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Effect of Bamboo Ash on Moisture Damage in Hot Mix Asphalt (HMA) Concrete

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ABSTRACT :
Mineral and organic fillers used in asphalt concrete production are vital in the performance of flexible pavements, hence, numerous mineral fillers are currently being used to improve the quality of asphalt concrete mixes. In this research, laboratory investigations on asphalt concrete mixes were carried out to determine the contribution of Bamboo Ash as filler, to the Stability and resistance to moisture damage of Hot Mix Asphalt (HMA) concrete under extreme moisture conditions; Marshall Stability, Retained Marshall Stability (RMS), Swell and Swelling index (SI) of asphalt mixes at 0, 1, 2, 3, 4, and 5% void filler content were investigated. For the purpose of this research, unmodified and Bamboo Ash-modified asphalt specimens were prepared and soaked for 0 to 5days, the 0 day representing unsoaked/dry specimen. Stability values of the specimens were obtained and the Retained Marshal Stability determined. Swell and Swelling Index (SI) of unmodified and modified specimens soaked for 0 to 5 days were also determined. The research showed that Bamboo Ash used as filler improved the Stability and Retained Marshall Stability of the asphalt concrete mixes at 3% optimum filler content. The result also indicated that Bamboo Ash used as filler improved resistance to moisture damage with a reduction in Swell and Swelling Index to a minimum at 3% filler content. The research concluded that Bamboo Ash is capable of reducing loss in Stability, and increasing resistance to moisture damage in Asphalt concrete mixes, and recommended that Bamboo Ash at 3% filler content be used in production of asphalt concrete.

KEYWORDS*: Bamboo Ash, Moisture Damage, Asphaltic Concrete.*

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I. INTRODUCTION

Hot Mix Asphalt (HMA) concrete mix design is a process to ascertain appropriate proportion of materials to produce suitable and long lasting performance pave mixture during its service life. Asphalt concrete is a composition of binder, coarse and fine aggregates, in different relative proportions to determine the strength and physical properties of the mix and the performance of the mix as a finished flexible pavement. The design of asphalt paving mixes is a huge issue in selecting and proportioning the material contents, in order to optimize all the expected results.The role of fillers in hot mix asphaltic concrete is essential and vital in improving its engineering properties especially in flexible pavements. Various studies and investigations have shown that properties of void fillers have significant effect on the capabilities of asphalt concrete pavements. Studies have shown that characteristics of asphalt binder and aggregates, traffic conditions and climates are the principal factors that contribute to premature pavement failures (Ajayi, 1987). As a result, void fillers have been incorporated into roadway specifications and has promoted greater use of the materials. Environmental factors such as temperature, air and water can have intense effect on the strength and affect the level of moisture damage which occurs in asphalt concrete mixtures; some of these factors are associated with the materials that make-up hot mix asphalt (HMA) such as aggregate and bitumen. The factors related to mixture design and constructions are air void level, asphalt thickness, permeability and drainage. Previous studies have been carried out on how to control deformations due to moisture damage, in this research, the properties of asphaltic concrete mixes modified using Bamboo Ash as void filler was assessed. The moisture resistance characteristics of the modified asphalt concrete mixture was evaluated using results of Marshall Stability and Swelling Index.

II. MATERIALS AND METHODS

2.1 Sample collection.

The materials used for this research includes fine and coarse aggregates, bitumen, and void filler. The fine aggregate used was sharp sand, while the coarse aggregates were graded granite chippings. The sharp sand and granite chippings were obtained from the local building materials market at Mile-3, Diobu, Port Harcourt, Rivers State, Nigeria. The bitumen was obtained from Julius Berger construction company site in Port Harcourt, Rivers State, Nigeria. The filler used was Bamboo Ash (BA) obtained from the local building materials market at Mile-3, Diobu, Port Harcourt, Rivers State, Nigeria. Bamboo Ash is an organic material resulting from the mechanical powdering of Bamboo into fine powder. The ash was obtained by incineration and has a specific gravity of 1.86. It was then dried and sieved through 75 µm sieve.

