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Stabilization of Gap-Graded Mix Using Oil Mesocarp Fibre as Additive

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Abstract

Purpose: The study used oil palm mesocarp fibre as an additive in gap-graded mix for the purposes of stabilization. The oil palm mesocarp fibre functions as reinforcement in the mix, providing additional tensile strength in the resulting composite whilst serving as an economic and efficient disposal of the oil palm fibre, which is a waste, generated from oil palm production.

Method: A Controlled Sample Mix (CSM) was prepared according to the Marshall procedure specified in ASTM D1559 and compared with Gap-Graded Mixes (GGM). The mix content i.e. Optimum Binder Content (OBC) for CSM and Optimum Oil Palm Mesocarp Content (OPMF) for GGM were from the Marshall Method. The CSM binder content of variations, 6, 6.5. 7, 7.5, 8% and fibre content in the GGM, from 0.1, 0.2, 0.3, 0.4, and 0.5% were used in the mixes. The mesocarp fibres were cut into small pieces (10-15 mm) and added directly to the aggregate sample in different proportion.

Results: The results plotted for Unit weight, Stability and Air content gave the OBC as 6.83% and a 0.22% OPMF at that determined OBC.

Conclusion: The stability values obtained from the Marshall Test showed the strength of the gap-graded mix (GGM) was lower than the strength of the controlled sample mix (CSM). However, the flow values were lower in the CSM as compared to the GGM specimen, which is an indication of a better resistance to deformation under sustained loading.

Keywords: gap-graded, stabilization, oil palm, fibre, sustainability, bitumen

1.0 INTRODUCTION

World population is significantly increasing at a fast rate with attendant rapid urbanization resulting in serious changes to the outlook of most regions of the world – Sub-Saharan Africa (SSA) inclusive. According to the United Nations Forum Population Agency (UNFPA) (2017) global population has risen in the last century from 1 billion in 2000 to 7 billion in 2011 and now estimated at 7.5 billion people with a projection that it will progress up to about 10 billion by the middle of this century (thus 2025), and levelling off at around 11 billion by the end of it. This increasing population coupled with rapid urbanization and industrialization globally, calls for additional infrastructure to cater for human needs amongst which are roads and transport networks. In the developing country of Ghana for instance, the Ministry of Roads and Transports (MRH) indicates that, a total of 4263.37 Km of roads were constructed between 2017 and 2021 (MRH, 2022). The effect of this call for increased infrastructure is reflected in the continuously increasing demand for construction materials that are of high quality, are more durable and good in skid- and wear-resistance for paving roads for the modern traffic. To this end, most countries in SSA have relied on conventional asphalt to meet this need over the years.

Several studies have however reported conventional asphalt as wanting when it comes to resisting pavement distresses owing to its dynamic properties and sturdiness (Zhang, et al., 2020). They added that, asphaltic surfaces are subject to rapid failure as a result of increasing traffic service, density, axle loading, and low maintenance services resulting from rapid population growth and urbanization. This therefore brings to fore the need to minimize the damage of pavements, make it resistant to such defects as rutting, and fatigue cracking. Studies have suggested the modification of Asphalt with selected fibre or polymer as the case may be. However, according to Polacco et al., (2004), the use of virgin polymers such as styrene-butadiene-styrene (SBS) and styrene-butadiene rubber (SBR) for producing well-graded aggregates of maximum density in many parts of the country especially in urban areas is becoming strenuous and uneconomical. In spite of the above, almost all high-type asphalt concrete used in most engineering works employ a densely graded aggregate. The advantages gap-graded aggregates promises, in both Portland cement and asphalt concretes has made it a point of attraction to engineers and researchers throughout the world. These have stimulated and necessitated the development of new asphaltic admixtures from sustainable materials such as Oil Palm Mesocarp Fibre (OPMF).

Oil Palm Mesocarp Fibre (OPMF) also known as Palm Pressed Fibre (PPF) is the biomass residue obtained after pressing the palm fruits for palm oil extraction. OPMF is nonabrasive, possesses low density and is biodegradability (Olusunmade et al., 2016). About 11% of OPMF is generated from the palm fruits after the oil extraction (Chiu, C.T et al 2007). Currently, OPMF is mostly used as steam boilers at the mills (Sreekala et al., 1997). It is the most abundantly available raw material on the Earth for the production of biofuels, mainly bio-ethanol. It is composed of carbohydrate polymers (cellulose, hemicellulose), and an aromatic polymer (lignin*)* potential utilization for bio composite production, whereby the fibre can be used to reinforce polymer materials such as thermoplastics (Olusunmade et al, 2016). They also assert that natural fibre-reinforced composites have numerous advantages including being; lightweight, low-cost, high toughness, and with reasonable strength and stiffness. The use of OPMF will be environmentally beneficial, and not only can it be anticipated to improve the bitumen binder properties and durability, but it also has the potential to be cost effective and thus contribute to the achievement of the Sustainable Development Goals (SDGs). Due to the lack of intermediate aggregates in the well-graded mixture (open-graded), they become porous and permeable asphalt mixes, which make them susceptible with less effect on the mixture resistance to rutting, deformation, aging, and moisture damage. Additives are normally added to help retain the binder in the mixture; that is, to prevent deformation, drain-down during production, transport, and laydown.

