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Proportion and Particle Size Distribution of Fine Aggregates Extracted From the Drained Binder in a Binder Drainage Test

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***Abstract*—**Binder drainage test is widely used to set an upper limit to the design binder content of porous asphalt. However, the presence of high amount of fine particles in the drained binder may affect the accuracy of the test result. This paper presents a study to characterize the composition and particle size distribution of fine particles accumulated in the drained binder. Fine aggregates and filler in the drained binder were extracted using a suitable solvent. Then, wet and dry sieve analysis was carried out to identify the actual composition of the extracted fine aggregates and filler. From the results, almost half of the drained binder consisted of fine aggregates and this significantly affects the accuracy of the design binder content of porous asphalt mix. This simple finding highlights the importance of taking into account the presence of fine aggregates in the calculation of drained binder.

***Keywords*—**Porous asphalt, Binder drainage test, Drained binder, Fine particle proportion

I. INTRODUCTION

POROUS asphalt (PA) was initially developed to improve traffic safety. Currently, it is applied due to pressures from environmentalist to reduce traffic noise, especially in the developed world. Huber [1] reported that measurements in most European countries had shown that the application of PA could reduce noise level by approximately 3 dB(A) for passenger car vehicles travelling at 80km/hr compared to the corresponding noise level from a reference dense asphalt wearing course. Bendtsen *et al.* [2] indicated that the noise level measurements achieved reductions of up to 6 dB(A) with the two-layer PA surfacing used in the Netherlands. Khalid and Perez [3], and Khalid and Walsh [4] indicated that the use of this material resulted in a significant reduction in fuel consumption due to enhanced smoothness. The improvement of pavement surface macro texture resulted in the reduction of tire wear due to the reduction in tire-pavement interface contact stress. According to Newcomb and Scofield [5], PA is 2.5 to 4.5 times more efficient in reducing noise compared to a noise barrier on a unit cost basis.Khalid and Perez [3] found that higher driver comfort levels could be experienced by using PA since noise reduction was perceived not only from the outside but also from the inside of the vehicle. Pagotto *et al.* [6] discovered that PA also improved the quality of runoff water where heavy metal loads discharged into the environment were reduced by 20% and 74% for copper and lead, respectively. Moreover, 87% of solids were retained, as well as 90% of hydrocarbons were intercepted.

Despite being an environmentally friendly road surfacing material, PA remains unpopular in some regions due to its short service life. Birgisson *et al.* [7] attributed this to premature clogging of the air voids which led to ineffective drainage of surface water. Alvarez *et al.* [8] stated that another major concern for this material was loss of its noise reduction capacity due to the clogging of air voids. One of the mechanisms associated with permeability loss was binder drain-down. Ferguson [9] noted the gradual asphalt drain-down during examination of a PA residential driveway near Macon, Georgia which was built in 1990. From close examination, binder was partly missing from the surface of the uppermost aggregate particles. Similar observations were made during numerous field observations of PA parking lots. The migration of the binder reduced the pavement surface integrity, as the binder was stripped away from the surface of aggregate particles.

The visco-elastic property of asphalt binder allows the binder to flow into the gaps in PA mix. Huber [1] stated that downward migration of asphalt binder in porous mix was known as binder drainage or binder drain-down. Generally, binder drainage took place during mix production, storage and transport, and this was more obvious if the binder content and mix temperature was excessively high. Binder drainage was not desirable from the economic standpoint whereas the excess binder could cause problems when transporting the mix from the mixing plant to the site. In the field study conducted, binder drainage resulted in an uneven distribution of asphalt mix with some parts of the pavement ended up being impervious with too much binder, while raveling took place in areas that were deficient in binder.

In order to quantify binder drain-down in a porous mix, the binder drainage test was developed by the British Transport Research Laboratory (TRL). According to Nicholls [10], the binder drainage test was used to determine the maximum binder content that can be blended with a particular aggregate grading without significant binder drainage. The test was first used on the A38 Burton bypass field trials, which showed that the most satisfactory target binder content, around 4.5% for 20

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mm nominal size aggregates, was difficult to achieve with unmodified bitumen. The binder drainage test involved preparing 1100g porous asphalt loose mix and transferring it into a perforated basket, then hung over a pre-weighed tray in an oven at the maximum mixing temperature for 3 hours. The suggested maximum temperature was to coincide with 0.5 Pa.s binder viscosity. The National Center for Asphalt Technology (NCAT) also developed a test method to determine a mixture's relative potential for drain-down [11]. An open-graded asphalt mix was placed in a wire basket having 1/4 inch mesh openings, and heated for one hour at 25°F above normal production temperature. The amount of asphalt binder that drained from the mixture was measured. However, the presence of high amount of fine aggregates in the drained binder may affect the accuracy of the test results. Based on this background, this paper evaluates the amount of fine aggregate particles in the drained binder during the binder drainage test.

