LABORATORY STUDY OF THE USE OF ALTERNATIVE MATERIALS AS FILLERS IN ASPHALTIC CONCRETES

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Abstract

This paper presents a comprehensive study on the use of recycled industrial and agricultural wastes converted to powder and used as fillers in asphaltic concrete production.Fillers are essential components of an asphaltic concrete as they not only fill voids in the coarse and fine aggregates but also affect the ageing characteristics of the mix.The study in evaluating the effect of different types of filler on the behavior of asphaltic concrete used broken bricks powder, broken tiles powder, cow bone ash and broken glass powder as fillers. Marshall stability and flow test were carried out on the asphaltic concrete samples. The materials used in this study include 60/70 penetration grade bitumen, river sand and crushed granites. The average marshall stability and flow values of the broken bricks powder, broken tiles powder, cow bone ash and broken glass powder is obtained as 12.21 KN, 12.51 KN, 10.75 KN and 16.05 KN for the stability and 3.10 mm, 3.06 mm, 2.69 mm and 3.28 mm for the flow respectively. This shows that broken glass powder has the highest marshall stability and flow value. The study concluded that the fillers have varying effects on the asphaltic concrete properties (rutting behavior, ageing characteristics, stripping behavior, stiffness, moisture resistance and durability) on judging from their varying marshal stability and flow values.

1.0 INTRODUCTION

Road pavements like any other engineering structure are expected to be adequately strong and durable for their design life and this can be achieved only when the pavements are properly designed, constructed, maintained and managed. Failures of some roads can be attributed to poor design of the asphalt mixes and/or materials being used. The availability of different local materials as industrial and agricultural wastes can be very useful in road pavements asphaltic concrete production.These industrial and agricultural wastes as discussed in this study include broken bricks powder, broken tiles powder, cow bone ash and broken glass powder. Various studies are beingconducted to evaluate the properties and performance of various materials as fillers in flexible pavements as they affect the consistency, void filling, resistance to displacement, water susceptibility, Marshall stability and mix strength (Parker, Kandhal & Lynn, 1998). Sadoon (2010) studied the effect of different filler types on performance properties of asphalt paving materials. The results indicate that filler type has a great effect on the cohesion and moisture damage of asphaltic concrete mix.

Fillers consists of finely divided mineral matter, such as rock dust, slag dust, hydrated lime, hydraulic lime, fly ash, loess, or other suitable mineral matter (Rahman, 2013), and they are generally finer than 75µm in size. Addition of filler to asphalt makes it harder and stiffer and the type and amount of filler added plays a huge role in enhancing a pavements performance. Fillers are essential components of an asphaltic concrete as they not only fill voids in the coarse and fine aggregates but also affect the ageing characteristics of the mix. A small amount of hydrated lime or cement as a replacement for some of the conventional filler material in a bituminous mix causes a chemical action to take place between the additives and the bitumen and results in the formation of compounds that are adsorbed on negatively charged aggregate surfaces and this improves adhesion and rendering the bitumen less vulnerable to stripping (Brennan &O'Flaherty, 2002).

The influence of different types of fillers on the properties of asphalt concrete mixture varies with the particle size, shape, surface area, surface texture and other physio-chemical properties (Bahia et al., 1999). Factors considered in selecting mineral fillers include: their ability to absorb water, its adhesive and sealant properties and its acid resistance ability (Kenth, 2012). Addition of filler to asphalt makes it harder and stiffer and the type and amount of filler added plays a huge role in enhancing a pavements performance. Fillers are essential components of an asphaltic concrete as they not only fill voids in the coarse and fine aggregates but also affect the ageing characteristics of the mix.

Glassphalt concrete is composed of inorganicmaterials called aggregates such as crushed stone and glasscemented together with some cementing material (mostlybitumen or binder) which when mixed together get hardened (Nkama, 2017). The termglassphalt consist of pellet of crushed glasses also known ascullet or fines or coarse aggregate and bitumen all mixedtogether in appropriate proportion. (Abraham, 1972).Jony, Al-Rubaie and Jahad (2010) investigatedthe possibility of using glass powder asfiller in hot asphalt concrete mixtures. Their study found that using of glass powder as filler at 7% optimum replacement produces asphalt mixture with higher stability (% of increase up to 13%), lower flow(% of decrease up to 39%) and lower density (% of decrease up to 10%) compared tocorresponding ordinary Portland cement or lime stone powder mixtures. Alhassan, Yunusa and Sanusi (2018) in the study potential of glass cullet as aggregate in hot mix asphalt show that asphaltic concrete produced with 8 % glass cullet can be used as wearing course material in pavement construction in accordance with the asphalt institute and Nigerian codes for roads and bridges. The study also posit that the use of glass cullet will provide an effective way of disposing the waste thereby safeguarding the environment.

