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# Contribution of Bamboo Ash as Void Filler on Mix Design Properties of Hot Mix Asphalt

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**ABSTRACT:** Studies have shown that loss of strength and stability are major factors responsible for failure of Asphaltic Concrete Pavement. Void fillers are of great significance in the processing of Hot Mix Asphalt (HMA) as it improves the service life of asphalt concrete pavements hence, should possess basic mixed design properties. Researches have revealed that modification and use of alternative mineral fillers in bituminous mixtures have significantly improved the mix design properties of Hot Mix Asphalt. In this study, Bamboo Ash as void filler was investigated using the Marshal Mix design method. The specimen preparation involved addition of varying amounts of Bamboo Ash (1% to 5%) to unmodified specimens. Mix design properties such as stability, flow, density, air voids and voids in mineral aggregates (VMA) were evaluated. Experimental results showed an optimum improvement in mix design properties at 3% modifier content indicating greater strength and resistance to moisture damage. The result also indicated that the mix design properties of the modified asphalt concrete were within minimum requirements as stipulated by the Asphalt Institute. The study concluded that Bamboo Ash is a good void filler for improvement of the performance of asphalt concrete and recommended its use in HMA concrete production.

**KEYWORDS**: Bamboo Ash, Void Filler, Mix Design Properties, Hot Mix Asphalt.

## I. INTRODUCTION

Highway engineering is a combination of design analysis of road pavement structures and economics of different materials employed in the design of these pavements. Flexible and Rigid pavements are being increasingly constructed in Nigeria and government allocates huge amount of resources to upgrade the characteristics of existing and new road networks nationwide. However, some premature distresses such as cracking and permanent deformation are usually observed on pavements within a few years of opening the roads for traffic, resulting in high cost of maintenance and road users cost with consequent negative effect on the nation's economy.

[1] Hot Mix Asphalt (HMA) mix design processes entail categorizing and determining types of aggregate and asphalt binder to use and exact quantities of these two components to attain the expected bituminous mixture performance.

[2] Fillers play essential role in hot mix asphaltic concrete as it improves the engineering properties of flexible pavements. Investigations have shown that properties of void fillers have considerable effect on the performance of flexible pavements hence, the use of economical, locally available alternative to mineral fillers have become of great interest in hot mix asphalt production.

[3][4][5] Research has also shown that the properties of asphalt binder, aggregates and fillers, traffic conditions and environment are the primary factors that contribute to premature pavement failures. The objectives of the use of void fillers in asphalt concrete production include:

- To reduce voids in HMA.
- To improve the bond strength of asphalt aggregate.
- To improve the after-compaction and resistance of the asphalt concrete.
- To meet aggregate gradation requirements.
- To reduce and fill voids in asphalt mix.
- To increase the stability of the HMA mix.

This research investigated the use of Bamboo Ash as void filler to improve the engineering properties of HMA, In the study, the mix design properties of Bamboo Ash-modified asphaltic concrete mixes were investigated.

## II. MATERIALS AND METHOD

In this study, sample collection, specimen preparation and testing procedure were in accordance with standard specifications such as AASHTO, ASTM and British Standards,

### 2.1 Sample Collection and Classification Test

Standard procedures were adopted to determine the properties of the bitumen, aggregates and Bamboo Ash (Void Filler). The method adopted

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in this research includes material classification of fine aggregates, coarse aggregates and bitumen. The specific gravity, viscosity, penetration, and softening point were also determined. The binder used was 60/70 penetration grade bitumen and was obtained from Julius Berger construction company, Port Harcourt, Rivers State, Nigeria. The fine aggregate used was sharp sand obtained from the local building materials market at Mile-3, Diobu, Port Harcourt, Rivers State, Nigeria., with specific gravity of 2.8, while the coarse aggregates were all-in graded gravel with specific gravity of 2.73 and having maximum size of 12.7mm ( half-inch). The filler used was Bamboo Ash (BA) obtained from the local building materials market at Mile-3, Diobu, Port Harcourt, Rivers State, Nigeria, with specific gravity of 1.86. Bamboo Ash is an organic material obtained by incineration and mechanical pounding of the material to powder form..

