



Use of Carbide Waste as Mineral Filler in Hot Mix Asphalt

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ABSTRACT

Increase in axle load and changes in weather condition due to global warming have led to the deterioration of our road. As such there is a need to look for an alternative waste material that can improve the properties of hot mix asphalt (HMA). Carbide Waste (CW) is a waste material that can be used to improve the properties of HMA because of its high percentage of calcium oxide. Therefore, this research objective is to use CW to partially replace stone dust (SD) as mineral filler in HMA and evaluate its effect on the properties of HMA. Tests were carried out on the constituent materials. Chemical analysis was performed on the CW. HMA samples were prepared with CW at 10, 20, 30 40 and 50% respectively by weight of SD at an optimum bitumen content. Marshall Stability was carried out on the modified samples to obtain its strength properties. The results of the tests carried out on the constituent materials conform to specification. This makes the materials suitable for use in HMA production. Chemical analysis on the CW indicates that it contains 51.599% of calcium oxide. The optimum modifier content was obtained to be 27.67% of the total mineral filler. The stability value of the modified HMA was obtained to be 7.6kN which was slightly higher than the control value of 6.9kN. The flow value of the modified HMA was obtained to be 3.43mm which was lower than the control HMA value of 4.3mm. The value of void in Mineral aggregate (VMA) of the modified HMA was obtained to be 3.90% which is slightly higher than the control value of 3.6%. In addition, the value of void filled with bitumen (VFB) of the modified HMA was obtained to be 77.13% which is slightly lower than the control HMA value of 78%. Based on results of tests, the partial replacement of filler with 27.67% carbide waste is recommended for use in HMA production.

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INTRODUCTION

Hot Mix Asphalt (HMA) pavements serve in a multitude of traffic and environmental conditions, demanding that the materials and design meet specific engineering requirements. The constituent

materials of HMA are aggregates and binder. The finest particles among the aggregates are fillers, (BS EN 13043, 2003), their addition to aggregates, non-bituminous and bituminous binder's mixtures will play a special role in the mixture. The role filler



plays in the production of asphaltic concrete, in terms of the mechanical and physical properties and composition of the mixtures are stiffness and toughness of the resulting mixture (Grabowski & Wilanowicz, 2008). Fillers also may modify the ageing processes (Recasens, et al., 2005).

With the rapid economy growth and continuously increased consumption, a large amount of waste materials is generated (Wu, et al., 2003). Wastes generated are disposed into the environment without adequate treatment. On getting into the soil its lead to accumulation of toxic compound and in some cases lead to nutrient enrichment (Dunbabin, 1992).

A number of studies have proven that the properties of mineral filler aggregate had a significant effect on the properties of the asphalt mixtures (Melotti, et al., 2013). With the increase of filler content, some properties of HMA improved while others decreased (Huang, et al., 2007). As natural resources become scarce, it is essential to find an alternative recycle material that can be used to construct pavement including asphalt pavements. Therefore, the idea of using recycled material in pavement construction has attracted the attention of many Highway engineers and Scientist who are thinking about different research methods to meet this growing challenge e.g., (Karlsson & Isacson, 2006; Huang, et al., 2007; Widyatmoko, 2008; Ahmedzadeh & Sengoz, 2009; Rafi, et al., 2011; Khan & Gundaliya, 2012; Menaria & Sankhla, 2015; Chandh & Akhila, 2016) in the pavement industry to investigate feasibility of the application of some waste materials as alternative material in pavement construction.

Considering the rational management of natural resources and wastes the use of fillers other than limestone powder is worth to be investigated. Other investigations also prove that such waste powders may have no negative influence on

asphalt mixture and they may even improve its engineering characteristics to some degree (Geber & Gomze, 2010; NCHRP Project 9-45, 2010; Pasandín & Pérez, 2015).