The findings of Adanikin,Falade and Olutaiwo(2019) reveals that asphatic concrete samples produced without Cow Bone Ash (CBA) as fillers are better as they have an average stability value of 15.61 KN and average flow value of 4.90 mm than those produced with CBA which have average stability value of 12.36 KN and an average flow value of 4.90 mm. Falade, Ikponmwosa and Fapohunda (2012) showed that pulverized bone has pozzolanic properties and it can be used as partial replacement of cement in concrete without damage to the strength provided that the level of replacement does not exceed 20%. Aschuri and Woodside (2007) investigated the behavior of the asphalt concrete mix containing fly ash and hydrated lime in binder. The fillers as modifier were prepared with 3%, 6% and 9% by weight of bitumen respectively. Test results showed that the performance of bitumen mixes prepared using fly ash and hydrated lime as modifier were better than the original bituminous mixes. The study of Nwaobakata and Agunwamba (2014)showed that asphaltic concrete mixes modified with palm kernel shell ash (PKA) were found to have improved fatigue and permanent deformation characteristics, and lower moisture susceptibility at 3% PKA as filler.

Dipankar, Manish, Ashoke and Umesh (2016) revealedthat bituminous concrete, prepared by 20% brick aggregate and 80% stone aggregate, gives the highest Marshall stability compared to 100% stone aggregates. This shows that applicability of brick aggregate in bituminous concrete production.The study of Mobili, Giosue, Corinaldesi and Tittarelli (2018) posit that mortars produced by bricks wastes even if more porous and more prone to the water capillary absorption than mortars produced by natural aggregates, result in mortars with less stiffness, reduced crack formation, increased permeability to water vapour, and less susceptible to sulphate attack.

Poon and Chan (2006) also indicated that the incorporation of crushed clay brick reduced the density, compressive strength and tensile strength of paving blocks. Due to high water absorption of crushed clay brick particles, the water absorption of the resulting paving blocks was higher than that of the paving blocks that did not incorporate crushed clay brick.Ali, Abd-Elmoaty and Hani (2014) showed that cement paste when modified with 25% crushed clay bricks (CBP) achieves smaller pore size, lower weight loss under high temperature than 100% cement paste and reduces the overall unit weight of concrete masonry units.Afifa, Syed, Sajal and Quazi (2012) reveal that brick dust filler bituminous paving mixes exhibits higher stability value compared to cement and stone dust filler bituminous paving mixes Electricwala, Ankit and Rakesh (2013)showed that with water – cement ratio (0.46), core compressive strength increase by 3.9% to 5.6% by replacing 20% cement content with ceramic tiles dust.Dipu et al., (2015) evaluated the marshal stabilities of bituminous mixes containingfiller fine sand and stone dust mixture, waste concrete dust and brick dust and found their marshal stability values to be 9.8 KN, 11.1 KN and 11.3 KN respectively. This indicates the fillers satisfy the limiting value of 5.33 KNaccording to Marshall Design criteria and they can therefore be used as fillers in bituminous mixes.Chandra and Choudhary (2012) suggest that marble dust, granite dust andfly ash has good potential for use as filler in bituminous mixes. Among the threeindustrial wastes, marble dust is the most promising filler and will prove to be veryeconomical also, as mixes with marble dust have the lowest optimum binder content (OBC).

The extant literature reviewed shows the important roles fillers plays in bituminous concrete. The use of broken bricks powder, broken tiles powder, cow bone ash and broken glass powder as fillers was also ascertained. Conventionally, cement, fine sand and stone dust are used as fillers in Nigeria but this study evaluates the performance of asphaltic concrete produced with alternative non-convectional materials.

2.0 MATERIALS AND METHOD

The materials used in this study include 60/70 penetration grade bitumen, river sand free from deleterious materials and crushed granites obtained within Ondo State, Nigeria. The non-convectional materials used as fillers in this study namely: broken bricks, broken tiles, cow bone and broken glass were obtained as waste from varying sources, crushed in a grinding machine and then sieved with sieve No. 200 to produce the ash which is used as filler in the asphaltic concrete mixture.