II. OBJECTIVES

The objective of this study is to characterize the quantum and particle size distribution of the fine particles accumulated in the drained binder collected from the binder drainage test. This study is essential to ensure a more accurate determination of the upper limit of porous asphalt design binder content.

III. MATERIALS AND METHODS

The main material used in this study was the drained binder from the binder drainage test as shown in Fig. 1. The binder drainage test was carried out according to the TRL procedure [12]. The main equipment in the test was a perforated basket made of 3 mm perforations, hung in an oven at the anticipated mixing temperature for three hours. The binder that was drained onto the aluminum was scrapped for further examination.

From visual observation, a high amount of fines was found to accumulate in the drained binder. Potential particles in the drained binder include filler and fine aggregate particles whose size was less than 3 mm since the perforated baskets were made of 3 mm openings as pictured in Fig. 2.

Fig. 1 Drained binder on the aluminum foil

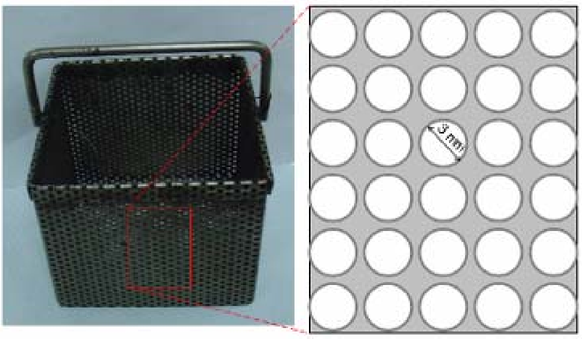

Fig. 2 Binder drainage basket with 3mm perforations

A. Wet and Dry Sieve Analysis

In the first stage, the drained binder on the aluminum foil was placed in the tray and heated in a draft oven at 170°C for 2 hours. The drained binder sample was dissolved in kerosene. The aggregate particles, filler and dissolved bitumen were separated via wet sieving on a 75 μm sieve. Extracted particles retained on the 75 μm sieve were transferred into the tray for the drying process and followed by dry sieve. The weights of original samples (drained binder with aluminum foil) with tray were recorded before and after the extraction process.

IV. RESULT AND DISCUSSION

A. Background

In the TRL binder drainage test procedure, the amount of retained binder was calculated using Equation. (1). However, this equation only considers the presence of filler in the drained binder, whereas fine aggregate is not accounted for in the calculations. It assumed the absence of fine aggregate particles drained together with the binder. Visual observations in Section III proved that this is not the case.

$$R = 100 \times \frac{B[1 - D/(B + F)]}{1100 + B} \tag{1}$$

Where;

D = Mass of binder and filler drained (g)
B = Initial mass of binder in the mix (g)
F = Initial mass of filler in the mix (g).

B. Proportion of Fine Aggregate Accumulated in the Drained Binder

Other than bitumen, the drained binder is made up of fine aggregates and filler. Wet and dry sieving analyses were adopted to separate the fine particles in the drained binder. Fig. 3 shows the mass of extracted fine aggregates, filler and bitumen that had been segregated from different samples.

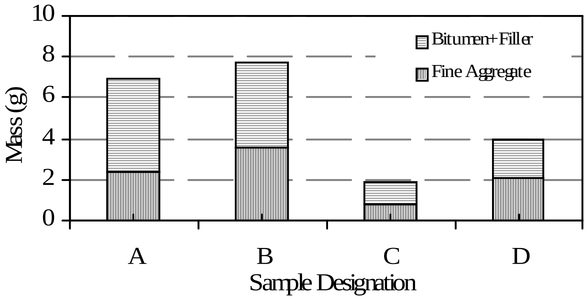

Fig. 3 Proportion of fine aggregate compared to mass of bitumen and filler

Fig. 4 presents the percentage by weight of fine aggregate incorporated in the drained binder. In this context, fine aggregate refers to those passing the 2.36 mm and retained on the 0.075 µm sieves. Since the material was sieved on the 75 µm sieve, majority of the filler would have filtered though with the bitumen solution. The fine aggregates extracted results showed that the average percentage of fine aggregate accumulated in the drained binder is approximately 45%. This value would be more if the proportion of filler drained was considered. Hence, it can be assumed that nearly half of the drained binder is made up of fine aggregate particles. On this premise, it is essential to take into consideration the percentage of fine aggregate in the calculation of drained binder.

