Suitability Of Sewage Sludge Ash As A Filler Material In Asphalt Concrete

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***Abstract*— this study investigates the suitability of sewage sludge ash as a filler material in asphalt concrete. The engineering properties tests of sewage sludge ash as a filler material were carried out in accordance with BS 1377 and BS EN 933-10. An optimum mix of the asphalt concrete with sewage sludge ash as the filler was achieved by varying the filler content through 4%, 6% and 8%, while the bitumen content was varied through 4% to 6% with 0.5% increments. The prepared Marshall specimens were then tested in accordance with AASHTO T245 and the variations in the engineering properties of the mix with when cement and lime are used as filler materials assessed. Test results indicate that the sewage sludge ash has a particle size distribution of 99.11% passing the 0.425mm sieve and 76.13% passing the 0.075mm sieve. It is non-plastic and has an average specific gravity of 2.40, bulk density of 0.87 g/cm3 with a low Methylene Blue value of 0.7925 g/mg. These properties of sewage sludge ash reveal its suitability as a filler material in asphalt concrete. The optimum sewage sludge ash filler content is determined to be 6%, at 4.5% bitumen content with the mix having a specific gravity of 2.102; air voids of 4.2%; voids in mineral aggregate of 13.6%; voids filled with bitumen of 69.2%; stability of 6900N and flow of 2.6mm, values which are satisfactory. The asphalt concrete designed using lime and cement however, have higher stability values of 8400N and 9400N respectively. It can therefore be concluded that sewage sludge ash can be used as a filler material in the design of Asphalt Concrete, and is recommended for the design of Asphalt Concrete Type I used in the binder course and the wearing course for low traffic roads.**

Keywords— sewage sludge ash; asphalt concrete, filler, optimum mix, Marshall Test

I. Introduction

Sustainable development advances the utilization of waste and by-products so as not only to conserve the limited resources but also to protect the environment from the various forms of pollution. Sewage sludge is one such waste product. Sewage sludge has been considered a waste – to be somehow disposed of and…generally at the least cost possible (Ellison and Jefferson, 2006). Land disposal has often been the least expensive option, in monetary terms and/or in terms of “hassle”. While landfilling may be cheap and easy, it is widely recognized as a less desirable practice and is being discouraged in many places. Disposal of biodegradable waste (including sludge) at landfills is not considered a sustainable waste management practice and not in line with the worldwide trends (Wong, 2006). This research investigates the suitability and hence possible utilization of sewage sludge ash (SSA) as a filler material, thus ensuring a sustainable management practice of the waste product.

According to Gezencvej (2011), fillers are one of the most important components of bituminous mixes. The quality and durability of bituminous road is influenced by the type and amount of filler material used. Various materials such as cement, lime, granite powder, are normally used as filler in bituminous mixes. Waste materials such as quarry dust have also been used as fillers.

Wypych (1999) defines filler as a solid material capable of changing the physical and chemical properties of materials by surface interaction or its lack thereof and by its own physical characteristics. Fillers in asphalt concrete are used to increase stiffness, reduce creep and hence permanent deformation, increase density, control bleeding of bitumen from the mixture and lower the cost of production of the mix (Saffar, 2013). It is important to note however, that too much filler in asphalt mixtures can lead to cracking or fatigue problems as Kandhal (1980) and Anderson et al. (1982) reveal.

According to Kavussi and Hicks (1997), in order to provide satisfactory properties in the asphalt concrete mix, filler should; not have adverse chemical reactions with bitumen, not possess hydrophilic surfaces to ensure good adhesion, not possess high porous particles which may lead to excessive stiffening through selective adsorption and, should contain a dense (well graded) particle size distribution. Kenyan Standard Specifications require that mineral filler; shall consist of finely ground particles of limestone, hydrated lime, Ordinary Portland cement or other non-plastic mineral matter as specified in the special specification, shall be thoroughly dry and free from lumps, at least 75% (by weight) shall pass a 0.075mm sieve and 100% shall pass a 0.425mm sieve, shall have a bulk density in toluene measured in accordance with BS 812 of between 0.5 and 0.9 g/ml (Ministry of Roads and Public Works, 1986). The various properties of fillers that are of interest therefore include particle density, particle size distribution, particle shape, maximum packing fraction, specific surface area and surface energy.

Sewage sludge ash (SSA) is the by-product produced during the combustion of dewatered sewage sludge in an incinerator. Sewage sludge ash is primarily a silty material with some sand-size particles. The particle size distribution generally ranges between 1 and 100µm, with a mean diameter around 26µm. A relatively large fraction of the particles (up to 90% in some ashes) are less than 0.075 mm (no. 200 sieve) in size. SSA has a relatively low organic and moisture content. Permeability and bulk specific gravity properties are similar to those of natural inorganic silt. Sludge ash is a non-plastic material because the making-water needed to attain a satisfactory level of plasticity for extrusion is higher than that for normal cement due to the soaking up and removal of some of the water from the mix during tempering (Anderson D.A., 1992). According to Wang et al. (2005), sewage sludge ash is a pozzolanic material with high-porosity and irregular shape. Monzó et al. (1999) also indicated that SSA is a reactive material, which enhances mortar strength due to its pozzolanic properties