Given the above background, this study explores the possibility of using Oil Palm fibre as a suitable additive to extend pavement service lives and improve the level of service by conducting a methodical comparative study of Laboratory tests to assess the stabilization impact of gap grading on stability, maximum density, voids, water resistance properties, and optimum binder and fibre contents. The study findings not only contributes to the body of literature but also helps provides a valuable reference for engineers and policy makers as a cheap alternative sustainable additive is reported. This would go a long way to help achieving the UN SDGs in developing countries in SSA such as Ghana.

2.0 LITERATURE REVIEW

2.1 Oil Palm Mesocarp Fibre (OPMF)

Two historic constructions confirms the use fibres in construction including the Great Wall of China and an old arch (built with clay earth mixed with fibres) dating back to 2000 and 4000 thousand years ago respectively (Hongu and Philips, 1990) with advanced developments of fibre reinforcement being reportedly arriving in the early 1960s according to Mahrez (2003). The study by Zube (1956) is recorded as the earliest on the reinforcement of bituminous mixtures and it concluded that all types of wire reinforcement prevented or greatly delayed the formation of longitudinal cracks. This was after an evaluation of the various types of wire mesh placed under an overlay in an attempt to prevent deflection cracking. The study further suggests that the use of wire reinforcement would allow the thickness of overlays to be decreased while achieving the same performance. No problem was observed with steel and bituminous mixture compatibility. Similar studies by Maurer and Gerald (1989) supports this assertion noting that reinforcement consists of incorporating certain materials with some desired properties within other material, which lack those properties. Fundamentally, the principal functions of fibres as reinforcing materials are to provide additional tensile strength in the resulting composite and to increase strain energy absorption of the bituminous mixtures (Mahrez et al., 2005).

It is important to know that the appropriate quantity of bitumen needed to coat the fibres depends on the absorption rate and the surface area of the fibres. It also depends on the concentration and type of fibres (Button and Lytton, 1987). If the fibres are too long, it may create the so called ‘‘balling” problem, i.e., some of the fibres may lump together, and the fibres may not blend well with the bitumen. In the same way, too short fibres may not provide any reinforcing effect. They may just serve as expensive filler in the mix. Fundamentally, fibre improves the different properties of the resulting mix. It changes the viscoelasticity of the modified bitumen (Huang and White 1996), increases dynamic modulus (Wu, Ye and Li, 2007), moisture susceptibility (Putman and Amirkhanian, 2004), creep compliance, rutting resistance (Chen et al., 2008) and freeze– thaw resistance (Echols, 1989), while reducing the reflective cracking of bituminous mixtures and pavements (Echols, 1989; Tapkın et al., 2009; Maurer and Malasheskie,1989). Goel and Das (2004) reported that fibre-reinforced materials develop good resistance to ageing, fatigue cracking, moisture damage, bleeding and reflection cracking.

2.2 Gap-Graded Mix

Strong evidence from systematic investigation exist, which shows that with proper combinations of aggregates and asphalts, both continuous and gap-graded aggregates mixtures having high density and other qualities satisfying current design criteria, can be produced. Pasquini et al. (2010) inquired into the mechanical performance (stiffness, fatigue, permanent deformation and thermal cracking) of a gap graded Asphalt Rubber Asphalt Concrete (ARAC). They found that, the great amount of AR binder used together with the selected reduced maximum aggregate size reflected in limited stiffness for the ARAC mixture; fatigue and rutting behavior of ARAC demonstrated to clearly outperform traditional asphalt concretes; permanent deformation properties of the ARAC mix seemed less susceptible to test temperature than that of the SMA. In addition, their ARAC mixture was excellent against thermal cracking and showed high tensile strength and energy to failure values (Pasquini et al., 2010). In related studies in China, asphalt rubber is commonly used in dense-graded asphalt mixtures (Sun et al., 2009; Liu et al., 2009; Sun, 2008).

Gap-graded mixture is an impervious wearing surface (Yamin Liu et al, 2012) which provides rut resistant and durable pavement surface layer (Ibrahim, 2005). It has been first introduced in Europe for more than 20 years for resisting damage from the studded tires better than other type of HMA (Roberts et al., 1996). In recognition of its excellent performance, a national standard was set up in Germany in the year 1984. Since then the concept of Gap-graded mix has spread throughout Europe, North America and Asia Pacific. Several individual countries in Europe now have a national standard for Gap-graded mix; the European Committee for Standardization is in the process of developing a European Product Standard. Because of its success in Europe, some States, through the cooperation of the Federal Highway Administration, constructed Gap-graded mix pavements in the United States in 1991 (Brown et al., 1997). Wisconsin was the first Gap-graded project followed by Michigan, Georgia, and Missouri (NAPA, 1999). Since that time, the use of SMA in the US has increased significantly. A vast published information on gap-graded concretes exist in comparison with continuously graded concretes (U.S. Army Corps of Engineers, 1962; Sankaran, K. S., 1959; Li, s. T., and V. Ramakrishnan, 1970 as cited in D. V. lee, H. T. David and R. W. Mensing, 1973).