2.2 Material Properties and Classification Tests

The properties of the bitumen, aggregates and the Bamboo Ash were determined using standard procedures. The technique used in achieving the outcome of this research comprised of classification of materials used; aggregates and bitumen. Specific gravity test and classification tests for bitumen such as viscosity, penetration, softening point and penetration were also determined.

2.3 Sampling Preparation.

The asphalt concrete briquette samples used for this study were prepared in accordance with the guidelines as stated by Bruce Marshal for Mix Design Procedures as presented in (Roberts *et al*, 1996; AASHTO, 2001; Asphalt Institute, 2001; Putra et al, 2009). The mix design procedure includes proportioning of coarse aggregates, fine aggregates and mineral filler. Gradation test was carried out according to (Kim *et al*, 1992). Asphaltic concrete briquette samples were prepared (Shuler *et al*, 1992) at different bitumen contents to obtain the optimum bitumen content (OBC) of 4.5%. This OBC was used in the preparation of specimen briquettes for the control mix at 0% and the modified mixes. The briquettes were prepared by addition of Bamboo Ash at 1, 2, 3, 4 and 5% by weight of the control mix and submerged in water for 0 to 5 days (0 day represents the dry and unsoaked specimens) and subjected to bulk specific gravity test. Additional briquette samples were prepared and placed under submerged conditions. Subsequently, on each day of curing, samples were crushed using the Marshall Test apparatus and subjected to stability, flow, density and void analysis at a temperature of 60^0C. Also, the weight in air and weight in water values were obtained and recorded. The durability properties determined under submerged conditions include; Marshall Stability, Retained Marshall Stability (RMS), Swell and Swelling Index (SI).

2.4 Marshall Stability and Retained Marshall Stability

Marshall Stability measures the maximum load sustained by the asphalt material at a loading rate of 50.8mm/minute. It is the performance prediction measure conducted on asphalt concrete mixes. The Marshall Stability test procedure consists of determination of the properties of the mix, Marshall Stability, flow analysis and optimum binder content. The Marshall Stability (RMS) can be defined as the stability retained by the sample after it must have been submerged in water over a stipulated period. RMS can be used to measure the resistance to moisture damage of the mix being tested (AASHTO, 2004). Retained Marshall Stability (RMS) is the ratio of Stability of immersed specimen to the Stability of dry specimen and expressed as percentage as presented in equation (1)

$$RMS = \frac{S_1}{S_0} x\, 100 \quad (1)$$

Where;
RMS = Retained Marshal Stability (%)
S_1= Stability after immersion of sample (N)
S_0 = Stability before immersion of sample (N)

2.5 Swell and Swelling Index

Swell is the increase in volume as a result of absorption of water by asphalt concrete when submerged in water for a period of time and can be determined using equation (2).

$$Swell = [V_2 - V_1] \quad (2)$$

Where,
V_1 = volume before immersion (m^3)

V_2 = volume after immersion (m^3)

Swelling index can simply be defined as the percentage increase in the volume of asphalt concrete as a result of absorption of water when submerged in water. Swelling in asphalt concrete pavement can be achieved using an index called swelling index. And it can be evaluated using equation (3)

$$SI = \left[\frac{V_2 - V_1}{V_1}\right] x\,100 \qquad (3)$$

Where;
SI = Swelling Index (%)
V_1 = Volume of HMA concrete specimen before immersion (m^3)
V_2 = Volume of HMA concrete specimen after immersion (m^3)

III. RESULTS AND DISCUSSIONS

3.1 Classification Tests and Aggregate Mix Proportion

Results of the classification test of materials are as presented in Table 1 while the schedule of aggregates used for mix proportion in accordance with (AASHTO, 2001) is presented in Table 2

Table 1: Properties of Materials and Classification Test

	Materials				
Tests	Bitumen	Gravel	Sand	Bamboo Ash	Asphalt Concrete
Specific gravity (G)	1.03	2.73	2.8	1.86	-
Penetration Grade (mm)	59	-	-	-	-
Viscosity (Secs)	13.4	-	-	-	-
Softening Point of Bitumen. (°C)	48	-	-	-	-
Mix Proportion Used (%)	-	59	41	-	-
Category of Traffic	-	-	-	-	HEAVY

Table 2: Schedule of Aggregates Used For Mix Proportion in Accordance With ASTM 2001: C136