Sewage sludge ash has been applied successfully as a useful civil engineering material. In order to widely utilize sludge for different practical applications, Tay and Goh (1991) investigated the chemical and physical properties of ash residues and evaluated possible applications in geotechnical areas. Studies of resource recovery methods, such as partial replacement of cement, fine aggregates, or as bitumen additives have been carried out from as early as the 1970s and 1980s (Cabrera and Stentiford, 1983; Chesener, 1998; Gray and Penessis, 1972; Tay, 1987a; Tay and Show, 1997; Wegman and Young, 1988). Lin and Weng (2001) applied 0% to 50% of incinerated sewage sludge ash as a substitute for clay to manufacture bricks. Liew et al., (2004); Tay (1987a) mixed dried wastewater sludge with clay to produce bricks, and bio bricks (Aleman and Berman, 1984). Tay and Goh (1991) replaced cement with incinerated sewage sludge ash in making concrete, thereby improving the workability and compressive strength of concrete. There is also the possibility of using sludge ash as fine aggregate in mortar (Bhatty and Reid, 1989; Chen et al., 2006), as synthetic sand (Wainwright and Creswell, 2001) and as pavement materials (Al-Sayed et al., 1995; Lin et al., 2006).

II. MATERIALS AND METHODS

A. Sewage Sludge Ash

Samples of sewage sludge from JKUAT wastewater treatment plant were collected. The harvested sludge consisted of up to 95% water content. This amount of water was reduced by spreading the sludge on a concrete surface for 2 days to dewater with regular turning to expose the inner parts of the piles. It was then left to air dry for 7 days after which it was incinerated in an incinerator to produce ash. The SSA was then tested for engineering properties of fillers as discussed in the subsequent sections.

B. Tests for Sewage Sludge Ash

1) Particle Size Distribution Test

To determine quantitatively, the proportion by weight of various particle sizes present in the sewage sludge ash, a sample of air dried clean sewage sludge ash passing 0.425 mm sieve, and weighing 1500g was taken. Dry sieving was then carried out on the SSA based on BS 1377: Part 2: 1990.

2) Particle Density Test

To determine the particle density of the SSA, dry clean sewage sludge ash passing 0.075 mm was weighed and the Pyknometer (density bottle) test carried out in accordance with BS 1377: Part 2: 1990.

3) Tapped Bulk Density Test

50 grams of dry clean SSA was weighed out to the nearest 0.1 gram, and transferred to a suitable graduated cylinder. The base of the cylinder was gently tapped on a slightly resilient surface (book), until the height of the sample in the cylinder was at a minimum i.e. the sample height did not reduce with further tapping. The volume of the sample was then read off in cc (ml).

4) Plasticity Index Test

The plasticity index (PI) of the SSA was obtained from Atterberg limit tests carried out in accordance with BS 1377: Part 2:1990. SSA was air-dried and then sieved through a 425µm piece.

5) Methylene Blue Test

Methylene blue (MB) test detects the presence of clays which possess very large surface areas and therefore if present in filler in sufficient quantities mask the surface activity of the filler. To determine the amount of methylene blue absorbed by the SSA filler sample, 40g of dry clean SSA passing 0.075 mm was measured. A standard aqueous solution of methylene blue dye (1.5%) was then prepared and the MB test carried out in accordance with BS EN 933-10: 2002.

C. Asphalt Concrete Mix Design

The Marshall Mix design method was adopted. It was carried out through steps consisting of: aggregate selection, binder selection, sample preparation and compaction, and stability and flow determination.

1) Aggregate Selection

Aggregates

Aggregate Crushing Value (ACV) and Flakiness Index (FI) tests were conducted on the aggregates to ensure that they met the required specifications. The specific gravity of the aggregates was then determined empirically. The aggregates had a mean ACV of 21.4%, FI of 24.1%, values which are within the Kenyan specifications of maximum 28% and 25% for class b aggregates and maximum 30% and 25% for class c aggregates. The specific gravity of both the coarse and fine aggregates was determined to be 2.6g/cm^3. The aggregates were graded and trial blends of the aggregate gradations calculated until a trial blend was within the specified envelope. Fig. 1 below shows the aggregate gradation envelope.

Filler

Three types of filler were used; Lime, Ordinary Portland Cement and Sewage Sludge Ash.

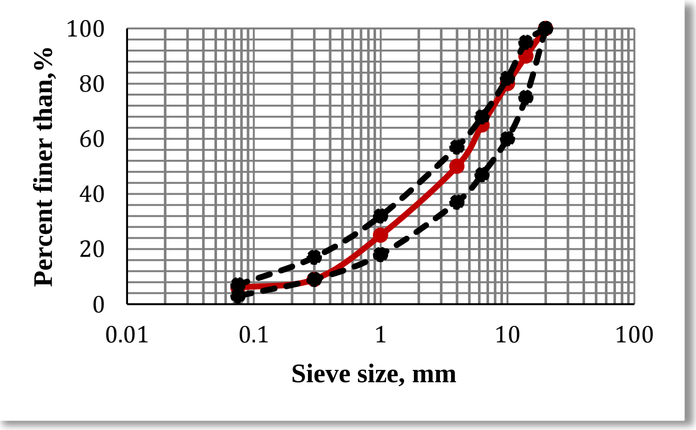


Fig.1: ***Aggregate Gradation Envelope***

2) Binder Selection

Bitumen was used as the binder. The bitumen grade used for the mix design was 80/100 penetration grade.