On the contrary, much less, academic study into gap-graded asphalt is reported and this data is scattered. This report presents the results of a comparative laboratory study between well-graded (CSM) and Gap-Graded Mixes (GGM) which has used Oil palm mesocarp fibre (OPMF) as an additive for stabilization.

3.0 METHODOLOGY

3.1 Materials Selection and Testing

Material selection formed the first step in the mix design. Materials suitable for gap grading include aggregates, asphalt binders and additives. Asphalt binder modifiers such as polymers and fibres were largely employed in this study.

3.1.1 Aggregates

The criteria used in selecting the aggregates was their ability to meet the specified criteria of gap-graded mix. Crushed stones of sizes 10mm and 20mm, which are common in Ghana, were used as aggregates and quarry dust as filler. These aggregates used were obtained from the Eastern Quarry located at Shai hills. Shai hills is a suburb near the district capital Dodowa in the Dangme West District of the Greater Accra Region of Ghana, north of Accra. Shai is plain by topography but has outcrops of hills. The hills in the Shai area are base to several stone quarries. The physical properties of the aggregates are shown in order to attain desirable engineering properties of the gap-graded mix, the *specific gravity test* to obtain the weight-volume characteristics of aggregates; *Aggregate Impact Value (AIV) and Aggregate Crushing Value (ACV) tests,* were conducted to simulate the aggregates resistance to impact loading.

Table 1 below shows the test results obtained after the physical test of the properties of aggregates and indicates that the AIV (BS 812 Part 111) and ACV (BS 812 PART 112) of the aggregates meet the required strength based on the code specifications in accordance to their respective test methods.

Table 1: Physical Properties of Aggregate

Property	Test Method	Test Result	Code Specification
Aggregate Impact Value (%)	BS 812 Part 112	28.0	<30
Aggregate Crushing Value (%)	BS 812 Part 111	26.81	<30
Specific Gravity (Coarse)	ASTM C136	2.89	2.6-2.9
Specific Gravity (Fine)	ASTM C136	2.78	2.6-2.7
Water Absorption (%)	AASHTO T85	0.1	<0.2

3.1.2 Oil Palm Mesocarp Fibre

Oil Palm Mesocarp Fibre (OPMF) as shown in **figure 1** was obtained from a local palm oil processing mill in Kasoa area of the Central Region of Ghana. OPMF is in abundance as waste in this area. The length of OPMF is about 90mm and diameter varied from 0.2 to 0.6 mm.

Fibre preparation

The OPMF was checked for foreign materials, and washed with detergent to rid them off remaining oils. After washing, the fibres were then sun-dried cut in to small pieces of 10-15 mm in length to ensure proper mixing with the aggregates and binder during the process of mixing.

Figure 1: Oil Palm Mesocarp Fibre

3.1.3 Binder

Bitumen (PG64-22standard) was also used for its good resistance to heat and for its thickness. It was obtained from Gbewaa Petrochemicals, a limited liability company in Tema-Ghana. **Table 2** shows the properties of the binder obtained from *the Asphalt Penetration Test that* was performed to measure its hardness. *Ductility Test and* the Solubility Tests were also performed to measure the purity of the bitumen as well as the flash point and fire tests. Results/Values obtained from each test conducted is within the code specification implying that the selected binder is suitable.

Table 2: Properties of Binder

Property	Test Method	Value	Code Specification
Penetration at 25°C (mm)	ASTM D5	68	60-70 (for Grade 60/70)
Viscosity at 60°C (mm2/s)	ASTM D4403	171	120-250
Specific gravity at 25°C	ASTM D70	1.02	0.97-1.3
Softening point (ring and ball)	ASTM D36	59.8	30-150
Flash and Fire point (°C)	ASTM D92	280 & 320	>232

3.2 Preparation of Mixes

The mixes were prepared according to the Marshall procedure specified in ASTM D1559. For gap-graded (GGM): the coarse aggregates, fine aggregates and filler were mixed according to the adopted gradation. The contents: Optimum Binder Content (OBC) and Optimum Oil Palm Mesocarp Content (OPMF) of the mix were found using Marshall Method. The binder content was varied from 6, 6.5. 7, 7.5, 8% and the fibre content from 0.1, 0.2, 0.3, 0.4, and 0.5%. The mesocarp fibres were cut into small pieces (10-15mm) and added directly to the aggregate sample in different proportions. The mineral aggregates mixed with fibres and binders were heated separately at 6 °C and 10 °C respectively. Required quantity of binder according to the varying percentages above, were added to the pre-heated aggregate-fibre mixture and thoroughly mixed until, there was uniformity and consistency in colour. The mixing was done between 2-5 minutes. The mixture was then poured in to pre heated Marshall Moulds and the samples were prepared. To achieve compaction in the samples, 75 blows on each side of the moulds were administered.

3.3 Tests on Mixtures

The specimens were kept overnight for cooling to room temperature. Then the samples were extracted and tested according to the standard testing procedure. All tests were performed at the Ghana Highways (materials Division) Laboratory in the capital Accra.