Sieve Size (inch)	Sieve size (mm)	Specification limit	Aggregate A (Gravel)	Aggregate B (Sand)	Mix proportion (0.59A + 0.41B)
¾	19	100	99.1	100	99.45
½	12.5	86 – 100	86.1	100	91.8
3/8	9.5	70 – 90	57.5	100	74.93
¼	6.3	45 – 70	21.8	100	53.86
No. 4	4.75	40 – 60	7.5	99.5	45.22
No. 8	2.36	30 – 52	3.5	97.3	41.96
No. 16	1.18	22 – 40	2.3	92.3	39.2
No. 30	0.6	16 – 30	1.8	69	29.3
No. 50	0.3	9 – 19	1.4	28.2	12.39
No. 100	0.15	3 – 7	1	8.4	4
No. 200	0.075	0	0.6	0.8	0.68

3.2 Marshall Stability.

The result of Marshall Stability of the compacted specimens at various filler (modifier) contents is as presented in Table 3 and Figure 1. From Figure 1, the results showed that for dry (unsoaked) specimens, on addition of Bamboo Ash, Stability increased from 12473N at 0% modifier content to an optimum of 14900N at 3% modifier content and on further addition of the filler, Stability decreased to 10080N at 5%

modifier content. This result indicated that addition of Bamboo Ash (BA) improved the Stability of asphalt concrete with an optimum result achieved at 3% modifier content.

Similarly, for the soaked specimen (day 1), Stability increased from 10544N at 0% modifier content to an optimum value of 14430N at 3% modifier content and decreased to 9300N at 5% modifier content. The same trend was shown for days 2, 3 and 4. The study also showed that the stability of Asphalt Concrete modified with BA decreased as the number of days of submergence increased, however, the results are within acceptable limits as stipulated by Asphalt Institute Criteria for Marshall Mix Design (Asphalt Institute, 2001; Chapuis *et al*, 1992).

Table 3: Marshall Stability of Bamboo Ash-Modified Asphalt

Marshall Stability (N) for Modified Concretes and Immersion Days						
Modifier Content (%)	**Immersion Days**					
	0	**1**	**2**	**3**	**4**	**5**
0	12473	10544	9803	8606	8306	8008
1	12980	12240	11140	10100	9110	8810
2	13420	13210	11960	10650	9380	9001
3	14900	14430	13220	11980	10900	10290
4	11790	11100	10090	9340	8676	8080
5	10080	9300	8465	7760	7320	6690