3) Sample Preparation and Compaction

The Marshall briquettes were prepared and compacted in accordance with AASHTO T245: Marshall Mix design and Test. The compaction pedestal was used to apply 55 blows on each face of the briquettes.

4) Stability and Flow value determination

The compacted specimen was immersed in a water bath of temperature 60°C for 30 to 40 minutes. The specimen was then removed from the water bath, lightly dried, placed in the breaking head, and then the complete assembly in position on the testing machine. The flow meter was placed in position over one of the guide rods on the breaking head and adjusted to zero. The load was then applied to the specimen by means of the constant rate of movement of 50.8mm/min until the maximum load was reached and the load just decreased. (The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination was not to exceed 30 seconds). The Marshall Stability (maximum load) and the Marshall Flow values were read from the ring dynamometer and the flow meter, respectively.

III. RESULTS AND DISCUSSIONS

A. Sewage Sludge Filler Test Results

Sieve analysis test was carried out on the sewage sludge ash to determine the particle size distribution, from the sieve analysis, a Particle Size Distribution (PSD) curve, represented as % by mass passing a particular particle size is drawn on a semi-log chart as shown in Fig.2 below.

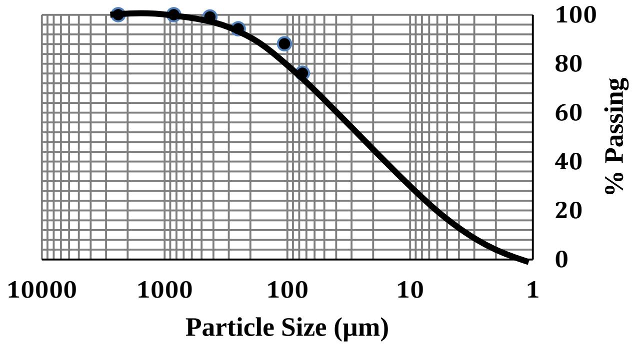


Fig. 2: ***Particle Size Distribution Curve***

From the PSD curve the mathematical descriptors of coefficient of uniformity (U_c) and coefficient of gradation (C_c) is calculated.

$$U_c = \frac{D_{60}}{D_{10}} \quad (1)$$

$$C_c = \frac{D_{30}^2}{D_{10} * D_{60}} \quad (2)$$

D_x is the size (µm) at which x% of particles are smaller than by mass.

The SSA has a U_C of 17.5 and C_C of 1.16. For the filler to be well graded the value of coefficient of uniformity has to be greater than 4 to 6 and coefficient of gradation should be in the range of 1 to 3. Therefore from the results, the sewage sludge ash is well graded. The standard specifications for mineral fillers require 100% passing the 0.425mm sieve and at least 75% passing the 0.075mm sieve. The particle size distribution of the SSA indicate 99.11% passing the 0.425mm sieve and 76.13% passing the 0.075mm sieve, values which are acceptable, factoring the effect of impurities. The PSD of the SSA therefore indicates the suitability of SSA as a filler material, as the fineness offers more stiffening effect on bitumen.

The test results for the engineering properties of sewage sludge ash to determine its suitability as a filler material are as shown in Table 1 below.

Table 1: SSA Engineering Properties

Properties	Quantity
Specific gravity, G_s	2.40
Bulk (tapped) density, ρ_{bulk}	0.87g/cm^3
Plasticity Index	Non-plastic
MB Value	0.7925 mg of MB/g of SSA

The average specific gravity of the SSA is obtained as 2.40. The range for the specific gravity values of bitumen filler is typically 2.65 - 2.75 g/cm^3 with some filler not derived from natural aggregates such as Hydrated Lime having a specific gravity of 2.30 g/cm^3. The SSA specific gravity value therefore compares favorably to other commonly used filler, which points to its suitability as a filler material in asphalt concrete. The SSA bulk density of 0.87 g/cm3 is within the Kenyan Standard Specifications which require that mineral filler shall have a bulk density in toluene measured in accordance with BS 812 of between 0.5 and 0.9 g/ml. The SSA bulk density, however not measured in toluene, indicates an acceptable value of 0.87 g/cm3 which points to its suitability as an asphalt concrete filler material in terms of its bulk density. The sewage sludge ash could not be rolled into a thread which indicates the non-plasticity of the SSA, further emphasized by a calculated plasticity index (PI) of zero. Kenyan Standard Specifications on mineral fillers for asphalt concrete require the mineral filler to be non-plastic; hence the SSA PI of zero is satisfactory. The SSA has a low MB value of 0.7925 mg/g which is well within the international specifications used for reference. It can therefore be concluded that based on the engineering properties, sewage sludge ash is a suitable Asphalt concrete filler material.

B. Asphalt Concrete Mix Properties

1) Mix Properties

The Marshall Mix Design method was adopted in the design of the asphalt concrete, by varying the bitumen contents in 0.5% increments from 4% to 6% and the filler contents in 2% increments from 4% to 8%. Table 2 below gives a summary of the mix properties of the various asphalt concrete specimens, using sewage sludge ash as the filler material.