[6] The gradation test was carried out according to standard methods for aggregates gradation.

**2.2 Preparation of Specimen.**

[7][8][9]10] The asphalt concrete briquette specimens were prepared in accordance with Bruce Marshall Test Procedure. Specimens were prepared at various bitumen contents to determine the optimum bitumen content (OBC) of 4.5%. The optimum bitumen content was used in the preparation of briquette for the unmodified (control mix) and modified mixes. The modified briquettes mixes were prepared by addition of Bamboo Ash at 1, 2, 3, 4 and 5% by weight of the control mix. Marshal test was carried out on the specimens and the values of stability and flow were recorded., Density, Air voids, and voids in mineral aggregate (VMA) were also determined. Additional briquette specimens were produced and submerged in water and the weight in air and weight in water values were recorded. On attaining curing, the specimens were crushed at a temperature of $60^0$C using the Marshall Test apparatus and subjected to Marshall stability, flow, density and void analysis.

**2.3 Determination of Mix Design Properties**

**2.3.1 Stability**

Stability of asphalt concrete regulates the performance of flexible pavements. It is a measure of the resistance to moisture damage of asphalt concrete mixes and depends on the bitumen content, viscosity, softening point of bitumen, stiffness of asphalt mix, and grading of aggregates. This was obtained using the Marshall Test apparatus.

**2.3.2 Flow**

Flow is derivative from the recurring loading and unloading of HMA specimen in which permanent deformation is recorded as a function of load cycles. This was obtained using Marshall Test Apparatus.

**2.3.3 Air voids**

Air Voids are small airspaces or pockets of air that occupy between the coated aggregate particles in the final compacted mix. It is determined using equation (1)

$$P_a = 100\left[\frac{G_{mm} - G_b}{G_{mm}}\right] \qquad (1)$$

Where;

$P_a$ = percent air voids in HMA concrete

$G_{mm}$= Maximum specific gravity of HMA concrete

$G_{mb}$= Bulk modulus of HMA concrete

**2.3.4 Density**

This is the unit weight of a mixture and determined using equation (2)

$$Density = \left[G_{mb} = \frac{W_2}{W_2 - W_w}\right] x1000kg/m^3 \qquad (2)$$

(2)

Where,

$G_{mb}$ = Bulk modulus of mix

$W_2$ = Weight of mix in air

$W_w$ = Weight of mix in water.

**2.3.5 Voids in Mineral Aggregate (VMA)**

This is the volume of voids in the aggregates, and is the sum of air voids and volume of bitumen, given by:

$$VMA = 100 - \left(\frac{G_{mb}}{G_{sb}}\right)P_s \qquad (3)$$

**Table 1**: Specific Gravity Test Results.

| Material Used | Bitumen (Gb) | Sand | Gravel | Bamboo Ash |
|---|---|---|---|---|
| Specific gravity | 1.03 | 2.8 | 2.73 | 1.86 |

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**Table 2:** Physical Properties of Bitumen

| Softening Point of Bitumen | Bitumen Grade | Viscosity | Penetration |
|---|---|---|---|
| 48 SECS | 60/70 | 13.4SECS | 59mm |

**Table 3; Aggregate** Gradation and Blending

| 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 |

Where,
VMA = Voids in mineral aggregates
$G_{mb}$ = Bulk modulus of asphalt concrete mixture
$G_{sb}$ = Bulk specific gravity of aggregates
$P_s$ = Percent of aggregates in mixture

## III. RESULTS

The specific gravity of Bitumen, Sand, Gravel and Bamboo Ash are as presented in Table 1 while the physical (rheological) properties of bitumen are presented in Table 2. The results of aggregate gradation and blending (combination) are as presented in Table 3 and Figure 1.

