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An Experimental Investigation of the Hydrualic and Durability Prpoerties of Asphalt Treated with Permeable Basecourses

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ABSTRACT

Treatment of the unbound open-graded has been done with the use of both asphalt and cement but the asphalt treated permeable basecourses is the most prominent. An experimental program was, therefore, conducted to determine the hydraulic and durability properties of asphalt treated permeable bases using three different aggregate types, 2 gradation types and three targeted percent air voids content of 15, 25 and 35. It was observed that the asphalt treated with permeable base course (ATPB) have appreciable coefficient of hydraulic conductivity but it looser strength and durability as the percent air voids content increases, making it unstable.

Key words: Asphalt, permeable, basecourse, hydraulic, durability

INTRODUCTION

The use of permeable basecourses as the principal drainage layer within a pavement's structural section has been growing for use over the years, due to their perceived role of drastically reducing the time, the pavement is exposed to saturated conditions. Their application has led to significant reduction in the occurrence of moisture-related distresses in both flexible and rigid pavements. However, due to the stability problems associated with pavement sections containing unbound open-graded drainage layers, many highway agencies have resorted for the use of bound open-graded basecourses. However, studies have found that after years of apparently satisfactory service, distresses have been observed in some pavements with free-draining bases even when they meet open-graded specifications Koroma and Kamara (2013). It has been observed that drainage from these layers is slowing overtime and there is now increasing concern as to how long the coefficient of hydraulic conductivity of open-graded base course can be maintained as the pavement ages. Also, some basecourse materials that meet the required gradation specification for use as free-draining bases have only produced fair to poor drainage. This has led to the observance of premature joint deterioration, faulting and crack sin pavement sections containing asphalt treated open-graded bases. In an effort to produce non-erodible and drainable base layer, many state highway agencies have moved from the traditional dense graded basecourse gradation specifications to more open graded basecourse specifications that allow for greater drainage in the pavement sub-layers. One major reason for this transition is due to the fact that dense gradations, even though they offer stiffer bases with good constructability, have serious long term stability problems as a result of prolonged saturation of the pavement structural section leading the stiffness as the pavement ages (Forsyth, 1994). However, one prominent drawback of these open-graded specifications is producing base layers that are difficult to construct and less stable under traffic and environmental loads. In order to overcome these drawbacks, some of these open-graded materials are now being stabilized with asphalt (Hansen *et al.*, 2009).

It has been observed that drainage from these layers is slowing over time and there is now increasing concern as to how long the coefficient of hydraulic conductivity of open-graded basecourse can be maintained as the pavement ages (Kazmierowski *et al.*, 1994). Also some basecourse materials that meet the required gradation specification for use as free-draining bases have only produced fair to poor drainage. This has led to the observance of premature joint deterioration, faulting and cracks in pavement sections containing these open-graded bases. As a result of these problems, concerns have been raised about the durability of free-draining bases and their influence on pavement performance. The California Department of Transportation had to discontinued its use of asphalt treated permeable bases, owing to the fact, a lot of premature moisture related diseases were found on cores taken from pavement sections containing ATPBs (Harvey *et al.*, 1999).

MATERIALS AND METHODS

The experimental program was carried out in two phases. A hydraulic conductivity testing program geared towards measuring the laboratory K value of the different samples and a durability testing program for measuring the resistance of the various samples to certain environmental variables like freeze-thaw and moisture damage.

Aggregate base materials: Three aggregate base materials, that were used to prepare the asphalt treated open-graded samples, were two natural aggregates and one recycled aggregate. The natural aggregates were natural gravel and dolomite while the recycled material was recycled crushed concrete. Dolomite has a specific gravity of 2.80 and absorption capacity of 0.78%, natural gravel has a specific gravity of 2.65 and absorption capacity of 1.04% and recycled concrete aggregate has a specific gravity of 2.53 and an absorption capacity of 5.3%.