Table 2: Asphalt Concrete Mix Properties for SSA filler

Specimen	**Bulk Specific Gravity of Mix, G_m**	***Air Voids percent, V_v (%)***	***Voids in Mineral Aggregate, VMA (%)***	***Voids Filled with Bitumen, VFB (%)***
A4B4.0	2.17	4.92	13.44	63.40
A4B4.5	2.17	4.22	13.86	69.55
A4B5.0	2.14	4.93	15.48	68.16
A4B5.5	2.15	3.81	15.47	75.37
A4B6.0	2.11	4.93	17.45	71.74
A6B4.0	2.11	4.53	12.85	64.74
A6B4.5	2.10	4.19	13.57	69.12
A6B5.0	2.08	4.42	14.75	70.03
A6B5.5	2.09	3.63	14.97	75.76
A6B6.0	2.07	4.03	16.26	75.21
A8B4.0	2.03	4.92	12.94	61.99
A8B4.5	2.04	4.13	13.21	68.73
A8B5.0	2.03	4.14	14.13	70.71
A8B5.5	2.03	3.48	14.54	76.06
A8B6.0	2.02	3.46	15.38	77.50

Specimen Denotation e.g. A4B4.0 – The 'A" represents Sewage Sludge Ash Filler, with the following '4' representing the filler content in percentage. The 'B' represents Bitumen binder with the following '4.0' representing the bitumen content by percent mass of aggregates.

The calculations were made from the following equations:

- Theoretical specific gravity of the mix (G_t)

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}} \qquad (3)$$

Where, W_1 is the weight of coarse aggregate in the total mix, W_2 is the weight of fine aggregate in the total mix, W_3 is the weight of filler in the total mix, W_B is the weight of bitumen in the total mix, G_1 is the apparent specific gravity of coarse aggregate, G_2 is the apparent specific gravity of fine aggregate, G_3 is the apparent specific gravity of filler and G_b is the apparent specific gravity of bitumen.

- Bulk specific gravity of mix (G_m)

$$G_m = \frac{W_m}{W_m - W_w} \qquad (4)$$

Where, W_M is the weight of mix in air, W_W is the weight of mix in water. W_M - W_W gives the volume of the mix.

- Air voids percent (V_V)

$$V_v = \frac{(G_t - G_m)100}{G_t} \qquad (5)$$

- Percent volume of bitumen (V_B)

$$V_B = \frac{\frac{W_b}{G_b}}{\frac{W_1 + W_2 + W_3 + W_b}{G_m}} \quad (6)$$

Where, G_b is the apparent specific gravity of bitumen,

- Voids in mineral aggregate (VMA)

$$VMA = Vv + Vb \quad (7)$$

- Voids filled with bitumen (VFB)

$$V\,FB = \frac{V_B\,x\,100}{VMA} \quad (8)$$

Table 3 below shows the Marshall Stability and Flow values for the asphalt concrete mix designed using SSA as the filler material.

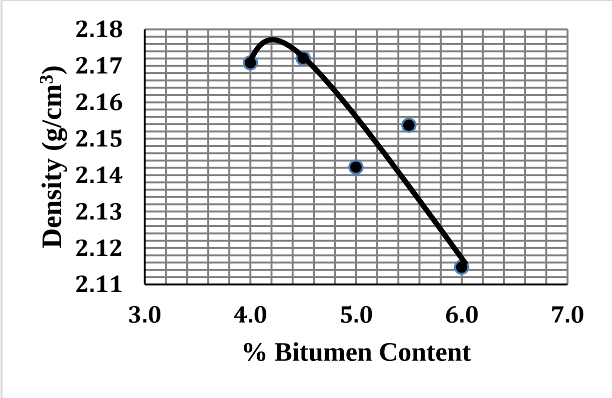
Table 3: **Marshall Stability and Flow**

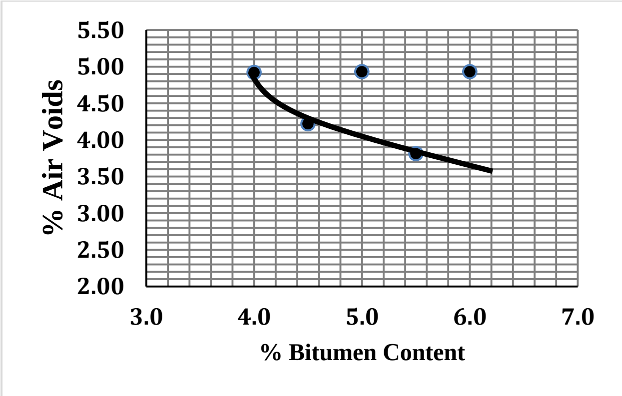
Specimen	Corrected Stability (N)	Flow, (0.25 mm units)	Flow (mm)
A4B4.0	6358.35	9.00	2.25
A4B4.5	6124.97	10.92	2.73
A4B5.0	6409.56	14.76	3.69
A4B5.5	5658.51	16.08	4.02
A4B6.0	7342.69	16.40	4.10
A6B4.0	4690.75	9.72	2.43
A6B4.5	6896.04	10.40	2.60
A6B5.0	6776.55	12.32	3.08
A6B5.5	6255.94	13.68	3.42
A6B6.0	6181.48	13.80	3.45
A8B4.0	4522.02	10.36	2.59
A8B4.5	7277.45	11.96	2.99
A8B5.0	5888.94	15.20	3.80
A8B5.5	7716.55	15.68	3.92
A8B6.0	6708.27	15.76	3.94