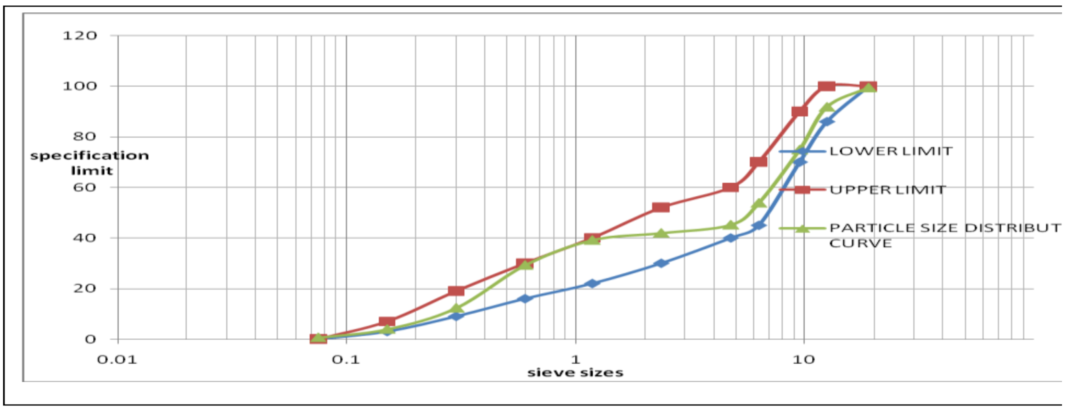


Figure 1: Aggregate Gradation Curve

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### 3.1 Mixed Design Properties

The result of the effect of Bamboo Ash (BA) on the mix design properties of asphalt concrete is as presented in Table 4

**Table 4**: Mix Design Properties of Bamboo Ash-Modified Asphalt Concrete

| Mix Design Properties of Modified Asphalt Concrete with Bamboo Ash (B.A) Contents. | | | | | |
|---|---|---|---|---|---|
| **Modifier Content (%)** | **Stability (N)** | **Flow (mm)** | **Density (Kg/m$^3$)** | **Air voids (%)** | **VMA (%)** |
| 0 | 12473 | 9.21 | 2101.00 | 5.65 | 21.57 |
| 1 | 12980 | 9.15 | 2165.00 | 5.64 | 17.05 |
| 2 | 13420 | 9.13 | 2178.85 | 5.24 | 15.47 |
| 3 | 15090 | 8.85 | 2188.85 | 4.61 | 13.19 |
| 4 | 11790 | 9.22 | 2153.04 | 4.30 | 13.33 |
| 5 | 10080 | 9.8 | 2142.17 | 4.48 | 14.01 |

## IV. DISCUSSION

The effects of Bamboo Ash (BA) as void fillers on Stablity, Flow, Density, Air Voids and Voids in Mineral Aggregates (VMA) of Hot Mix Asphalt (HMA) are as shown in Figures 2, 3, 4, 5 and 6 respectively

Figure 2 showed that Stability increased from 12473N at 0% modifier content to an optimum of 15090N at 3% modifier content and decreased to 10080N at 5% modifier content. The result indicated that addition of Bamboo Ash improved Strength and resistance to moisture damage of the asphalt concrete mix with an optimum result at 3% modifier content.

Figure 3 showed that the addition of Bamboo Ash as modifier decreased the Flow from 9.21mm at 0% modifier content to a minimum of 8.85mm at 3% modifier content and later increased to a maximum of 9.80mm at 5% modifier content. The relative decrease in flow of the asphalt concrete mix is an indication of improved resistance to temperature effect when compared with the unmodified mix.

The effect of Bamboo Ash on Density of HMA is shown in Figure 4. The result showed that on addition of Bamboo Ash, the density increased from 2101Kg/m$^3$ at 0% modifier content to a maximum 2188Kg/m$^3$ at 3% modifier content, and decreased to 2142Kg/m$^3$ at 5% modifier content. This result implied improved resistance to deformation.

On Airvoids, as shown in Figure 5, the addition of Bamboo Ash as modifier decreased percent airvoids from 5.65% at 0% modifier content to a minimm of 4.61% at 5% modifier content. This is an an indication that Bamboo Ash-modified HMA at 3% optimum content relatively improved resstance to deformation and moisture when compare with the unmodified mix.

