retained binder content values obtained from the binder drainage test. It was concluded that increasing maximum aggregate sizes decrease the maximum retained binder content, critical binder content, target binder content, maximum mixed binder content, and mixed content for both binders, but however for all mixtures, SBS is the highest.

Keywords: Porous Asphalt, Binder Drainage, Binder, Target Binder Content.

INTRODUCTION

Compared to traditional mixes such as asphaltic concrete, porous asphalt is a relatively new material. It was developed in the 1950's in the UK to solve skidding problems faced by fast moving aircraft traffic. The material was adapted for use on roads on similar traffic safety grounds. In Malaysia, the first porous asphalt trial took place along the Cheras-Berang Road. The patchy application of porous asphalt along the North-South Highway in short stretches is a particularly unique experience. Subsequent trials included the heavily trafficked Jalan Tebrau, Johor Bharu. The porous asphalt placed along the Federal Highway carries some of the highest average daily traffic in the country and has reached its design life. A more recent application is along the Kerinchi Link whereby porous asphalt was laid in an attempt to seek an alternative material that could potentially reduce traffic noise.

OBJECTIVES

The main objective of this laboratory investigation is to determine the effects of binder types on the binder drainage characteristics of a porous mix made of various maximum aggregate sizes 20, 14 and 10 mm using the Transport Research Laboratory (TRL) binder drainage test methodology.

SCOPE OF WORK

The scope of investigation is limited to a binder drainage study of a porous mixture made of various maximum aggregate sizes 20, 14 and 10mm. This gradation is developed based on the packing theory. The porous mixture used conventional 60/70 pen bitumen and SBS modified bitumen. The binder drainage characteristic was studied in the laboratory following the TRL Method.

Note: Discussion is expected before June, 1 st 2004. The proper discussion will be published in "Dimensi Teknik Sipil" volume 6 number 2 September 2004

DESIGN BINDER CONTENT (DBC) FOR POROUS ASPHALT

Porous asphalt differs significantly from dense mixtures in terms of function, mix design and behavior. As a wearing course layer, it functions to expedite surface water removal. Traditional mix design methods which normally incorporates the Marshall test, are not appropriate to design porous asphalt because of the insensitivity of the Marshall stability values to variations in binder content. It is therefore appropriate to specify the design binder content (DBC) for porous asphalt rather than the optimum binder content. The design binder content incorporates an upper and a lower limit. The lower limit of the DBC can be dictated by requirements to resist disintegration while the upper limit is specified to limit binder drainage yet maintaining a porous structure that would promote permeability.

AGGREGATE GRADING FOR POROUS ASPHALT

Many experimental studies have been made with mixtures of two or more particle sizes to obtain minimum void, mainly by using smaller particles. Produced curves show the minimum voids in the system against percentage of the larger size fraction for a number of size ratio [1].

A porous asphalt aggregate grading consists predominantly of coarse aggregates. The fine aggregate fractions are added so as not to bulk or interfere with the interlock of coarse aggregate matrix but to leave enough voids to maintain a pervious structure.

However, all porous mixes are dominated by the coarse aggregate fraction to achieve open structure. Aggregate top sizes varies quite considerably. The maximum aggregate size used should be not greater than a third of the layer thickness [2].

Some researchers have used various maximum aggregate sizes in porous mixtures. A special study for grading design of porous asphalt based on the packing theory, were found to be better than the empirical design. Also it was found that the permeability, stability and porosity values are influenced by maximum size, and proportion of aggregates. The gradation of aggregates used in this investigation can be shown on Figure 1 [3].

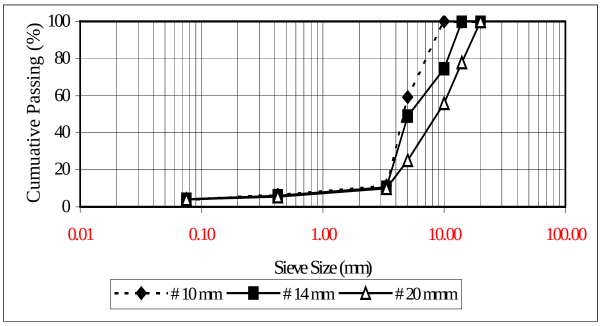

Figure 1. Gradation for Porous Mixtures Made of Max. Aggregate Sizes 20, 14 and 10 mm

THE PHENOMENON OF BINDER DRAINAGE

In a bituminous mix, the bitumen functions to coat the aggregate. This is possible when the bitumen is at the appropriate viscosity, hence temperature. At a given binder temperature, hence viscosity, there will be a maximum bitumen film thickness to coat the aggregate, beyond which the excess binder will be drained. The higher the temperature, the lower is the viscosity and hence a thinner bitumen film. Consequently, higher temperature implies more drainage. The phenomenon of binder drainage can be explained in this context and is experienced by mixes of small aggregate surface area such as in porous asphalt, stone mastic asphalt and open-textured bituminous macadams. In the field, binder drainage is not really objectionable because the excess binder will seal the pavement base making it impervious.