3.3.1 Marshall Test

Marshall Method of mix design is a standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. In Ghana, it is a very popular method of characterization of bituminous mixes. Many researchers to test bituminous mixes have also used this test. This test method is widely accepted because of its simplicity and low cost. Considering various advantages of the Marshall method it was decided to use this method to determine the Optimum Binder Content (OBC) of the mixes and study various Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voids etc. **Table 3** and **table 4** shows the Marshall properties obtained. Other properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and optimum oil palm mesocarp fibre contents (OPMF) are used to plot the graphs recorded in **figures 2-9**. The mix volumetric of the Marshall samples such as unit weight, air voids were calculated by using the procedure reported by Das and Chakroborty (2003). The equations below that have been widely used in practice according the standards were very useful in the computation of various properties of the mixtures.

Bulk Specific gravity of compacted mix (Gmb)

The following formula is used for calculating bulk specific gravity of a saturated surface-dry specimen:

$$Gmb = \frac{wa}{wa-ww} \dots \dots \dots \dots \dots \dots \dots \dots \dots \; (1)$$

Where

Gmb= bulk specify gravity of the compacted specimen

Wa = mass of dry specimen in air, g

Ww = mass of the specimen in water, g

Average Aggregate Specific Gravity (Gsb)

This average value can be calculated using the following equation:

$$Gsb = \frac{P\frac{S1}{A} + P\frac{S2}{A} + P\frac{S3}{A} \dots\dots\dots P\frac{Sn}{A}}{\left(\frac{P\frac{S1}{A}}{Gsb1}\right) + \left(\frac{P\frac{S2}{A}}{Gsb2}\right) + \left(\frac{P\frac{S3}{A}}{Gsb3}\right) \dots\dots\dots \left(\frac{P\frac{Sn}{A}}{Gsbn}\right)} \dots\dots\dots\dots\dots\dots\dots .2$$

where

Gsb= overall bulk specific gravity of aggregate blend

Ps1/A= volume % of aggregate 1 in aggregate blend

Gsb1= bulk specific gravity of aggregate 1

Ps2/A = volume % of aggregate 2 in aggregate blend

Gsb2= bulk specific gravity of aggregate 2

Ps3/A = volume % of aggregate 3 in aggregate blend

Gsb3= bulk specific gravity of aggregate 3

Air Void Content (VA)

Air void content is calculated from the mixture bulk and theoretical maximum specific gravity:

$$VA = 100[1 - \left(\frac{Gmb}{Gmm}\right)] \dots\dots\dots\dots 3$$

where

VA= Air void content, volume %

Gmb= Bulk specific gravity of compacted mixture

Gmm= Theoretical maximum specific gravity of loose mixture

Percent voids in compacted mineral aggregate (VMA)

The percent voids in mineral aggregate (VMA) is the percentage of void spaces between the granular particles in the compacted paving mixture, including the air voids and the volume occupied by the effective asphalt content

$$VMA = 100 - \frac{GmbPta}{Gsb} \ldots\ldots\ldots\ldots\ldots\ldots..4$$

where

VMA= percentage voids in mineral aggregates

Gmb=Bulk specific gravity of compacted specimen

Gsb=Overall bulk specific gravity of aggregate blend

Pta=Aggregate percent by weight of total paving

Optimum Binder Content

Optimum binder content is selected as the average binder content for maximum density, maximum stability and specified percent air voids in the total mix. Thus

$$Bo = \frac{B1 + B2 + B3}{3} \ldots\ldots\ldots\ldots\ldots\ldots.5$$

where,

B0= optimum Bitumen content.

B1= % binder content at maximum unit weight.

B2= % binder content at maximum stability.

B3= % binder content at specified air void in the total mix.

Optimum Oil Palm Mesocarp Fibre Content.

OPMF is selected as the average binder content for maximum density, maximum stability and specified percent air voids in the total mix. Thus

$$Fo = \frac{F1 + F2 + F3}{3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

where,

F0= optimum Fibre content.

F1= % Fibre content at maximum unit weight.

F2= % Fibre content at maximum stability.

F3= % Fibre content at specified air void in the total mix.

4.0 RESULT AND DISCUSSION

Gap-graded mixtures (GGM)-Stabilised with fibre (OPMF)

Test results showing volumetric and mechanical properties of GGM are tabulated in **Table 3** and are discussed below.

Marshall Stability and flow value

Per the results in **Table 3**, the evidence is convincing that the addition of the OPMF in the gap-graded mixture had a positive contribution to the stability values, and ultimately will lead to an improvement in the toughness of the mixture. There is also reason to believe that GGM would result in higher performance than CSM.

Table 3: Marshall Properties of sample with fibre

Fibre %	Avg W_a	Avg W_w	Avg G_{mb}	Avg V_A%	Avg Stability Kn	Flow mm
0.1	1195	674.7	2.30	19.65	7.39	1.93
0.2	1195.7	691.1	2.38	16.90	9.81	2.20
0.3	1185.633	667.8	2.29	19.95	9.66	2.67
0.4	1191	676.1	2.31	19.14	8.23	2.30
0.5	1194.1	674.1	2.29	19.72	7.73	2.47

The Marshall stability was plotted against the flow values with different fibre contents. Figures 2 and 3 below show the graphs of the plots. In Fig. 2, the stability of GGM increases initially (up to about 0.2%), reaches a maximum value of 0.24% before decreasing as the fibre content continues to increase.