Mechanical and strength tests such as flakiness index, elongation index, aggregate impact value (AIV), aggregate crushing value (ACV) amongst other tests were carried out on the coarse aggregates used for the test to determine their suitability for use. Sieve analysis test was also carried out on the sand used as fine aggregate in the study. Tests on bitumen such as penetration, specific gravity, flash and fire point, ductility, softening point and angular frequency were also carried out on the bitumen sample used in the study. Specific gravity test was also carried out on the coarse, fine, and fillers used in the study.In the Marshall test, the heights of the samples were measured and specimens were immersed in a water bath at 60°C for 35±5 minutes. Specimens were removed from the water bath and quickly placed in the Marshall loading head. The Marshall stability of mix is defined as a maximum load carried by a compacted specimen at a standard test temperature of 60ºC. The flow value is deformation the Marshall test specimen under goes during the loading up to the maximum load, 0.25 mm units.

Figure 1 -6 shows the procedure for the asphaltic concrete production and testing.

Fig. 1: Mixing of Asphaltic Concrete

Fig 2: Extruding the Asphaltic Concrete

Fig. 3: Asphaltic Concrete samples inside water bath.

Fig. 4: Asphaltic Concrete Samples

Fig. 5: Asphaltic Concrete Samples

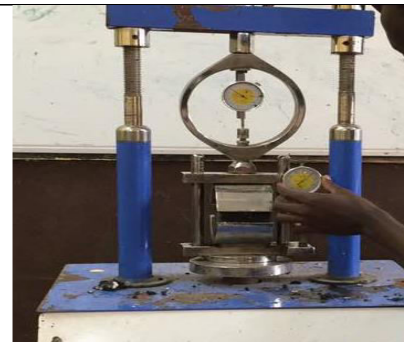

Fig. 6: The marshal testing machine

3.0 RESULTS AND DISCUSSION

The results of all the laboratory tests carried out on the coarse aggregates samples is as shown in Table 1.

Table 1: Summary of Tests on the Coarse Aggregates

Source of Aggregates (Quarry)	Loose Density of Aggregates (Kg/dm^3)	Water Absorp-tion(%)	Flakiness Index (%)	Elongation Index (%)	ACV Test (%)	AIV Test (%)	AAV Test (%)
Stone Works Quarry, Akure	1.38	0.37	16	27.5	26.5	15.93	28.8
Permissible limit (Standard Specification)	Min is $0.75kg/dm^3$ Max is $1.867kg/dm^3$	≤1.0% BS 812-109: 1990	≤25% BS 812-105.1: 1989	≤35% BS 812-105.2: 1990	≤30% BS 812-110: 1990.	≤35% BS 812-112: 1990	≤30% BS 812-113: 1990

Table 3.1 presents a summary of tests carried out on the aggregates. The Loose density of aggregates test shows that the coarse aggregateused for the research exceeded the minimum standard ($0.75kg/dm^3$) and fall below the maximum standard ($1.867kg/dm^3$). The aggregates also satisfied the water absorption limit as their values are below 1.0%. The Flakiness index test result falls below the permissible standard of less than 25% as it has a value of 16% therefore making it suitable for use. The result of ACV test obtained shows that the aggregates tested have their ACV values less than 30% which is in conformity with the requirement of “Not more than 30% for Surface or wearing course”. The lower the ACV the better the aggregates as this implies that when a force of about 4000KN crushes it, the fine particles sieved from the aggregates is the lowest. The AIV test results shows that the aggregates fall within the “very tough” rating. The AIV test indicates that when vehicles have impact with the road surface during movement, aggregates will not break down easily under loading since the result falls below the permissible standard. The AAV test shows that the aggregatehas AAV value of 28.8%

which is below the permissible limit of 30%. All these shows that the aggregates are considered satisfactory for road surfacing/wearing course construction.

Sieve Analysis

The result of sieve analysis carried out showed that the fine aggregate used for the research is Well Graded according to USCS classification and belong to (A-1-b) by ASHTO classification. This is as shown in Figure 7.