However, the idea is not favorable in economic terms. During transportation, the binder of rich mixes migrated to the bottom of the transport vehicle due to haul distance and mix temperature. Laying such a binder-segregated material will result in some areas being either rich or deficient in binder leading to an inconsistent finished surface. Areas of insufficient binder lack cohesion and early failure are expected. Areas of excessive binder experience low permeability.

Generally, the upper limit of the DBC should be sufficiently low to prevent binder run-off and to produce more porous mixes of higher permeability. On the other hand, the binder content should be sufficiently high to retard oxidation. A number of methods have been proposed to determine the upper limit of binder content that the aggregate skeleton can support without binder drainage before being laid and compacted.

REVIEW OF BINDER DRAINAGE TEST

An earlier attempt to quantify binder drainage was made by the Federal Highway Administration, FHWA [4]. The procedure initially involved the determination of the surface capacity of the aggregate fraction greater than 4.75 mm, which is the amount of SAE No. 10 lubricating oil retained. This value represented the total effect of surface area, the aggregates absorptive properties and surface roughness. The amount of binder required was then computed from Equation (1).

$$\text{Percent of binder} = 2K_c + 4 \quad (1)$$

where K_c = Surface capacity constant of the coarse aggregate.

For aggregates whose specific gravity differs significantly from 2.65, Equation (1) was modified into Equation (2).

$$\text{Corrected \% binder} = \text{\% bitumen } (2.65/SG_c) \quad (2)$$

where SG_c = The apparent specific gravity of the aggregate

A mixing pan method involved preparing a series of trial mixes starting with a 2% binder content and increasing it by 0.2% in each mix [5]. Each mix was compared visually and the lowest binder content that completely coated the aggregate with a continuous film without any binder drainage was determined. The design binder content is equivalent to this value plus an additional 0.4%.

The glass plate method, used for cross-checking, involved spreading the freshly prepared mix on a glass plate and subsequently allowed to cool to room temperature for 1 hour. The plate was then raised and fixed in an upright position. The mix adherence to the plate was observed. Lean mixes lost adherence in a matter of minutes. The design binder content was selected based on mixes that adhered for at least 0.5 hour with no signs of binder drainage on to the bottom of the glass plate.

To obtain an initial estimate of the required binder content the FHWA procedure can be used. Mixes to be studied were prepared at respectively 0.5% and 1.0% higher and lower than the estimated value. The mixes were placed on a clean, flat pan tilted at an angle of 45° in an oven at 135°C. After one hour, the mixes were removed from the oven and the extent of binder drainage observed. The design bitumen content was reported as the binder content 0.5% below that at which drainage commenced [6].

A more rational method based on the binder drainage test was developed at TRL. A wide range of binder types in full-scale trial has been used to specify the binder content [7]. The binder drainage test involved preparing a 1.1 kg porous mix and transferring it into a perforated basket, which in turn was placed, on a pre-weighed tray in an oven at the maximum mixing temperature for 3 hours. The suggested maximum temperature was to coincide with binder viscosity of 0.5 Pa s. At the end of the test, the mass of binder drained was determined. The test was repeated for a series of binder contents and the amount of material drained measured each time. The data was presented as a graphical plot between retained binder content, corrected for filler content, versus mixed binder content. A typical plot is shown in Figure 2. The retained binder content and mixed binder content are equal up to the point where drainage just begins. The maximum mixed binder content is the binder content at which the retained binder peaked to a maximum value. The mixed binder content M is assumed to coincide with a 0.3% drainage. The target binder content is equivalent to (M-0.3)%. The term 'target binder content' refers to the maximum binder content that can be safely accommodated without the risk of excessive binder run-off during mixing, transport and laying.

METHODOLOGY

In this investigation, the binder drainage tests were conducted on all mixes following closely the TRL procedure as described by Daines [8]. The binder contents and additive contents used are summarized in Table 1 while Table 2 indicates the test temperatures. The binder drainage conditioning or oven temperature is more than the mixed temperature to ensure drainage will take place when mix is in the oven rather than in the mixer itself during the mixing process.