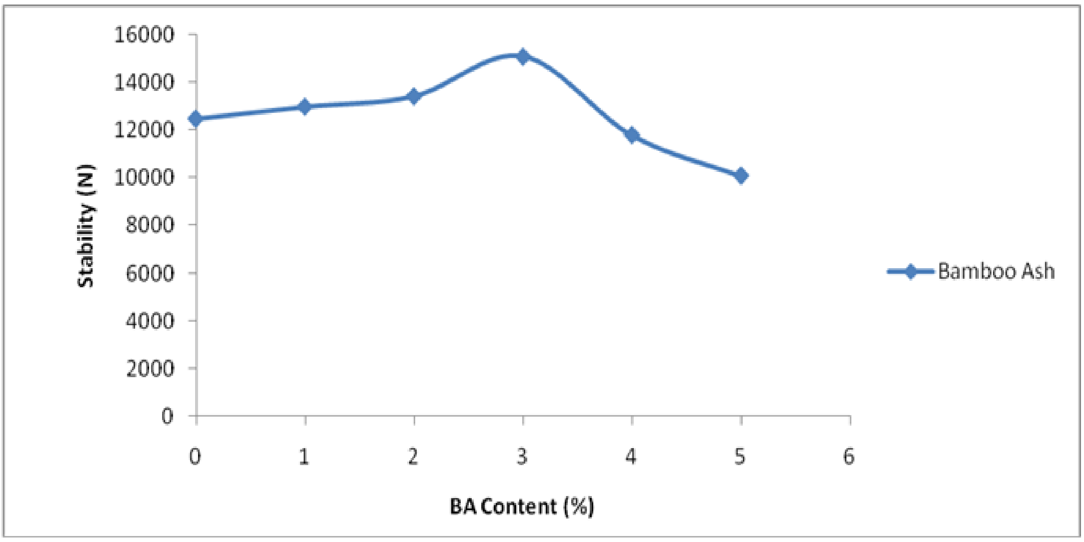


**Figure 2:** Variation of Stability with Modifier Content

Figure 6 showed that the VMA decraesed from 21.57% at 0% modifier content to a minimum of 13.19% at 3% modifier content and increased to 14.01% at 5% modifier content, indicating a material with relatively incresaed resistance to moisture absorption and deformation when compared with the unmodified mix.

Generllly, the result showed that Bamboo Ash as void filler increased Stability and Density at an optimum modifier content of 3%, decrease flow from 0% modifier content to an optimum of 3% modifier content, reduced voids in HMA thereby increasing strength and durability.

[11] The result of the mix design properties of the Bamboo Ash-modified asphalt concrete was compared with the minimum requirements as stipulated by Asphalt Institute as shown in Table 5. The result showed that the Stability, Flow, Air Voids and VMA fall within allowable limits, an indication that Bamboo Ash is a good modifier (void filler) for HMA concrete.