Non-uniform distribution of the fibres is expected since the viscosity of bitumen will make the mixture inconsistent and non-uniform, resulting in a multi-phased composite material of aggregates and sticky bitumen. The explanation is that, fibres if added in excess, may coagulate together to form weak points inside the mixture resulting in the stability decrease.

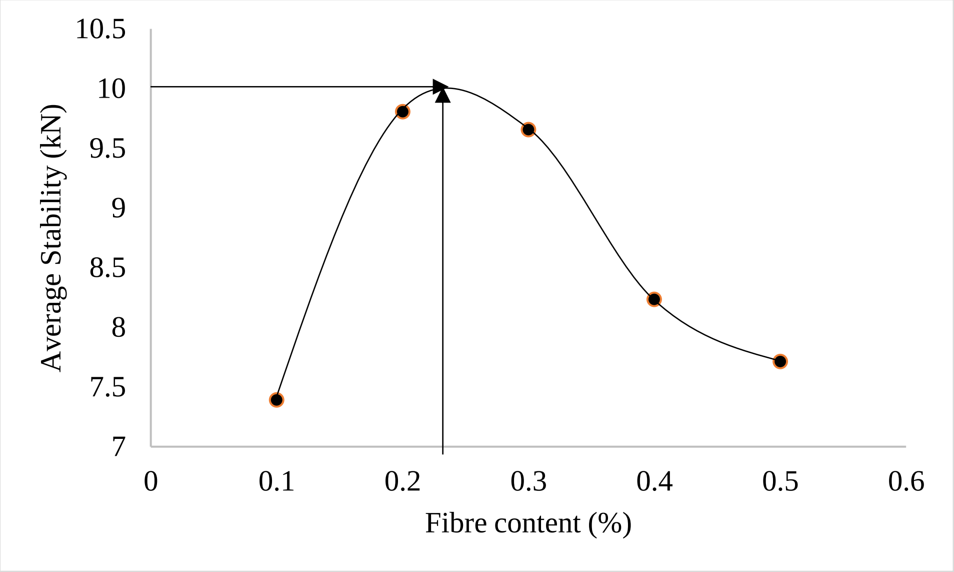

Figure 2: Plot of Average Stability against Fibre content at OBC for GGM

It may be observed also, that the GGM attained maximum stability at 0.24% fibre content.

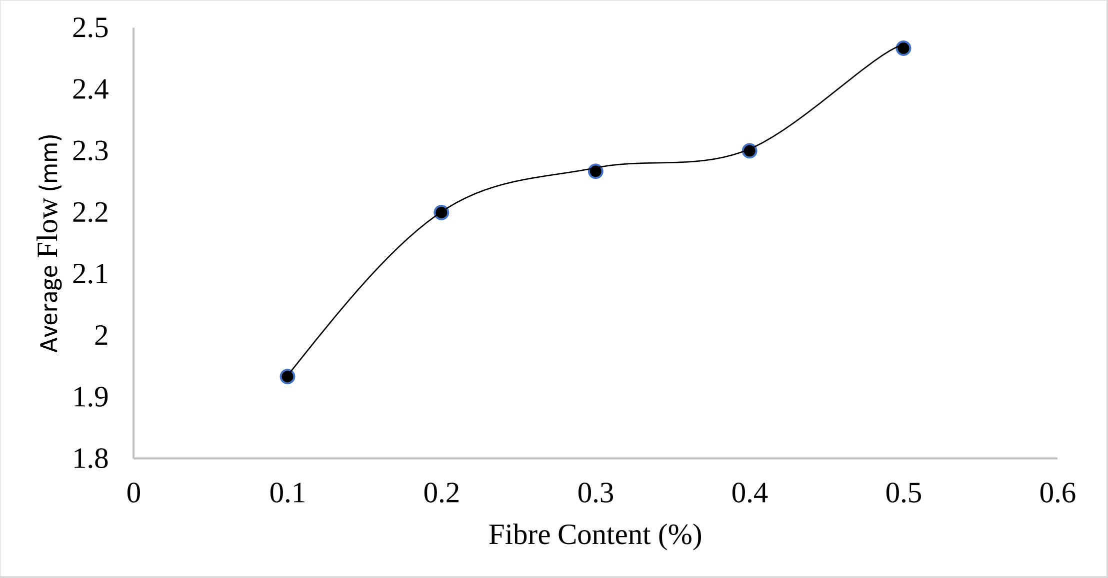

Figure 3: Plot of Average Flow against Fibre content at OBC for GGM

Marshall Air Void

As evidenced in Figure 4 below, as the fibre content increases in the beginning, the air voids sharply reduce until the fibre content reached 0.2%. The possibility is that of the networking effect of the fibre within the mix. Too much air voids in the GGM would lead to cracking due to insufficient bitumen binders to coat on the aggregates. On the other hand, too low air void will result in rutting and bitumen bleeding. According to AASHTO T 312, the air voids of mixtures should be within the specification range of 3% to 5%. This implies the use of the OPMF as an addictive.