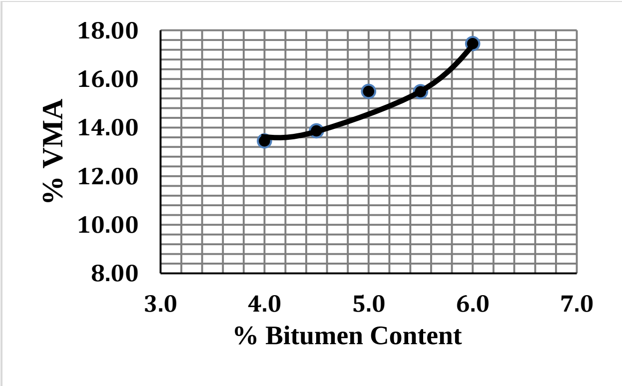
From Table 2 and Table 3 above; specimens A4B4.0 and A4B4.5 had the highest bulk densities of 2.17g/cm^3 while A4B5.0 and A4B6.0 had the highest % air voids of 4.93%, with A8B6.0 registering the lowest at 3.46% which could be attributed to the high filler content. A8B5.5 yielded the highest stability of 7716.55N, with A8B4.0 the lowest at 4522.02N. A4B6.0 had the highest flow of 4.10mm with A4B4.0 having the least at 2.25mm.

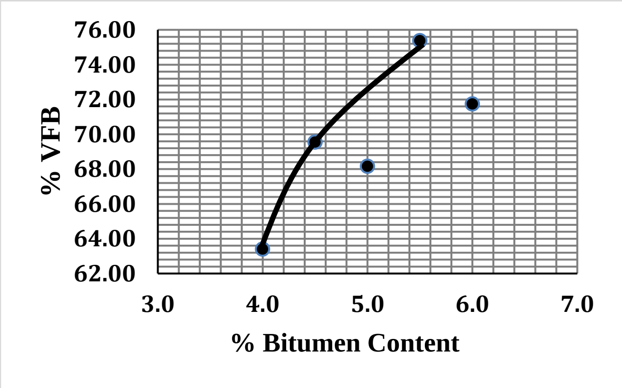
2) Optimum Bitumen Content

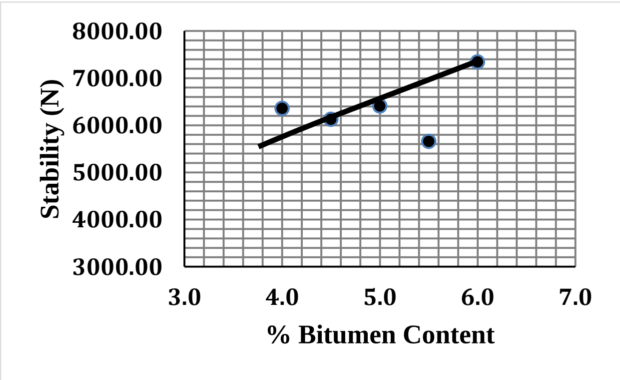
Graphical plots of Density, Percent Air Voids, %VMA, %VFB, Stability, and Flow versus Percent Bitumen Content are used to determine the optimum bitumen content. The average of the bitumen contents corresponding to the maximum density, median of the design limits of % air voids (4%) and the maximum stability is taken as the optimum bitumen content. Fig. 3 below shows the graphical plots for 4% Sewage Sludge Ash Filler.











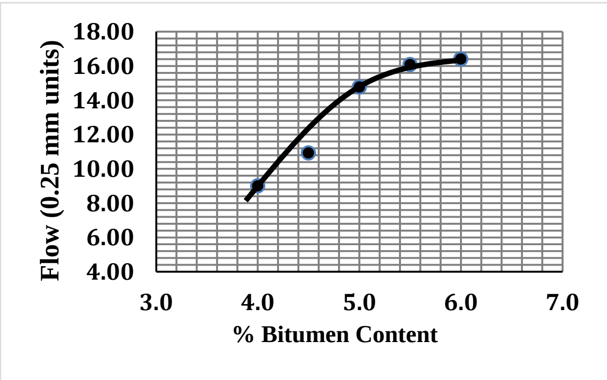


Fig.3: ***Graphical Plots for 4% SSA Filler***

From the plots in Fig.3;

Bitumen content corresponding to maximum specific gravity of 2.176 is **4.2%**

Bitumen content corresponding to the median of design limits of percent air voids of 4% is **4.9%**

Bitumen content corresponding to the maximum stability of 7300N is **6.0%**

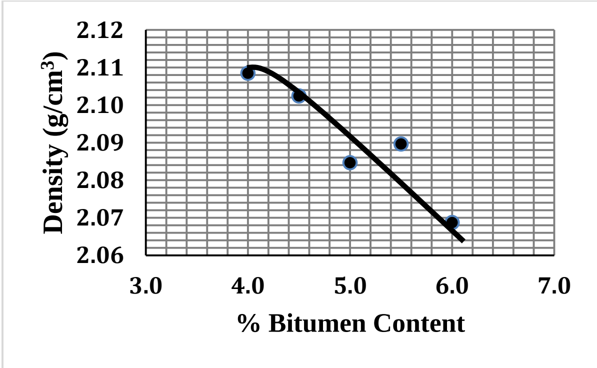
The optimum bitumen content when 4 % Sewage sludge ash filler is used is therefore given as the average of the three bitumen contents:

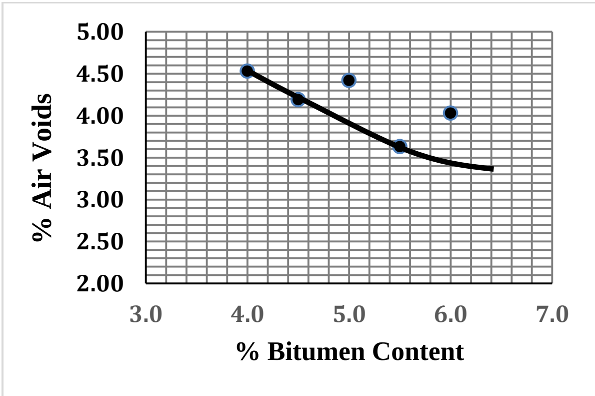
4 % SSA Filler Optimum Bitumen Content

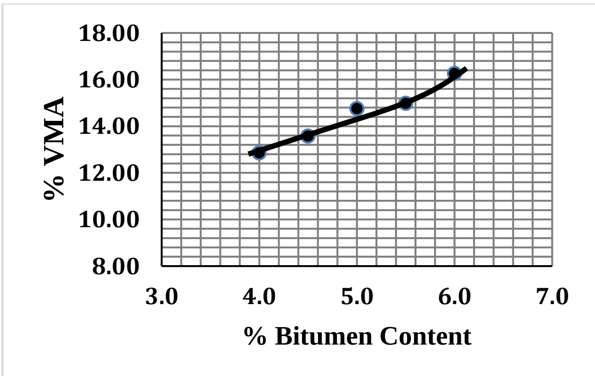
$= \frac{4.2+4.9+6.0}{3}$ = **5.03%.**

At 5.03% Bitumen Content, Mix properties are: Gm = 2.154, % Air Voids = 4.0%, VMA = 14.4%, VFB = 72.6%, Stability = 6600N, Flow = 14.5 (0.25mm units). Hence accept the mix since its properties are considerably within the Asphalt Concrete Specification ranges.

The filler content was increased to 6%, while varying the bitumen content (4% - 6%). Fig. 4 below shows the graphical plots for the Marshall Test results of 6% Sewage Sludge Ash Filler.







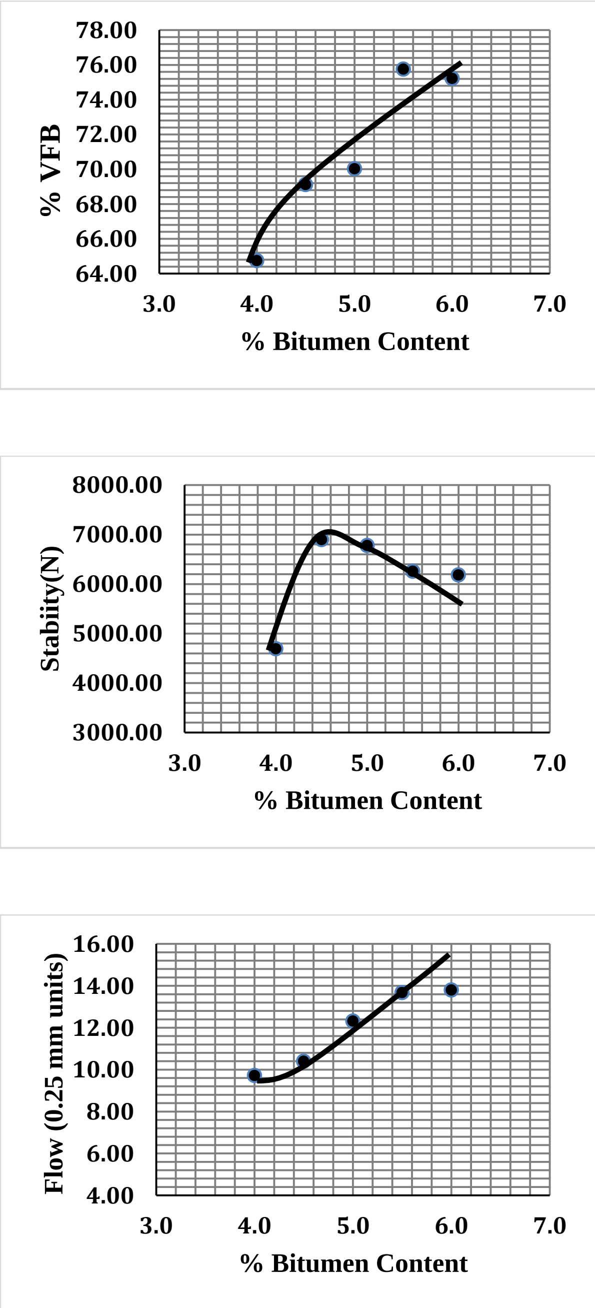


Fig.4: ***Graphical Plots for 6% SSA Filler***

From the plots in Fig. 4 above; Bitumen content corresponding to maximum specific gravity of 2.108 is **4.0%.**

Bitumen content corresponding to the median of design limits of percent air voids of 4% is **4.8%.**