Stabilizing agents: For this study, asphalt grade PG of 58-28 was used for the asphalt treated open-graded samples. The asphalt was provided by the Pavement Research Group of Michigan Technological University. The asphalt has mechanical properties as shown in Table 1.

Aggregates' gradations: Two gradation types were used namely the AASHTO No. 67 and MDOT 5G. These are shown in Table 2.

Laboratory testing program: Types of ATPB samples prepared are shown in Table 3.

An asphalt content of 3% by weight of the dry weight of aggregate was used. APG58-28 asphalt binder provided by the Pavement Research Group of Michigan Technological University (MTU) was

Table 1: Asphalt properties

Properties	Value
Phase angle	8.642802+01^{e}
Complex modulus	1.507037+03^{e}

Rolling Thin Film Oven (RTFO)

Table 2: Aggregate gradation specifications-percent finer by weight

Sieve size (inches)	AASHTO No. 67	Michigan 5G
2.5	-	-
2.0	-	-
1.5	-	100
1	100	-
3/4	90-100	-
1/2	-	0-90
3/8	20-55	-
4	0-10	0-8
8	0-5	-
16	-	-
30	-	-
40	-	-
50	-	-
200	-	0-3

Table 3: ATPB prepared sample

	ATPB (%)		
Material type	15	25	35
Recycled	RC_5G_15	RC_5G_25	RC_5G_30
Natural	NG_5G_15	NG_5G_25	NG_5G_30
Dolomite	DL_5G_15	DL_5G_25	DL_5G_30

used to make the asphalt treated open-graded samples. Three air voids contents were targeted in this study: as 15, 25 and 35%, respectively. The aim was to determine how the variations in the volumetric properties of the ATPB mix affect its hydraulic, mechanical and durability properties. Two major concerns with regard to preparing laboratory mixes of the aforementioned percent air voids content is; the kind of compaction procedure to employ and the process of determining the percent air voids of the compacted permeable specimen. The gyratory compaction procedure was used to compact the asphalt treated open-graded mixes. The challenge of using the gyratory compaction method is to determine the number of gyrations to be applied in order to achieve the targeted percent air voids content. It was also required that the number of gyrations applied should produce a sample height that meets the requirement of both, the permeability and indirect tensile strength test procedures. In order to achieve this, several trial mixes using different numbers of gyrations and computing the corresponding percent air voids content were carried out.

After several trial runs, the following mixes and number of gyrations were used to arrive at the designated percent air voids content:

- 15% air voids content: Total weight of sample 3500 g and 40 gyrations
- 25% air voids content: Total weight of sample 2500 g and 25 gyrations
- 35% airvoids content: Total weight of sample 4200 g and 20 gyrations

For each material, percent air voids content and gradation type, four samples were prepared and tested. This resulted in a total of 72 samples. The maximum theoretical rice specific gravity was calculated according to AASHTO T209-05 (2007) in the same manner as is done with compacted asphalt specimen. The only variation was with the procedure used to measure the bulk specific gravity of the compacted treated permeable base material. AASHTO T166 is the testing procedure mostly used to determine the bulk specific gravity of compacted asphalt specimen. However, this procedure requires that the specimen should be in asaturated surface dry state. Due to the porous nature of the materials under investigation, a SSD state was impossible to attain and as such an alternative testing procedure was used to measure the bulk specific gravity of the ATPB samples. As a result, therefore, the Corelok was used to measure the bulk specific gravity of the compacted ATPB specimens in this study (Cooley *et al.*, 2002).

The determination of the bulk specific gravity of the ATPB sample using the Corelok device was done in strict accordance with ASTM D 6752.

Hydraulic conductivity testing program: Hydraulic conductivity was done in accordance with the AASHTO provisional procedure P-125 entitled: "Determination of Saturated Hydraulic Conductivity using a Flex wall Permeameter." The apparatus set up and the procedure employed a falling head approach. The test procedure, however, requires the height of the test specimen about 80 mm. Therefore, some of compacted samples with height greater than 80 mm were cut while some within ±5 were not cut.