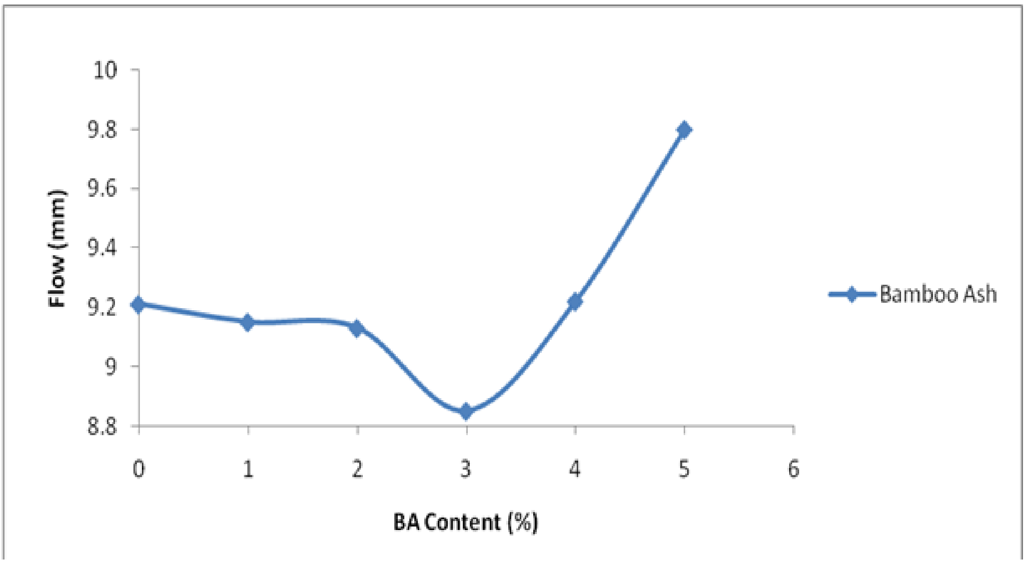


Figure 3: Variation of Flow (mm) with Modifier Content

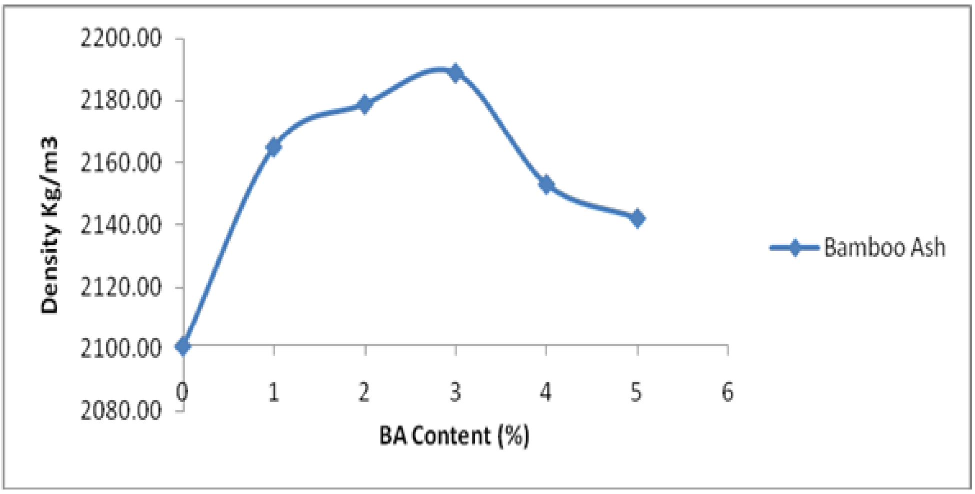


Figure 4: Variation of Density (Kg/m3) with Modifier Content

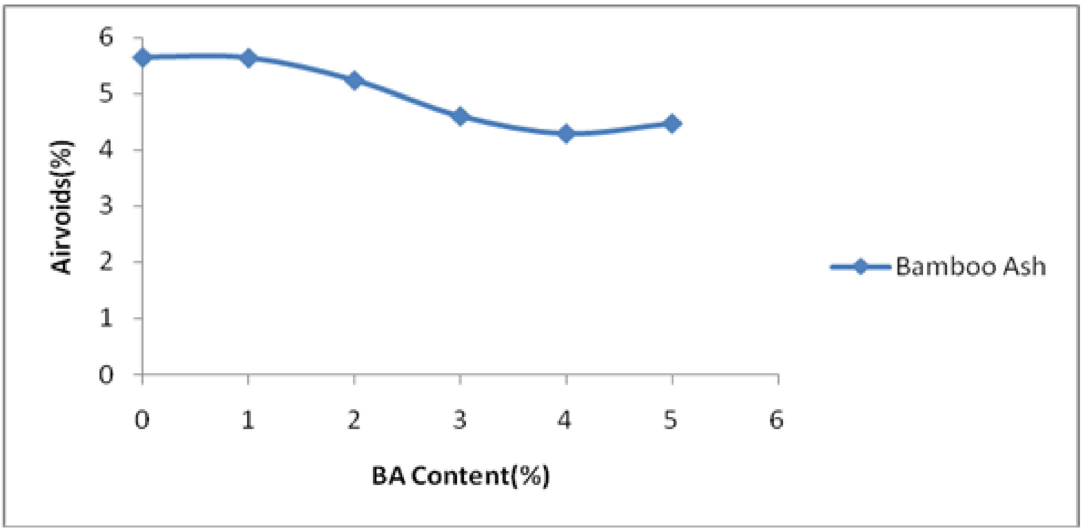


Figure 5: Variation of Air Voids with Modifier Content

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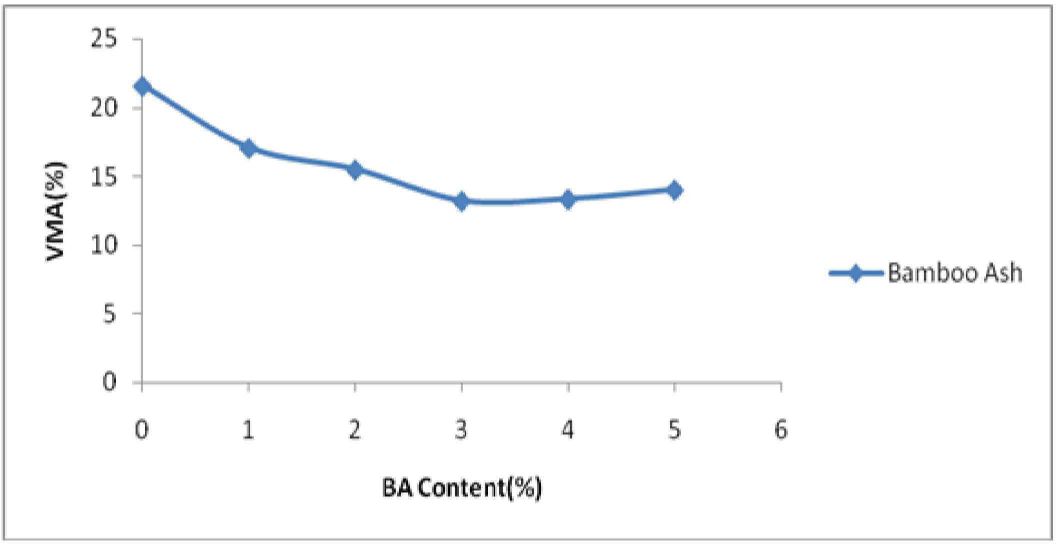


Figure 6.0 Variation of VMA with Modifier Content

**Table 5:** Validation of result

| Mixed Design Properties | Asphalt Institute Criteria for Marshall Mix Design | | Bamboo Ash Modifier Contents(%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Min.** | **Max.** | **0** | **1** | **2** | **3** | **4** | **5** |
| **Stability (KN)** | 8.01 | - | 12.473 | 12.98 | 13.42 | 15.09 | 11.79 | 10.08 |
| **Flow, (0.25mm)** | 8 | 14 | 9.21 | 9.11 | 9.09 | 9.08 | 9.14 | 9.21 |
| **AirVoids, (%)** | 3 | 5 | 4.96 | 4.88 | 4.64 | 4.54 | 3.86 | 3.51 |
| **VMA, (%)** | 9 | 21 | 20.57 | 15.01 | 13.07 | 11.39 | 11.99 | 12.04 |

## V. CONCLUSION

The study carried out laboratory investigation of the contribution of Bamboo Ash on the mix design properties of Hot Mix Asphalt concrete. The result indicated that the addition of Bamboo Ash to asphalt concrete mixes produced positive changes with respect to Strength and mixed design properties. From the result, the following conclusions are made:

1. Bamboo Ash improved strength and mix design properties of asphalt concrete mix
2. The results of the mix design properties of Bamboo Ash-modified asphalt concrete are within minimum requirements as stipulated by Asphalt Institute.
3. The optimum Bamboo Ash content to achieve maximum Stability and minimum Flow is 3%.
5. Addition of Bamboo Ash increased density and reduced Air Voids in the asphalt concrete mix.
6. Bamboo Ash should be incorporated as void filler in asphalt concrete production.

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