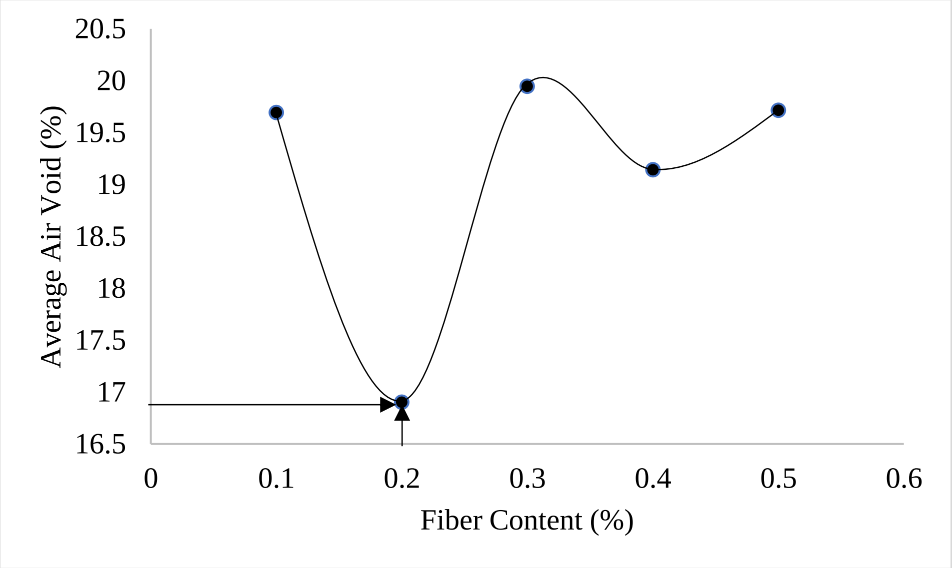

Figure 4: Plot showing variation of Air void content at different percentages of fibre

Controlled Sample Mix (CSM)-without fibre

Test results showing volumetric and mechanical properties of CSM are tabulated in **Table 4 below** and discussed following.

Table 4: Marshall Properties of sample without fibre.

Binder (%)	W_a	W_w	G_{mb} (kg/m^3)	V_A (%)	Stability (kN)	Flow (mm)
6	1193.5	698.9	2.40	16.14	10.09	1.98
	1198.5	649.4	2.17	24.01	9.98	1.31
6.5	1196.3	632.3	2.12	18.14	9.75	1.62
	1194.6	678.6	2.30	19.71	9.94	1.56
7	1192.6	661.4	2.23	22.08	10.49	1.67
	1194.5	687.8	2.35	17.86	10.32	1.84
7.5	1191.9	677.9	2.31	19.36	10.04	2.21
	1195.1	668.7	2.27	20.85	9.92	2.41
8	1194.2	687.7	2.24	20.25	9.82	2.12
	1193.1	679.8	2.11	19.34	9.91	2.5

Marshall Stability and flow value

Per the results in **Table 4**, the evidence is convincing that the addition of the OPMF in the gap-graded mixture had a positive contribution to the stability values, and ultimately will lead to an improvement toughness of the mixture. There is also reason to believe that GGM would result in higher performance than CSM.

In **figure 5**, the results shows the CSM records stability at a 7% binder content. It will also be noted that the shapes in both **figures 5 and 6** are an inversion of plot of GGM shown in **figure 2 and 3** above. This affirms that believe that the fibre has an influence on the stability of the GGM as earlier mentioned from the results of **figure 2 and 3.**

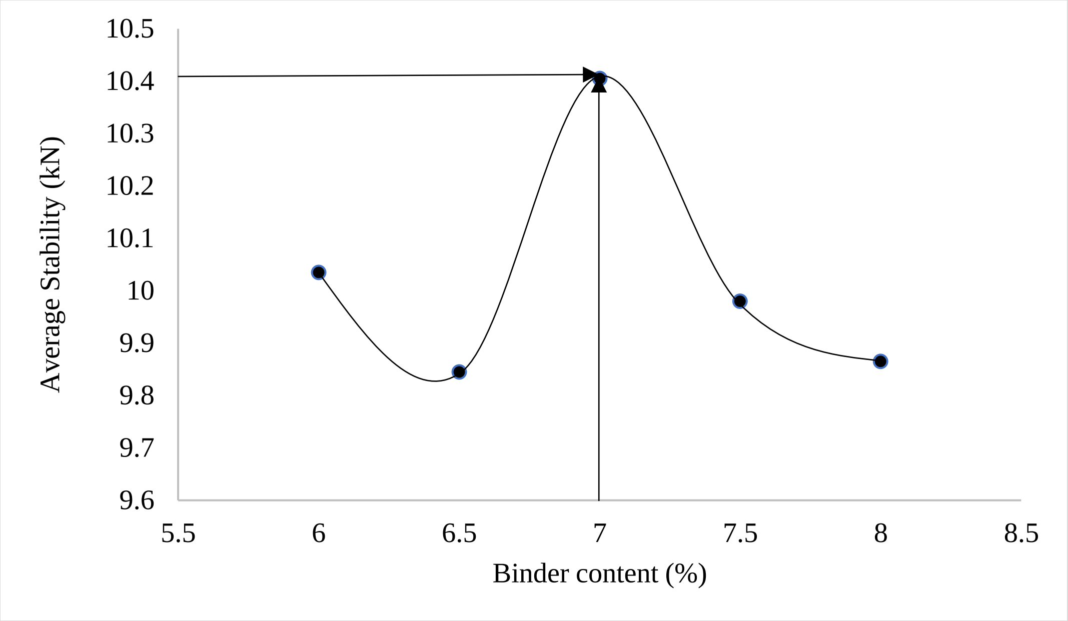

Figure 5: Plot of Average Stability against Binder content without fibre.