Bitumen content corresponding to the maximum stability of 7000N is **4.65%**

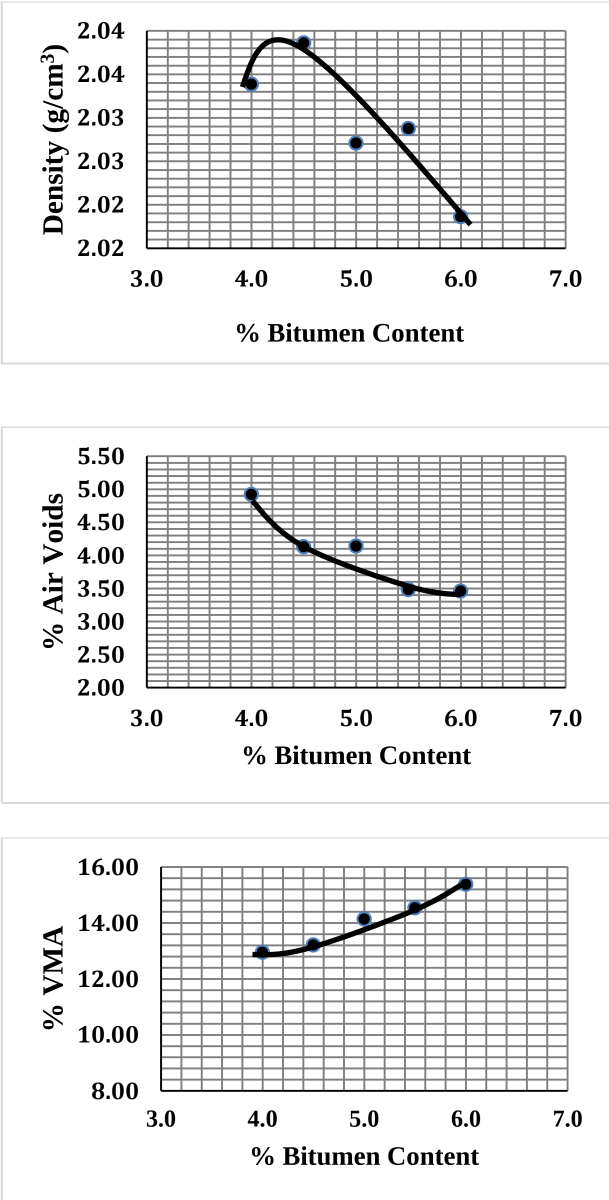
The optimum bitumen content when 6 % Sewage sludge ash filler is used is therefore given as the average of the three bitumen contents:

6 % SSA Filler Optimum Bitumen Content

$$= \frac{4.0+4.8+4.65}{3} = \textbf{4.48\%.}$$

At 4.48% Bitumen Content, Mix properties are: Gm = 2.102, % Air Voids = 4.2%, VMA = 13.6%, VFB = 69.2%, Stability = 6900N, Flow = 10.4 (0.25mm units). Hence accept the mix since its properties are within the Asphalt Concrete Properties Specification ranges.

The filler content was increased to 8% and while varying the bitumen content between 4% and 6%. The graphical plots for the 8% Sewage Sludge Ash filler are shown in Fig. 5 below.



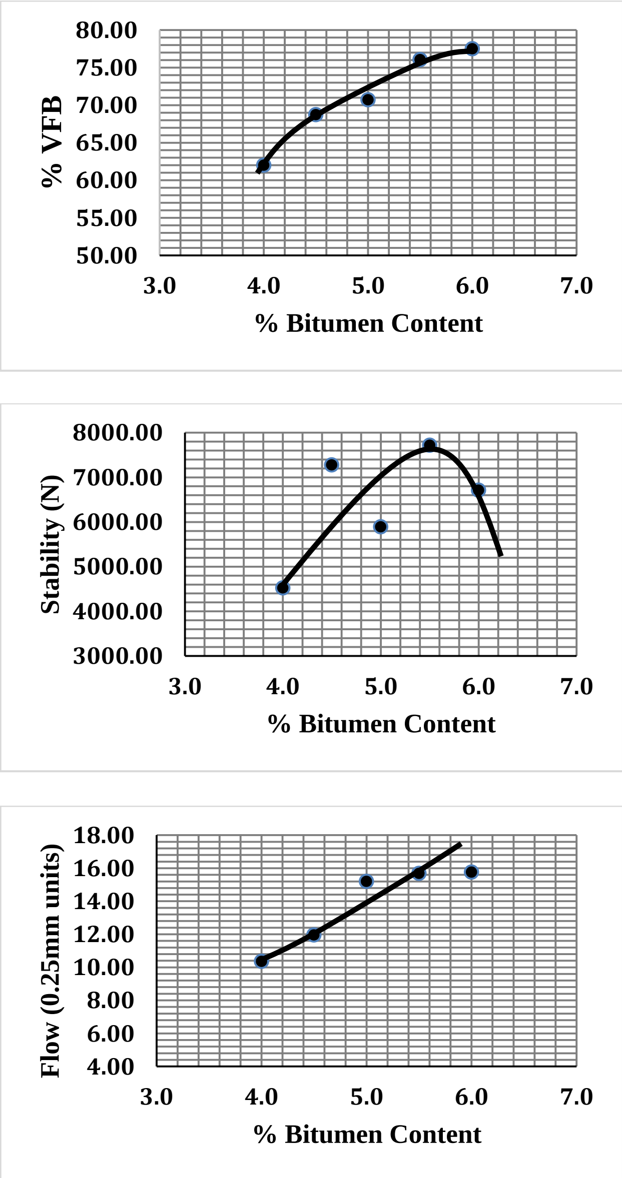


Fig.5: ***Graphical Plots for 8% SSA Filler***

From the plots in Fig.5 above; Bitumen content corresponding to maximum specific gravity of 2.044 is **4.5%.**