Durability tests for ATPBs: The resistance to moisture damage in asphalt treated open-graded samples is a direct function of both the aggregate type, binder type and percent binder content by weight of dry aggregate. Durability test on the asphalt treated open-graded samples was done in strict accordance to AASHTO T283 (2007), the standard method of test for resistance of compacted hot mix asphalt to moisture-induced damage. Durability tests were conducted on each of the asphalt treated open-graded mix types. Test protocols contained in AASHTO T283 (2007), the standard method of test for resistance of compacted Hot Mix Asphalt (HMA) to moisture-induced damage were used to determine the moisture susceptibility of ATPBs. Specimen preparation and testing procedures were in accordance with AASHTO T283 (2007). The test was conducted on compacted ATPB specimens at a given air void content. The four ATPB samples for each mix type were divided into two groups labeled "control group" and "conditioned group". The two control specimens were then tested for tensile strength after the bulk specific gravity and coefficient of hydraulic conductivity tests have been performed. Two other ATPB specimens were conditioned by saturating with water in accordance with the conditioning procedure outline in the standard. The specimen as allowed to undergo a freeze cycle and then a warm-water soaking cycle. The specimens were then tested for tensile strength by loading the specimens at a constant rate. For each specimen, tensile strength was calculated as follows:

$$S_t^x = 2 \times \frac{Pmax}{\pi tD} \tag{1}$$

where, S_t = Tensile strength, P_{max} = Maximum load, t = Height of specimen and D = Specimen diameter. For each material and gradation type four in direct tensile strength, tests were conducted on 3 control specimens and 3 conditioned specimens. The results of these six tests were then averaged for both the control and conditioned to give average tensile strength for the control specimen and average tensile strength for conditioned specimens. The figures also show the associated Tensile Strength Ratio (TSR) which was then computed as follows:

$$\text{TSR} = \frac{\text{Avg. tensile strength of conditioned specimens}}{\text{Avg. tensile strength of control specimens}} \times 100 \tag{2}$$

RESULTS AND DISCUSSION

Hydraulic conductivity test results are shown in Table 4 and durability test results are shown in Fig. 1-6.

Table 4: Average percent air void content and coefficient to hydraulic conductivity of ATPB samples

Specimen	No. of samples	Rice specific gravity	Nominal asphalt content (%)	Avg. air void content for control group (%)	Avg. airvoid content, for conditioned group (%)	Avg. K (cm s^{-1})
RC_15_5G	4	2.426	3	16.2	15.8	2.73
RC_25_5G	4	2.426	3	20.4	21.4	3.50
RC_35_5G	4	2.426	3	29.6	30.8	5.13
RC_15_67	4	2.44	3	15.3	15.1	2.58
RC_25_67	4	2.44	3	19.2	19.7	3.30
RC_35_67	4	2.44	3	29.1	29.3	4.96
NG_15_5G	4	2.65	3	17.7	17.2	2.96
NG_25_5G	4	2.65	3	22.4	21.2	3.70
NG_35_5G	4	2.65	3	33.2	33.6	5.67
NG_15_67	4	2.62	3	16.4	16.8	2.82
NG_25_67	4	2.62	3	20.7	21.4	3.58
NG_35_67	4	2.62	3	30.1	31.4	5.22
DL_15_5G	4	2.744	3	18.4	18.7	3.15
DL_25_5G	4	2.744	3	24.3	25.2	4.20
DL_35_5G	4	2.744	3	35.4	36.3	6.09
DL_15_67	4	2.722	3	17.2	17.6	2.96
DL_25_67	4	2.722	3	22.4	23.1	3.92
DL_35_67	4	2.722	3	31.4	32.6	5.44