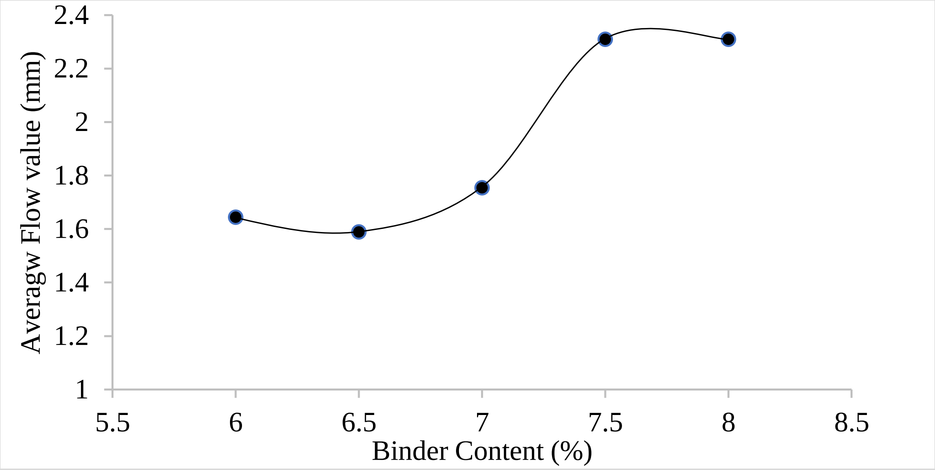

Figure 6: Plot of Average Flow against Binder content without fibre (CSM)

Air Void

With respect to the results for the CSM (as shown in **figure 7**), when the binder content increases from 6% to 6.5%, there is a drop in the air void by about 2.0%, and then increase with increase in binder content after 6.5% content. It then falls again albeit gently, when the binder content exceeded 7.3%. However, all the results are within the required specification range and thus, supports the use of OPMF as additive.

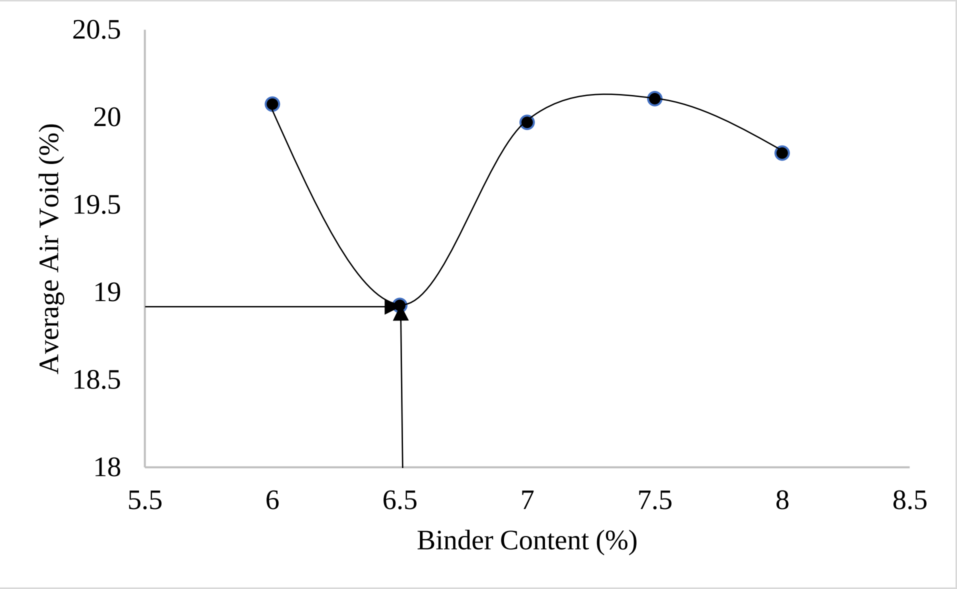

Figure 7: Plot of Average Air void against Binder content

Relationships of the Marshall Average Unit weight of CSM versus GGM.

The **figures 8 & 9** below shows a relationship between the average Unit weight, binder and the

Fibre content at the various percentages with the arrows showing point of optimum values. From

Figure 8, there is a sharp and sustained drop in the weight of the mixture after a binder content of

7.2%. The absence of the fibre is clearly seen in the curves in **figure 7 and 8**. The air void and the average unit curves have similar curves.