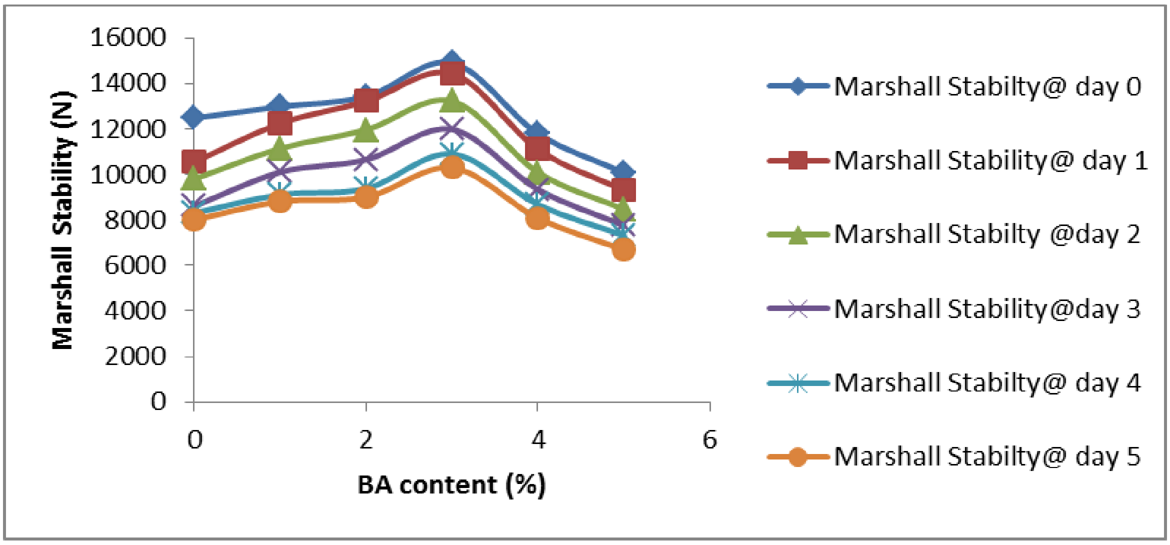

Figure 1. Variation of Marshall Stability with Bamboo Ash Content

3.3 Retained Marshall Stability

The Index of Retained Marshall Stability (RMS) of the modified and unmodified asphalt concrete under submerged conditions for a period of 0 to 5 days are presented in Table 4 while the influence of Bamboo Ash as filler on RMS is shown in Figure 2. RMS measures the resistance to moisture damage of asphalt concrete mixtures. For day 1, Figure 2 showed that the index of RMS under submerged conditions increased with addition of BA from 84.53% at 0% modifier content to an optimum of 96.44% at 3% modifier content. The trend was repeated for days 2, 3, 4 and 5. The result implied that the addition of Bamboo Ash reduced loss in Stability by increasing the RMS hence, increasing resistance to moisture damage of the material between 0% - 3% Bamboo Ash content for immersion days of 0 – 5%.

Table 4: Retained Marshall Stability of Bamboo Ash Modified Asphalt Concrete

Retained Marshall Stability (%) for Modified Concretes and Immersion Days (%)						
Modifier Content (%)	**Immersion Days**					
	0	**1**	**2**	**3**	**4**	**5**
0	100	84.53	78.36	69	66.45	63.9
1	100	86.83	80.88	77.81	65.7	64.29
2	100	89.93	83.59	79.22	66.85	67.05
3	100	96.44	93.12	83.34	76.59	74.2
4	100	94.42	86.66	80.4	71.65	68.19
5	100	89.69	80.93	77.36	70.25	62.43

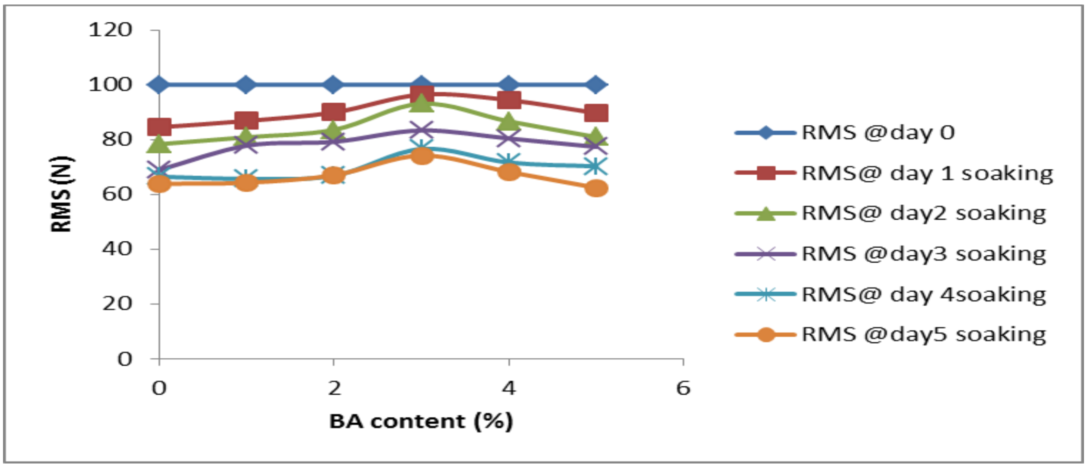

Figure 2: Variation of Retained Marshall Stability with Bamboo Ash content

3.4 Swell

The result of Swell which represents the increase in volume as a result of absorption of water by the modified and unmodified asphalt concrete specimen when submerged in water for a period of 0 – 5 days is a presented in Table 5 and Figure 3. It can be observed from Figure 3 for day 1 that the Swell under submerged conditions (day 1) reduced with addition of BA from 1.50m 3 at 0% modifier content to 1.19m 3 at 3% modifier content. Further addition of the modifier resulted to an increase in Swell. The trend was the same for days 2, 3, 4 and 5. The result implied that the addition of Bamboo Ash reduced moisture susceptibility of the mix by reducing the Swell hence, increasing resistance to moisture damage of the material between 0% - 3% Bamboo Ash content for immersion days of 0 – 5%.