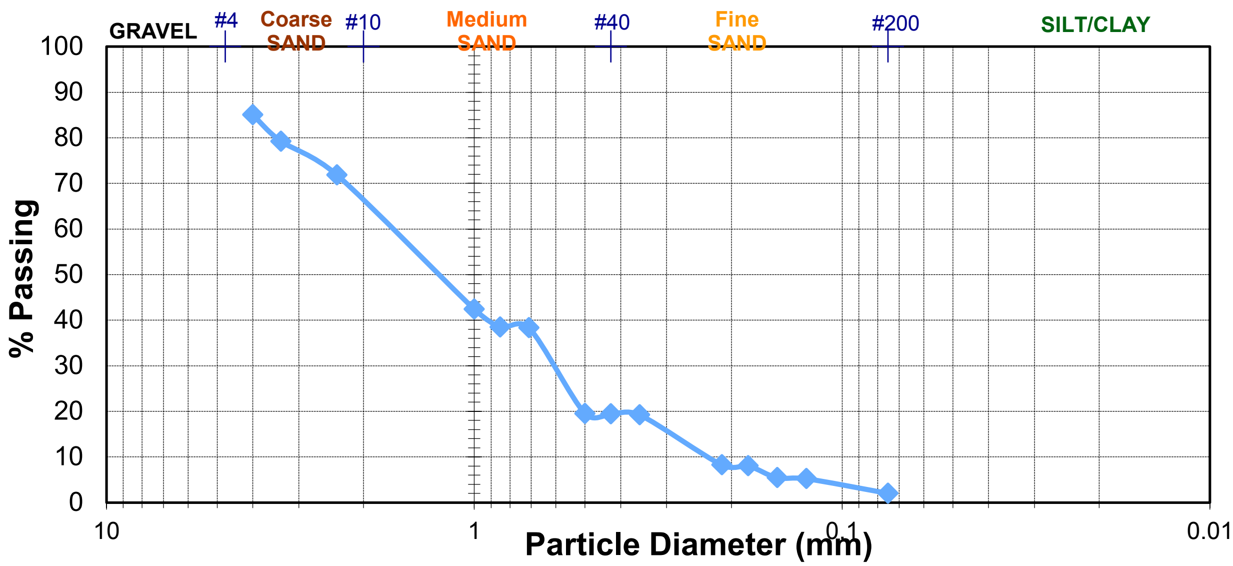

Figure 7: Particle Distribution Curve for Fine Aggregate

Table 2 shows the result of the tests carried out on the bitumen sample used in the study.

Table 2: Summary of Tests on Bitumen

S/N	Test	Obtained Value	Standard Values
1	Penetration	66 mm	60/70 mm (ASTM D5)
2	Specific Gravity at 25 ^{o}c	1.04 ^{o}c	1.01 – 1.06 (ASTM D70)
3	Water in Bitumen	3%	2% (IS:1211-1978)
4	Flash Point	282 ^{o}c	250 (ASTM D92)
5	Fire Point	313 ^{o}c	300 ^{o}c -320 ^{o}c
6	Ductility at 25 ^{o}c	101 mm	100 (ASTM D113)
7	Softening Point	49 ^{o}c	49 ^{o}c -56 ^{o}c (ASTM D36)
8	Angular frequency at 60 ^{o}c	1.6	
	Angular frequency at 120 ^{o}c	1.6	
9	Viscosity at 60^{o}c	0.65 mPas	
	Viscosity at 120 ^{o}c	0.53mPas	

Tests carried out on the bitumen sample shows that it is of penetration grade 60/70 with a penetration value of 66 mm making it suitable for road construction and production of asphalt pavements. The specific gravity of the bitumen at 25 ^{o}c is 1.04 ^{o}c, a 3% water in bitumen value is obtained though this exceeds the 2% by weight as specified by IS:1211-1978, the bitumen is still considered good for use. The water in bitumen is vital as high-water content hinders bonding between the bitumen, aggregates and fillers. Also, it is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when it is heated above the boiling point of water. The flash point for the bitumen was obtained as 282^{o}c while the fire point was 313^{o}c. This is important because at high temperatures bituminous material become volatile and can catch fire which is very hazardous. The flash point thereby reflects the lowest temperature (282^{o}c) at which the vapor of the bitumen momentarily catches fire in the form of a flash under specified test conditions while the fire point is the lowest temperature (313^{o}c) under specified test conditions at which the bituminous material gets ignited and burns. The ductility which is a function of the bitumen deformation or elongation without breaking is 101mm. The softening point which denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test was obtained as 49 ^{o}c which is within the acceptable limit according to ASTM D36. The angular frequency of the bitumen at both 60^{o}c and 120^{o}c is obtained as 1.6. The viscosity of the bitumen sample which connotes the fluid property of the bituminous material and it is a measure of resistance to flow at 60 ^{o}c is 0.65mPas while that at 120^{o}c is 0.53mPas.