Bitumen content corresponding to the median of design limits of percent air voids (4%) is **4.65%**

Bitumen content corresponding to the maximum stability of 7700N is **5.5 %**

The optimum bitumen content when 8 % Sewage sludge ash filler is used is therefore given as the average of the three bitumen contents:

8 % SSA Filler Optimum Bitumen Content

$$= \frac{4.5+4.65+5.5}{3} = \mathbf{4.88\%.}$$

At 4.88% Bitumen Content, Mix properties are: Gm = 2.039, % Air Voids = 3.80%, VMA = 13.5%, VFB = 72.0%, Stability = 6800N, Flow = 13.2 (0.25mm units). Hence accept the mix since its properties are within the Kenyan Standard Asphalt Concrete Properties Specification ranges.

3) Optimum Sewage Sludge Ash Filler Content

The optimum bitumen content when 4 % Sewage sludge ash filler (by aggregate mass) is used is 5.03%. At this bitumen Content, Mix properties are: G_m = 2.154, % Air Voids = 4.0%, VMA = 14.4%, VFB = 72.6%, Stability = 6600N, Flow = 14.5 (0.25mm units). The optimum bitumen content when 6 % Sewage sludge ash filler is used 4.48%, the mix properties being: G_m = 2.102, % Air Voids = 4.2%, VMA = 13.6%, VFB = 69.2%, Stability = 6900N, Flow = 10.4 (0.25mm units). The optimum bitumen content when 8 % Sewage sludge ash filler is used is 4.88%, mix properties being: G_m = 2.039, % Air Voids = 3.80%, VMA = 13.5%, VFB = 72.0%, Stability = 6800N, Flow = 13.2 (0.25mm units). From the mix properties determined for the various SSA filler contents, the optimum sewage sludge ash filler content can therefore be stated as 6%, since it is at this filler content that the mix has the highest stability of 6900N with all the other properties i.e. Percent Air Voids, Voids in Mineral Aggregate, Voids Filled with Bitumen, and Marshall Flow being within the required standard specifications.

4) Assessment of Variations with Lime and Cement Filler

Separate Marshall Tests were done briquettes designed using corresponding proportions of lime, and cement fillers. The Marshal Test results reveals little variations in the asphalt concrete properties when SSA filler is used and when lime and cement fillers are used, with SSA filler results particularly yielding low stability values as compared to lime and cement fillers. The SSA stability values are nevertheless satisfactory.

The optimum lime filler content is 8% of the aggregate weight at 4.6% bitumen content, with the mix having a bulk specific gravity 2.167, % air voids of 3.60%, VMA of 13.4%, VFB of 73.5%, stability of 8400N and a flow value of 8.0 (0.25mm units). The optimum cement filler content is also 8% of the aggregate weight at 4.6% bitumen content, with the mix having a bulk specific gravity of 2.22, % air voids of 3.90%, VMA of 13.6%, VFB of 72.0%, stability and flow values of 9400N and 12.0 (0.25mm units) respectively (see Appendix for determination of optimum lime and cement filler contents). These values vary with the optimum sewage sludge ash filler content which was determined to be 6%, at 4.48% bitumen content with the mix having a specific gravity of 2.102, % air voids of 4.2%, VMA of 13.6%, VFB of 69.2%, stability of 6900N and flow of 10.4 (0.25mm units). The lower stability value in asphalt concrete using Sewage Sludge Ash as filler could be attributed to the relatively low strength value of the sewage sludge ash, in comparison to lime and cement.

IV. CONCLUSIONS

The main objective of this research is to assess the suitability of sewage sludge ash as a filler material in asphalt concrete. Generally satisfactory results have been found on the engineering properties tests and Marshall Tests for asphalt concrete designed using sewage sludge ash, thereby pointing to its suitability. The tests reveal that:

1. The sewage sludge ash has a particle size distribution of 99.11% passing the 0.425mm sieve and 76.13% passing the 0.075mm sieve. It is non-plastic and has an average specific gravity of 2.40, bulk density of 0.87 g/cm3 with a low Methylene Blue value of 0.7925 g/mg. These engineering properties of sewage sludge ash reveal its suitability as a filler material in asphalt concrete.

2. The optimum sewage sludge ash filler content is 6%, at 4.5% bitumen content with the mix having a specific gravity of 2.102, percent air voids of 4.2%, percent voids in mineral aggregate of 13.6%, percent voids filled with bitumen of 69.2%, stability of 6900N and flow of 10.4 (0.25mm units).

3. The properties of asphalt concrete designed using sewage sludge ash vary unfavorably with those for commonly used fillers, lime and cement which had higher stability values of 8400N and 9400N respectively. However the properties are acceptable.

It can therefore be concluded that sewage sludge ash can be used as a filler material in the design of Asphalt Concrete.

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