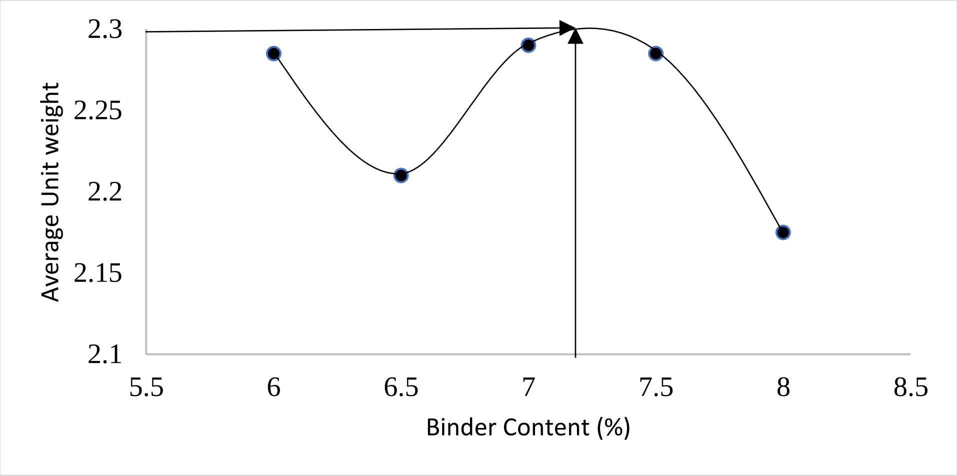

Figure 8: Plot of Average Unit weight against Binder content without fibre (CSM).

From the points indicated by the arrows in **figure 9**, the unit weight of the GGM is maximum before declining sharply to about 2.3% at a fibre content of 0.3%. As seen in **figure 4**, the air voids of the GGM was rising thereby leading to a reduction in its average unit weight.

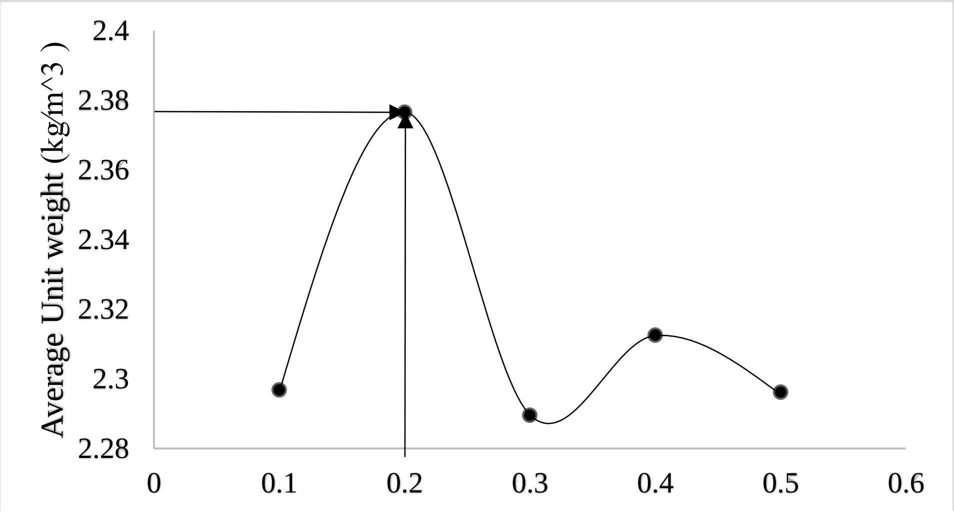

Figure 9: Plot of Average Unit weight against Fibre content at OBC (GGM)

CONCLUSION

The test carried out showed that OPMF were suitable for use in this research work. Aggregate gradation for gap graded Mix were now carried out in accordance to ASTM C136.

The gap graded mix samples were prepared using varying bitumen content of 6, 6.5, 7, 7.5, and

8%. This was done to find out the effect of increasing bitumen content on the stability value. These plots also helps us to find the Optimum binder content (OBC) for this mix. From the plot of the Unit weight, Stability and Air content, respectively the OBC was obtained to be 6.83%. However, for the mix with the oil palm mesocarp fibres, it was determined in a similar manner as the optimum binder content, at fibre content of 0.1, 0.2, 0.3, 0.4, and 0.5% and the optimum oil palm mesocarp fibre content (OPMF) was 0.22% at the determined OBC.

The strength of the gap-graded mix for the mix with the fibre was observed to be lower, when compared to the mix without fibre as observed from their respective stability values obtained from the Marshall test procedures discussed above. The findings also revealed that the flow values were lower in the mix without the oil palm mesocarp fibre, but were higher in the specimen with the oil palm mesocarp fibre, which is an indication of a better resistance to deformation under sustained loading.

The study findings not only contributes to the body of literature but also helps provides a valuable reference for engineers and policy makers as a cheap alternative sustainable additive is reported. This would go a long way to help achieving the UN SDGs in developing countries in SSA such as Ghana.

Gap graded mix has been observed to suffer from drain-down as reported in the literature, however, this study could not investigate it, therefore further research is recommended to ascertain the effect the oil palm mesocarp fibre would have on the drain-down characteristics of the mix and other engineering properties, such as the fatigue resistance, creep and resilience modulus.

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