Figure 8 shows the result of the specific gravity test carried out on the aggregates and the various fillers used in the study.

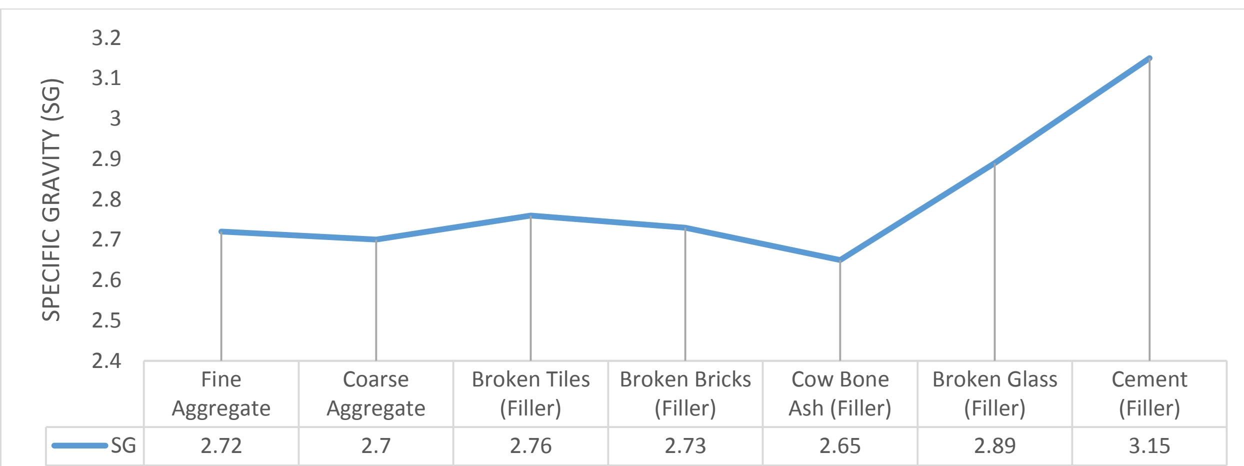

Figure 8: Specific gravity valuesfor aggregates and fillers used in the study.

Specific Gravityaccording to ASTM D1429 is a comparison between the weights of a volume of a particular material to the weight of the same volume of water at a specified temperature.It is a value to calculate whether the material is able to sink or float on water. Every material has some specific gravity. The value is normally in digits like 0.1 – 100. If the value is less than 1, then the material will float on water. If the value is greater than 1, then the material will sink. This will allow the user to determine if the test fluid will be heavier or lighter than the standard fluid. Test carried out showed that cement has a specific gravity of 3.15 which means cement is

3.15 heavier than the water of the same volume while cow bone ash, broken bricks, broken tiles, broken glass, coarse aggregate and fine aggregate have 2.65, 2.73, 2.76, 2.89, 2.70, 2.72 respectively.

Marshall Stability Test

Table 3: Marshall Stability Test Result

Material	**Stability (KN)**						
	Percentage replacement (%)						
	100	**90**	**80**	**70**	**60**	**50**	**0**
Broken brick powder	13.57	12.91	12.02	11.54	10.05	9.67	15.72
Broken tiles powder	13.63	12.98	12.07	11.57	10.93	10.70	15.72
Cow bone ash	11.88	10.59	9.99	9.15	9.13	8.82	15.72
Broken glass powder	16.55	16.14	16.10	16.17	15.90	15.79	15.72