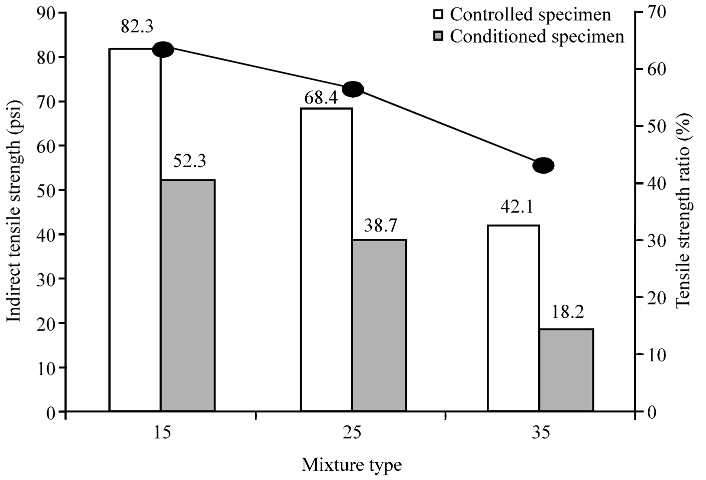

Fig. 1: Asphalt-treated dolomite AASTO No. 67 samples

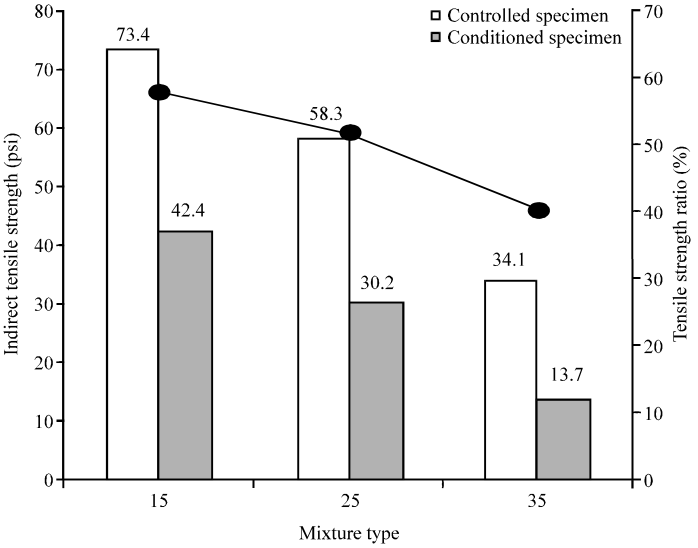

Fig. 2: Asphalt-treated dolomite MDOT No. 67 samples

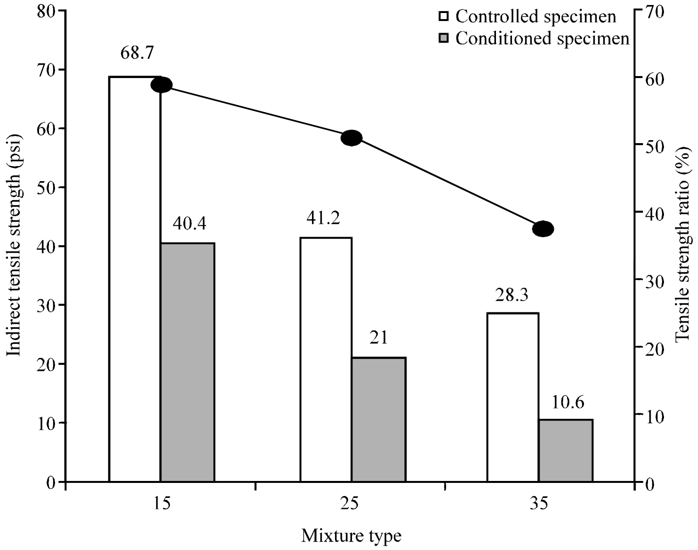

Fig. 3: Asphalt-treated natural gravel AASHTO No. 67 samples

Based on the results of permeability, tensile strength and durability of asphalt treated permeable specimens, the following trends were observed and discussed.