Table 1. Binder Content and Additive

Maximum Agg. Size (mm)	Binder content (%)	
	Conventional 60/70 pen Bitumen	SBS Modified Bitumen
10	6.0; 6.5; 7.0; 7.5; 8.0; and 8.5	7.0; 7.5; 8.0; 8.5; 9.0 and 9.5
14	6.0; 6.5; 7.0; 7.5; 8.0; and 8.5	6.5; 7.0; 7.5; 8.0; and 8.5
20	4.5; 5.0; 5.5; 6.0; 6.5; 7.0; and 7.5	5.0; 5.5; 6.0; 6.5; 7.0; 7.5; 8.0 and 8.5

Table 2. Mixing and Binder Drainage Test Temperatures

Binder Type	Mixing Temperature (°C)	Binder Drainage Test Temperature (°C)
SBS Modified Bitumen	170	185
Conventional 60/70 pen Bitumen	130	150

To speed up the experimental work, a total of ten drainage baskets were fabricated from perforated metal. Each basket has a moveable wire and fixed handles fitted with an S-shaped clip at the top. This enabled the drainage basket to be conveniently hung over a pre-weighed drainage tray from the oven steel rack via the metal clip.

The test procedure consisted of firstly weighing and hanging each drainage basket over its corresponding drainage tray inside an oven set at the test temperature of Table 2 for at least 2 hours before testing began. The drainage trays placed underneath the basket were wrapped with aluminum foil so that it could be used repeatedly. A mass 2.2 kg of aggregate was blended with binder at the mixing temperature shown in Table 2. The mix, starting with a low bitumen content, was then transferred in equal proportions into the two drainage baskets. The mixer bowl and mixing paddles were scrapped thoroughly to ensure that all mix had been transferred into the drainage baskets. This stage of the experimental procedure was carried out briskly to minimize heat losses. The drainage baskets with the mix were hung over the pre-weighed trays. After a period of 3 hours, the drainage baskets and trays were removed from the oven. The mix in the baskets was discarded and any signs of bitumen draining onto the tray were noted. The drained bitumen and filler was then weighed. The test was repeated in duplicate.

The material that was drained onto the tray was a combination of bitumen and filler. The retained binder (%), R, shall be calculated from Equation 3 and drawn in Figure 2.

$$R = 100 \times B[1-D/(B + F)]/(1100 + B) \qquad (3)$$

where, D = the mass of binder and filler drained.(g)

B = the initial mass of binder in the mix (g)

F = the initial mass of filler in the mix (g)

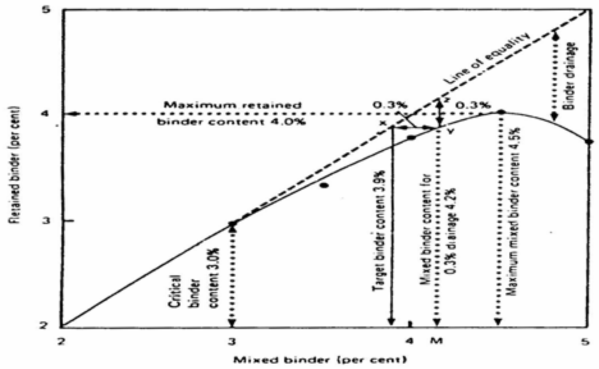

Figure 2. Typical Plot from the TRL Binder Drainage Test

RESULTS AND DISCUSSION

The relationship between the retained binder content (%) and mixed binder content (%) for mixes incorporating conventional 60/70 pen bitumen, and SBS modified bitumen are shown in appendix. If no drainage takes place, then the graph obtained will be a straight line sloping at 45 degrees, which is the line of equality. The results of binder drainage test for conventional 60/70 pen bitumen and SBS modified bitumen are shown in Table 3 and Figures 3, 4, 5, 6 and 7.

Table 3. Binder Drainage Test Results – TRL Method

Max. Agg. Sizes (mm)	Max. Retained Binder Content (%)		Critical Binder Content (%)		Target Binder Content (%)		Max. Mixed Binder Content (%)		Mixed Binder Content (%)	
	60/70	SBS	60/70	SBS	60/70	SBS	60/70	SBS	60/70	SBS
10	7.5	8.2	7.0	7.8	7.4	8.2	7.8	9.0	7.7	8.5
14	7.2	7.5	6.5	7.1	6.8	7.4	7.8	8.0	7.2	7.8
20	5.9	6.2	5.5	5.5	5.9	6.2	6.6	8.0	6.3	6.6