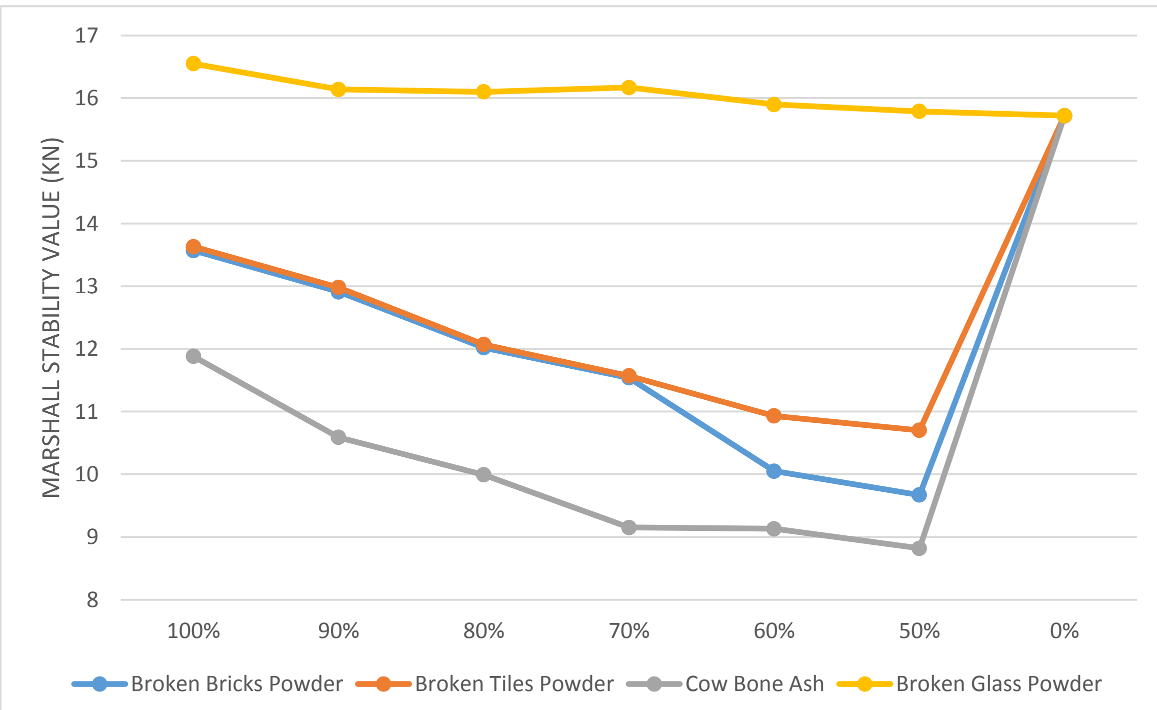

Figure 9: Marshall stability values of fillers at varying replacement percentages

The stability values obtained using 100%, 90%, 80%, 70%, 60%, 50% and 0% of broken bricks, broken tiles, cow bone ash and broken glass as partial / full replacement were showed in the table 3 and Figure 9. Figure 9 shows that the marshall stability for the mix ratios increased between 50% and 100% replacement. However, the stability values for broken tiles and broken glass powder are shown to have optimum values.

The Marshall Design Criteria for Stability provided by the Asphalt Institute requires minimum values for different traffic classifications starting at: 750 pounds or 340kg or 3.4KN for Light Traffic; 1200 pounds or 544kg 0r 5.44KN for Medium Traffic; 1800 pounds or 815kg or 8.15KN for Heavy Traffic.

For light traffic, all the Marshall Stability values obtained are more than minimum values. It can be deduced from the Table 3 and Figure 9 that none of the materials falls below the minimum value of 815kg/ 8.15KN which invariably makes them suitable for use in light, medium and Heavy Traffic pavements. It can also be observed that the stability recorded or got from broken glass powders were higher than other materials, this makes it more suitable than other materials and the flow is within the recommended range of (2-4 mm) as specified by ASHTO.

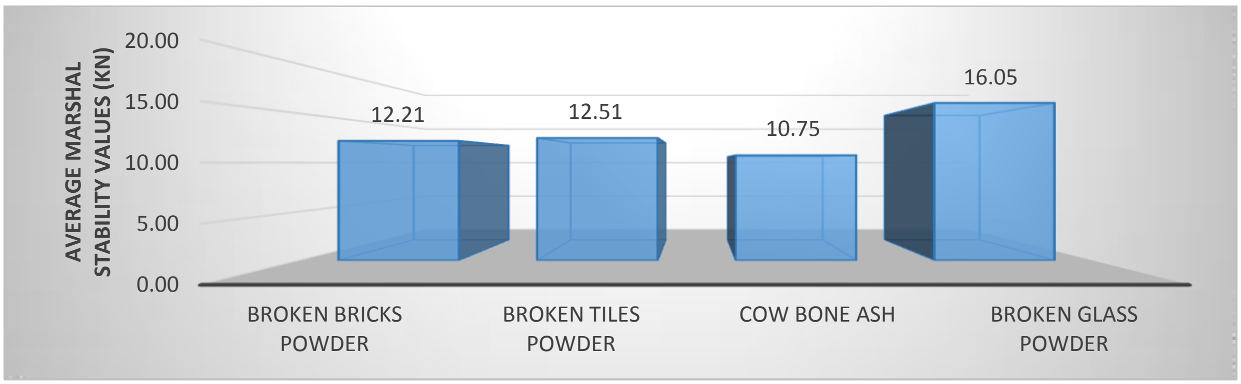

Figure 10: Average marshal stability values of fillers at varying replacement percentages