Table 5: Swell of Bamboo Ash-Modified Asphalt Concrete

Swell for modified concretes at varying percentages and Immersion days					
BA Content (%)	**Swell = V_2-V_1 (m^3)**				
	Immersion Days				
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
0	0.0344	0.0632	0.0654	0.0778	0.0979
1	0.0341	0.0606	0.0646	0.0688	0.0952
2	0.0319	0.0593	0.0632	0.0662	0.0951
3	0.0290	0.0484	0.0593	0.0651	0.0904
4	0.0321	0.0566	0.0622	0.0692	0.0945
5	0.0341	0.0631	0.0666	0.0723	0.0999

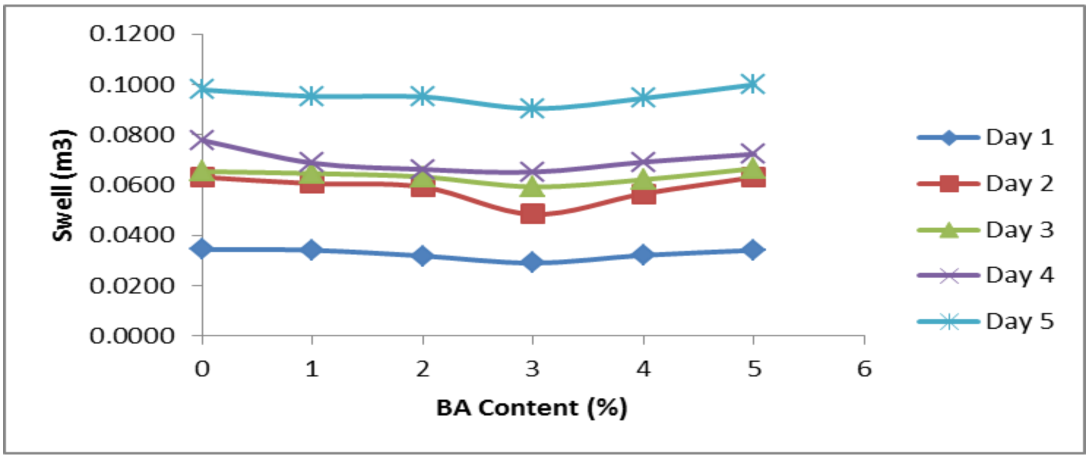

Figure 3: Variation of Swell with Bamboo Ash content

3.5 Swelling Index

The result of the reduction in Swell measured using Swelling Index (SI) is as presented in Table 6, while the variation of Swelling Index with Bamboo Ash content is shown in Figure 4. The results showed a reduction in swell between 0-3% Bamboo Ash content with SI of 1.19% at Day 1, 1.99% at Day 2, 2.40% at Day 3, 2.58% at Day 4 and 3.56% at Day 5. The results also showed that SI of asphalt concrete modified with BA increased as the number of days of submergence increased. The reduction in SI of the asphalt concrete mix is an indication of reduced moisture absorption and by extension improved resistance to moisture damage.

Table 6: Swelling Index of Bamboo Ash modified Asphalt Concrete

Swelling Index (%) for modified concretes and Immersion days					
	Swelling Index SI (%) = (V2-V1)/V1 * 100				
Modifier Content (%)	Immersion Days				
	Day 1	Day 2	Day 3	Day 4	Day 5
	B.A	B.A	B.A	B.A	B.A
0	1.50	2.75	2.80	3.28	4.04
1	1.46	2.59	2.72	2.84	3.88
2	1.34	2.51	2.65	2.71	3.81
3	1.19	1.99	2.40	2.58	3.56
4	1.28	2.26	2.47	2.69	3.64
5	1.33	2.44	2.51	2.68	3.70