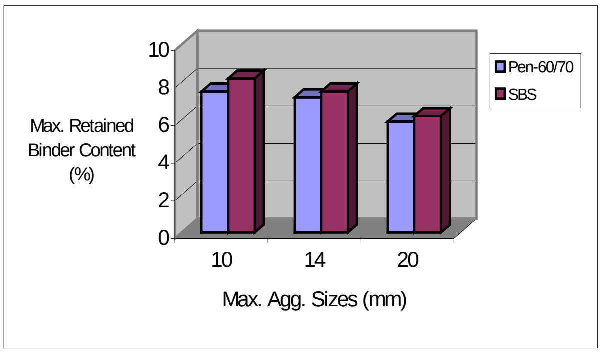

Figure 3. Maximum Binder Content for Binder Pen 60/70 and SBS

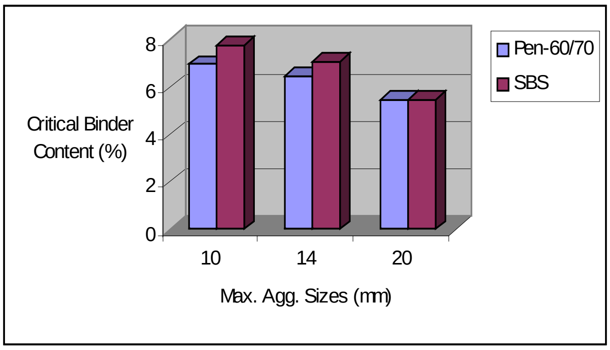

Figure 4. Critical Binder Content for Binder Pen 60/70 and SBS

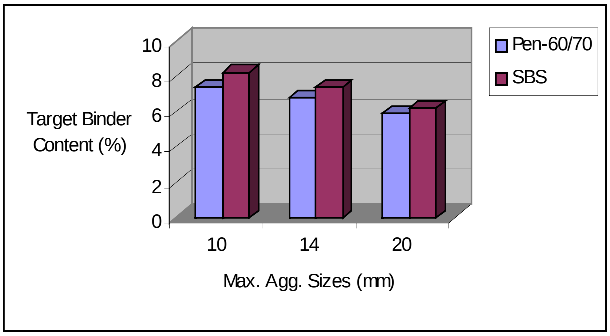

Figure 5. Target Binder Content for Binder Pen 60/70 and SBS

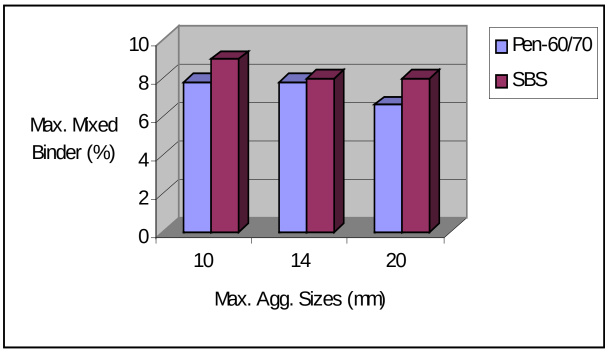

Figure 6. Maximum Mixed Binder Content for Binder Pen 60/70 and SBS

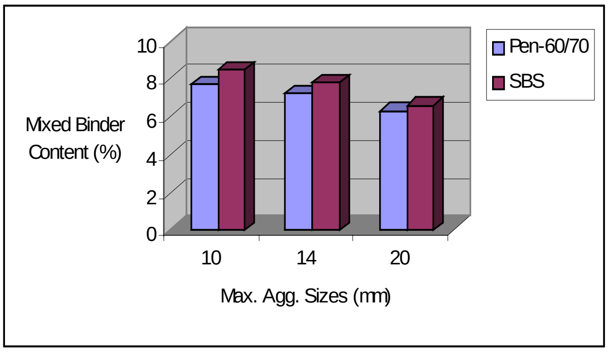

Figure 7. Mixed Binder Content for Binder Pen 60/70 and SBS

It was observed that the values of maximum retained binder, critical binder, target binder, maximum mixed binder and mixed binder for conventional 60/70 pen bitumen is lower than SBS. From figure 6, it can be seen that increasing the maximum aggregate size slightly decreased the maximum binder content. This value for SBS is higher than conventional 60/70 pen bitumen. This trend is the same for critical binder content, target binder content and mixed binder content.

For design purposes, the target binder content is adopted, which is 0.3% less than the mixed binder content. With conventional 60/70 pen bitumen, the target binder contents are 7.4%; 6.8% and 5.9% respectively for mixes made of maximum aggregate sizes 10, 14 and 20 mm. However, using SBS has the effect of an increased target binder content.

CONCLUSIONS

The binder drainage test indicates the maximum binder content that a porous mix can sustain without experiencing binder drainage. Therefore it can be used to specify the upper limit of the design binder content. Unlike the FHWA Method, it takes into account the change in viscosity of the type of bitumen used including modified binders. Increasing the maximum aggregate sizes decreases the maximum retained binder content, critical binder content, target binder content, maximum mixed binder content, and mixed content. Using SBS modified bitumen gives higher results than the conventional 60/70 pen bitumen.

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