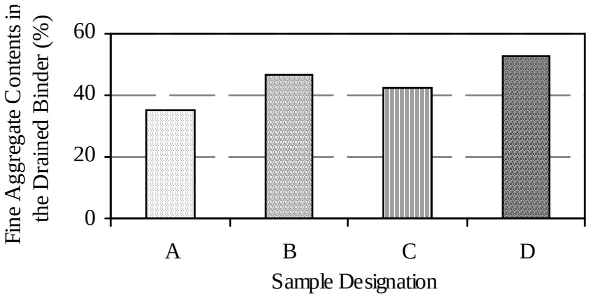

Fig. 4 Percentage fine aggregate accumulated in the drained binder

The polynomial regression line has been plotted (Fig. 5) to graphically express the relationship between extracted fine aggregate mass and mass of drained binder, which also includes filler. The result indicates that the regression line fixed the data well with high coefficient of determination (R^2) approximately 0.94. Hence, the mass of fine aggregate increases as the drained binder mass increases.

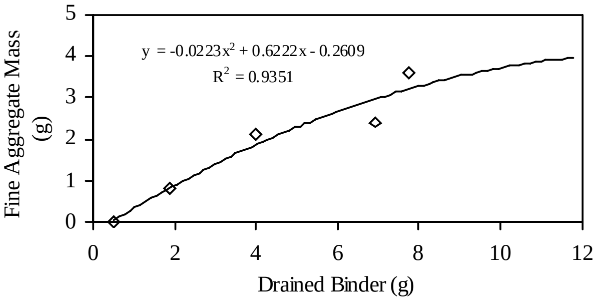

Fig. 5 Relationship between fine aggregate and drained binder

C. Sieve Analysis of Fine Aggregate

A dry sieve analysis was also carried out on the extracted fine aggregates. The oven dried extracted aggregate samples were combined to form a sizeable quantity since each sample mass was less than 5 g. Despite the effort, the cumulative mass of extracted fine aggregate sample was less than 10 g but suffice for dry sieving on 2.36 mm, 1.18 mm, 0.425 mm, 0.150 mm and 0.075 µm sieves. The dry sieve analysis result is plotted on a particle size distribution curve shown in Fig. 6 or alternatively plotted in a pie chart shown in Fig. 7.

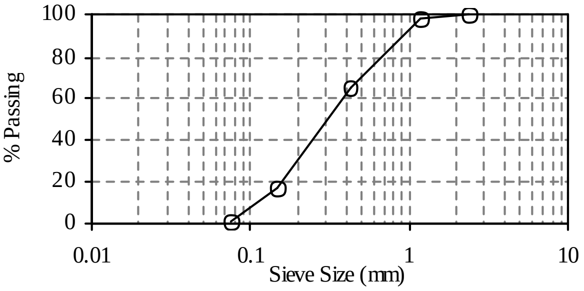

Fig. 6 Particle size distribution of the extracted fine aggregate

Fig. 7 indicates that almost half (48.87%) of the extracted fine aggregate is dominated by the size fractions 0.425 to 0.150 mm, followed by 1.18 to 0.425 mm, 0.150 to 0.075 mm, and 2.36 to 1.18 mm, respectively corresponding to 32.9%, 15.8%, and 2.37% by total mass. The extracted fine aggregates particle, in pictorial form, obtained from the dry sieving process is shown in Fig. 8.

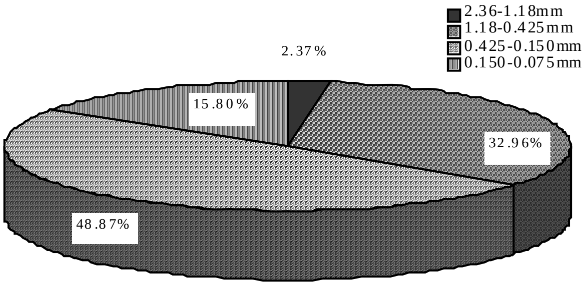

Fig. 7 Percentage of extracted fine aggregate fraction

Fig. 8 Extracted fine aggregate particles

The findings from this study indicate the necessity to evaluate the effects of binder types, binder contents, total mass of fine aggregate in the PA gradations and size of wire mesh or openings on the perforated basket on the amount of fine particles in the drained binder. Such an extensive result will enable changes to be made to drained binder calculation that consider not only drained filler but also drained fine aggregates.

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