Figure 10 shows the average marshal stability values of fillers at varying replacement percentages. The average marshall stability values of broken bricks powder, broken tiles powder, cow bone ash and broken glass powder is obtained as 12.21 KN, 12.51 KN, 10.75 KN and 16.05 KN respectively. This shows that broken glass powder has the higher marshall stability value.

Marshall Flow Test

Table 4: Marshall Flow Test result

Material	FLOW (mm)						
	Percentage replacement (%)						
	100	90	80	70	60	50	0
Broken brick powder	3.6	2.3	2.7	3.3	3.5	3.9	2.4
Broken tiles powder	2.25	2.65	2.95	3.5	3.7	4	2.4
Cow bone ash	1.75	2.15	3.01	3.05	2.19	4.3	2.4
Broken glass powder	3.6	3.33	3.05	2.85	4.0	3.75	2.4

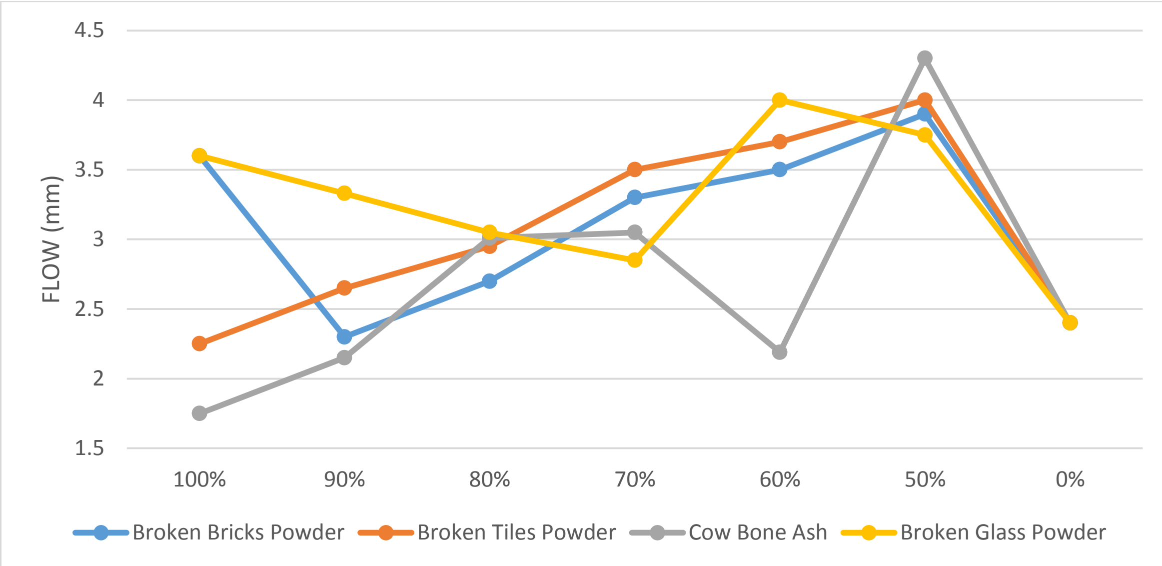

Figure 11: Marshallflow values of fillers at varying replacement percentages

Findings of the study as shown in Table 4 and Figure 11 reveals that the flow of the asphaltic concrete samples produced satisfied the Asphalt Institute specifications for Stability of Asphaltic concrete of (Not less than 2 mm) except the sample with CBA which has 1.75mm at 100% replacement. The flow for the asphaltic concrete produced with CBA has a value of 4.3 mm at 50% replacement.