All thes samples have a K value well in excess of FHWA minimum of 304 m day^{-1}. The recycled concrete samples made from the AASHTO No. 67 gradation have the least K with an average K of 22293.07 m day^{-1}. The dolomite MDOT 5G gradation samples have the highest K with an averagevalue of 5361.00 m day^{-1}.

For the same gradation and mix type, dolomite samples have the highest coefficient of hydraulic conductivity. On average, dolomites samples have a K value about 7% greater than that of natural gravel samples. Recycled concrete aggregate samples have the least K value. A likely reason for this

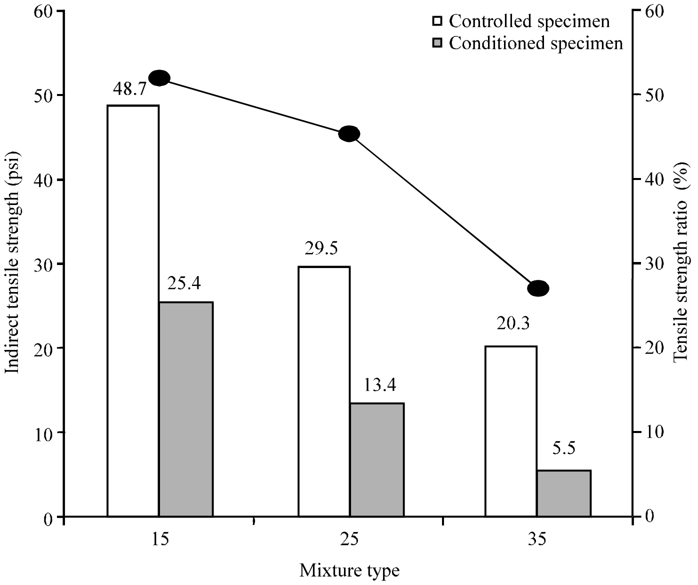

Fig. 4: Asphalt-treated natural gravel MDOT No. 67 samples

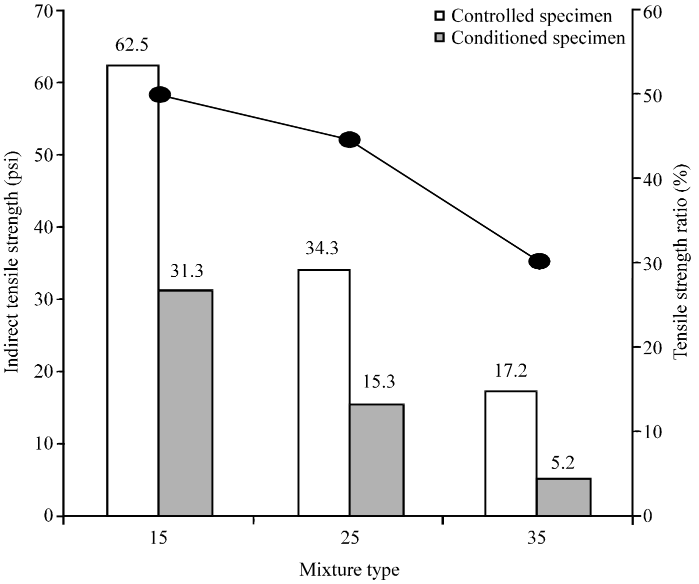

Fig. 5: Asphalt-treated recycled concrete AASHTO No. 67 samples

can be attributed to the greater degradation of recycled concrete aggregate particles as a result of the gyratory compaction. This degradation leads to break down of particles which produces smaller size fractions which can block flow channels, thus reducing the K value in the process.