It was reported that an addition of 20 percent of recycled roofing material improves the rutting resistance in pavement (Paulsen, et al., 1987). According to (Burak & Ali, 2004) the use of asphalt roofing shingles in hot mix asphalt, can improve the Marshall stability and rutting resistance of the asphalt mixtures. Utilization of LDPE in Stone Mastic Asphalt mixtures generally decrease penetration at 25°C as LDPE content increases, which indicates an improved shear resistance in medium to high temperatures. Softening point tend to increase with the addition of LDPE, which indicates improvement in resistance to deformation (Al-Hadidy & Yi-qiu, 2009). Compressive strength test result of concrete made with RHA-cement exhibited great improvement with the addition of 10% CW after which a decline in compressive strength was observed, similar trend was also observed with indirect tensile strength of cement-RHA-CW combination (Manasseh, 2009).

Carbide Waste (CW) is a waste material generated from oxy-acetylene gas used in welding works in most automobile workshop (Chukwudebelu, et al., 2013). CW is rich in calcium oxide (CaO) which is an essential ingredient in mineral filler. Increase in the value of CaO, SO₃ and LOI increases the complex shear modulus and stiffness of mastic asphalt. Thus improves the rutting resistance at high temperature, stripping to moisture attack, minimize pavement raveling, and also improve aging resistance (Osuya & Mohammed, 2017).

From literature, calcium oxide composition of carbide waste ranges between 50 – 61% which is close to the range obtained for Portland cement. Addition of lime is the most accepted way to improve the moisture susceptibility of HMA



in many parts of the country. If the aggregate contains more fines, more lime may be required to be added to the mix due to the increased surface area of the aggregate (Hunter & Ksaibati, 2002). It is assumed that the mechanism by which hydrated lime improves the moisture susceptibility of the HMA involves a chemical interaction between the calcium in the lime with the silicates in the aggregate (Selim, 1997).

Marshall stability of an asphalt concrete mixtures with carbide waste increased with increasing lime content, with rate equal to (40%) for (2.5%) carbide waste content. Also, the air voids decreased with increasing carbide waste content, especially at the optimum content (2%) hydrated lime (Mohan & Obaid, 2014).

The Nigerian Automobile Technicians Association (NATA) with average membership of twenty-five thousand (25,000) panel beaters are scattered all over the country. Each panel beater produces an average of 30kg of carbide waste daily. The sludge generated by this activity (industry) has accumulated over the years. The sludge are dumped indiscriminately resulting in environmental problems and health hazard such as adverse effects on the fertility of land, as these wastes are deficient in plant nutrients, drainage problems, contamination of water resources. It also causes air pollution as the dry powder becomes air borne on windy days, wastage of valuable resources of calcium hydroxide (slaked lime) and handling and disposal problem (World Bank, 2003).

MATERIALS AND METHOD

The materials used for the research are aggregates, bitumen and CW. The aggregates are crushed rock obtained from

quarry site of Mother Cat Construction Company in Zaria. The laboratory tests carried out in accordance to standard specifications on the aggregate were sieve analysis (BS 812 103.1, 1985), specific gravity and water absorption test (BS 812 2, 1995), aggregate crushing value (BS 812 110, 1990), aggregate impact value (BS 812 112, 1990), elongation index (BS 812 105.2, 1990), and flakiness index (BS 812 105.1, 1989). The crushed stone dust (control) was obtained from quarry site of Mother Cat Construction Company in Zaria. The test conducted is specific gravity (BS 812 2, 1995). The binder (bitumen) was obtained from Mother Cat Construction Company, Zaria. The laboratory tests carried out in accordance to standard specifications on the bitumen were penetration (ASTM D5, 2005), softening point (ASTM D36/D36M, 2009), ductility (ASTM D113, 2007), flash and fire point (ASTM D92, 2005), specific gravity test, solubility (ASTM D2042, 2015), and viscosity test (ASTM D2170, 2010). Laboratory mix designs of HMA are done by Marshall Test procedure (ASTM D6926-16, 2016). The bulk specific gravity of each test specimen was determined in accordance with (ASTM-D2726, 1992).

RESULTS AND DISCUSSION

Test Result of Unmodified Bitumen

The result of the consistency test carried out on the pure bitumen are as shown in Table 1. It can be observed that the entire test conducted falls within the specification for heavy weight traffic as 80/100 penetration grade bitumen by (Federal Ministry of Works and Housing, 2016). As such, the bitumen can be used for heavy weight traffic design.