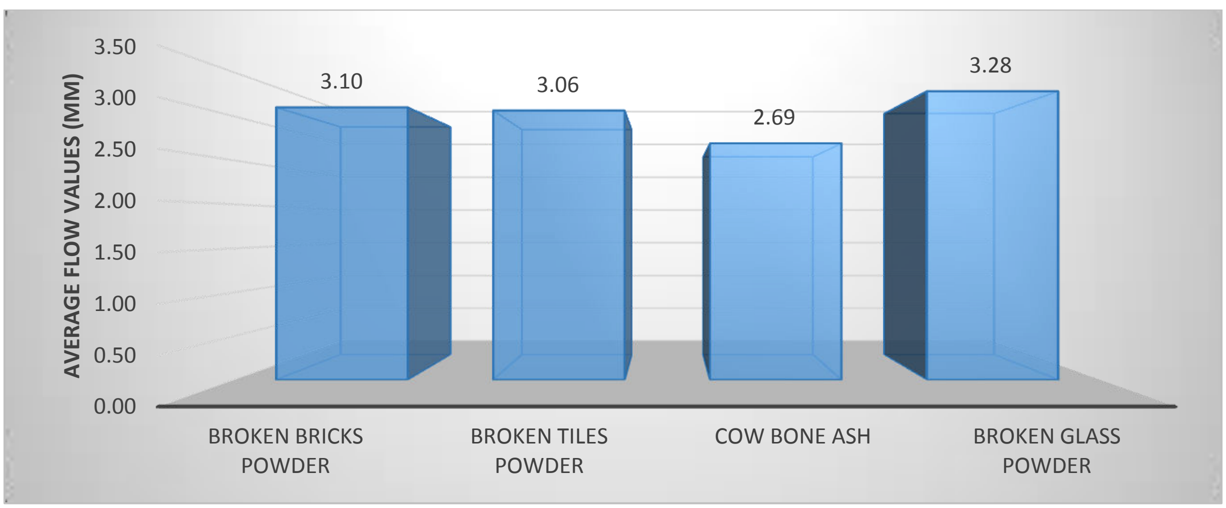

Figure 12: Average marshall flow values of fillers at varying replacement percentages

Figure 10 shows the average marshal flow values of fillers at varying replacement percentages. The average marshall flow values of broken bricks powder, broken tiles powder, cow bone ash and broken glass powder is obtained as 3.10 mm, 3.06 mm, 2.69 mm and 3.28 mm respectively. This shows that broken glass powder has the higher marshall flowvalue.

Comparison of Marshall Stability and Flow Results with Acceptable Standards

This study seeks to compare the marshall stability and flow results obtained from the study with acceptable standards such as the Asphalt Institute (1999), Federal Ministry of Works (FMW) 1997, Roads and Highway Department (RHD) Bangladesh, Ministry of Road Transport and Highways (MoRT&H) India.

Table 5: Comparison of Marshall Stability and Flow Results with Acceptable Standards

Average Marshall Stability and Flow Values Obtained and Standards		**Asphaltic Concrete Properties**	
		Stability (KN)	**Flow (mm)**
Average Values Obtained	Broken brick powder	12.21	3.10
	Broken tiles powder	12.51	3.06
	Cow Bone Ash	10.75	2.69
	Broken glasspowder	16.05	3.28
Standards			
Asphalt Institute		5.3 Min.	2 Min; 4 Max.
FMW Nigeria		3.5 Min.	2 Min; 4 Max.
RHD Bangladesh		5.33 Min	2 Min; 4 Max.
MoRT&H India		9 Min	2 Min; 4 Max.

The results show that the asphaltic concrete produced with the different fillers satisfies the various standards considered in the study. The MORT&H standard of India had the highest stability value of 9 KN minimum while the FMW standard of Nigeria had the lowest stability value of 3.5 KN minimum. The marshall flow values for all the standards are the same and the asphaltic concrete produced from this study are all above the minimum flow values and below the maximum flow values.

4.0 CONCLUSION

The purpose of this study was to evaluate and investigate the use of waste materials from different sources (broken vbricks, broken tiles, cow bone Ash and broken glass) as fillers in Hot Mix Asphaltic concrete.It can thus be concluded, based on the results of standard tests carried out on the materials, that the materials can be used as a suitable material for partial replacement / full replacement for fillers in asphaltic concrete up to 100% in Light, medium and heavy Traffic roads. Based on the average marshall stability values, the study reveals that broken glass filler produces the highest stability of 16.05 KN while cow bone ash had the least stability value of 10.75. the marshall flow results also indicates that the workability of asphaltic concrete produced from broken glass powder had the highest value of 3.28 mm hence shows that the workability of the asphaltic concrete composites will be at best. The study recommends that the Nigerian government should set new design standards for the minimum stability values for its road design considering it is below the average in relation to other standards considered in this study and quite low. This could be a contributing factor to the dilapidated condition of flexible pavements in the country as they tend to deform under traffic loadings.

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