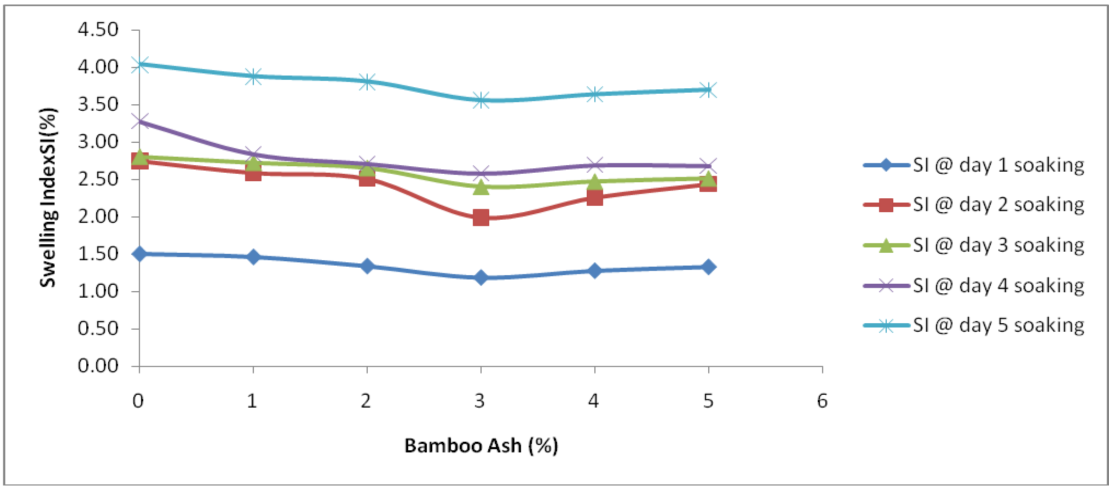

Figure 4. Variation of Swelling Index with BA content

IV. CONCLUSION

On the basis of experimental results of the investigation of the effect of Bamboo Ash as void filler on moisture damage of asphalt concrete mixtures, the following conclusions were drawn:

1. The performance of asphalt concrete mixes with Bamboo Ash as filler is good in terms of resistance to moisture damage measured using Retained Marshall Stability and Swelling Index.
2. The addition of Bamboo Ash to asphalt concrete up to 3% reduced the amount of Swell in the concrete when submerged.
3. From the study, Bamboo Ash recorded best result at 3% optimum modifier content.
4. Bamboo Ash can serve as a good material for the modification of asphalt concrete and should be recommended for use in asphalt concrete production.

REFERENCES

[1]. Ajayi, L. A. (1987) Thoughts on Road Failures in Nigeria, The Nigerian Engineer, 22(1): 10-17.

[2]. Chapuis R.P. and Legare P. P. (1992) A Simple Method for Determining the Surface Area of Fine Aggregates and Fillers in Bituminous Mixtures, Effect of Aggregates and Mineral Fillers on Asphalt Mixtures Performance, ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia.

[3]. Kim Y. R., Kim N. and Khosla N. P (1992) Effects of Aggregate Type and Gradation on Fatigue and Permanent Deformation of Asphalt Concrete, Effect of Aggregates and Mineral Fillers on asphalt Mixtures Performance, ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia.

[4]. Shuler T. S. and Huber G. (1992) Effect of Aggregate Size and Other Factors on Refusal Density of Asphalt Concrete by Vibratory Compaction, Effect of Aggregates and Mineral Fillers on asphalt Mixtures Performance, ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia.

[5]. Roberts, F. L., Kandhal P. S., Brown E. R., Lee,D. Y. and Kennedy, T. W, (1996) Hot Mix Asphalt Materials, Mixture Design, and Construction, *National Asphalt* Pavement Association Education Foundation, Lanham, MD..

[6]. ASTM C136, (2001) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate, ASTM International, West Conshohocken, PA.

[7]. ASTM D 1559 – 76, (2004) Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus, ASTM International, West Conshohocken, PA.

[8]. Putra A. M., and Suparma L. B. (2009) Laboratory Study on the Durability Characteristics (Moisture Damage Evaluation) of Asphalt Concrete Wearing Course (AC-WC) Utilizing Bantak and Clerang as Aggregate (using Marshal Methods), Proceedings of the Eastern Asia Society for Transportation Studies.

[9]. Asphalt Institute, (2001) *Mix* Design Methods for Asphalt, 6th edition MS-02. Asphalt Institute, Lexington.