For the same material type, MDOT 5G samples have higher coefficient of hydraulic conductivity than AASHTO No. 67 samples. However, the AASHTO No. 67 samples have higher tensile strength values and TSR. This was expected since the MDOT 5G gradation is a more open gradation than

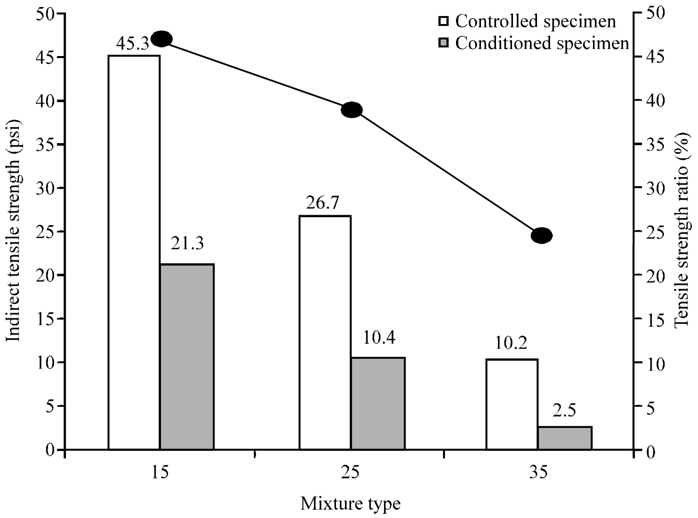

Fig. 6: Asphalt recycled concrete MDOT 5G samples

the AASHTO No. 67. As a result of this more open-graded matrix, MDOT 5G samples will have higher K values but there will also be less contact between the aggregate particles giving its lower tensile strength values.

The K values of asphalt treated specimens are much higher than the cement treated samples but this is due to the method used to determine the K value for each material type. The flex wall permeameter used to measure the K value of the cement treated samples was not designed to measure the K of highly porous specimens like CTPBs and as a result, this limitation of the testing equipment may have placed a limit on the measured K values of cement treated samples.

Another important deduction that can be made from the test results is the critical importance of material and gradation selection for asphalt treated permeable material. Lime stone samples have the highest tensile strength followed by those of natural gravel and the least being recycled concrete aggregate. Limestone samples also showed the least tensile strength reduction i.e., highest TSR value. For each material and gradation type, the Indirect Tensile Strength (ITS) decreases as the percent air void content increases due to reduced contact between the aggregate particles.

The Tensile Strength Ratio (TSR), which is a measure of the moisture susceptibility of the asphalt mix also reduces with increasing percent air void content for all the samples. For most dense Hot Mix Asphalt (HMA) and open-graded asphalt materials used as surface course in asphalt pavement, a TSR of 80-85% is normally specified. A TSR value less than that specified, is normally interpreted to mean that the mix may have long term durability problems. A pavement layer containing such a mix is therefore expected to be susceptible to moisture damage leading to premature failure of the pavement structure.

CONCLUSION

All the samples under investigation in this study have TSR value lower than that which was specified. The highest TSR value was that of DL_15_AA67 samples with a value of 64.7% and the least being 27.4% for a RC_35_5G samples. These low TSR values will mean that these mixes have very low resistance to moisture damage. The question, however, is whether the same TSR specification used for the surface course can be used for the asphalt treated drainage layer or whether the TSR is an appropriate performance criterion for asphalt treated permeable bases considering their high percent air void content. In the estimation of this study, since the TSR can be related to both fatigue and rutting of asphalt pavement, it seems only appropriate to use it to determine the moisture susceptibility of asphalt treated drainage layer. Furthermore, it shows that this reduced tensile strength will affect the value of the vertical tensile strength at the bottom of the HMA layer. One of the important performance criterion of asphalt pavement is the vertical tensile strain at the bottom of the HMA which governs the fatigue life of the pavement. For the most part, the drainage layer is located just underneath the surface course and even though some designs may not assign any structural significance to the drainage layer, its position will no doubt affect the magnitude of the vertical tensile strain at the bottom of the HMA layer.

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