Table 1: Test Conducted on Unmodified Bitumen

S/N	Test Conducted	Unit	Result	Light Traffic	Medium Traffic	Heavy Traffic
1	Penetration	0.1mm	84	40/50	60/70	80/100
2	Softening point	°C	49	52-60	48-56	42-50
3	Ductility @ 25°C	cm	77.7	100 (Min)	100 min	100 min
4	Specific gravity	NIL	1.042	1.01-1.06	1.01-1.06	1.01-1.06
5	Flash-point	°C	251	250 (Min)	232 min	250 min
6	Fire-point	°C	218	NIL	NIL	NIL
7	Solubility in C ₂ S	%	100	99.5 min	99 min	99.5 min
8	Viscosity @ 60 °C	Secs	1522	NIL	NIL	NIL

Proportion of Aggregate Size

Figure 1 shows the gradation of particle size distribution curve. This curve shows that the mix was well graded, and maximum volume of aggregate will be achieved in the aggregate mix (Chen &

Richard-Liew, 2003). Also a dense material will be obtained when aggregate is compacted (Brennan & O’Flaherty, 2002). The gradation curve is also within the required envelop of (Federal Ministry of Works and Housing, 2016).

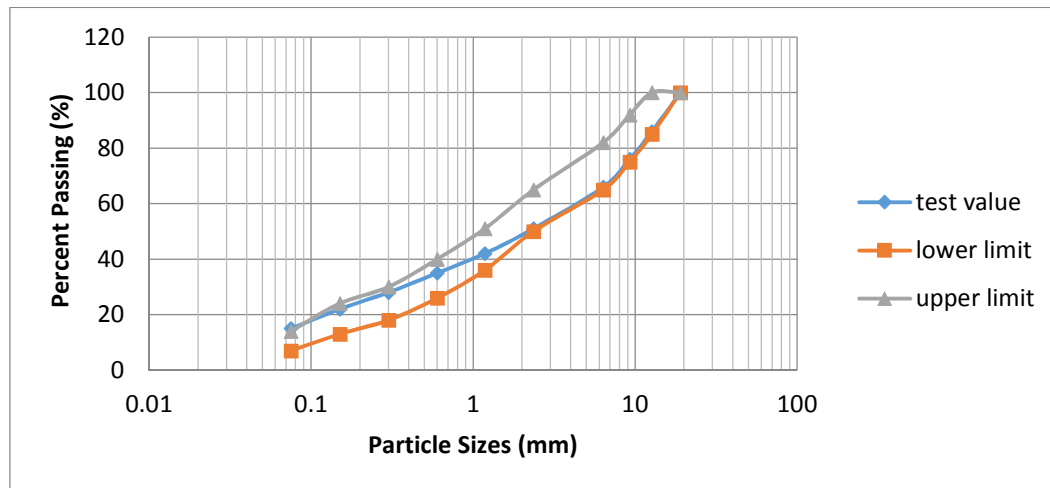


Figure 1: Gradation Curve of Aggregate

Physical Properties Test on Aggregate

The results of the various physical properties conducted are as presented in Table 2. The values of specific gravities of coarse and fine aggregates are within the acceptable values recommended by (Mageswari & Vidivelli, 2009; Garber & Hoel, 2009). Flakiness and Elongation index of 27.50 and 24.70 are both within the allowable limits specified by (Federal Ministry of Works and Housing, 2016). There

will be reduction in strength of pavement if flaky and elongated aggregates are in enormous proportion as the aggregate will have low workability in the mix and then tend to break under apply load. The ACV which is obtained to be 26.22% and the AIV which is 28.89% are within acceptable limits specified by the (Federal Ministry of Works and Housing, 2016). Aggregates with ACV and AIV greater than 30 are normally

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regarded as being too weak and brittle for use in pavements.

Table 2: Physical Properties of Aggregates

Properties	Test values	Standard Spec.		Remarks
		Min.	Max.	
Specific Gravity (Coarse)	2.637	2.6	2.9	OK
Specific Gravity (fine)	2.544			OK
Specific gravity (filler)	2.592			OK
Flakiness Index	27.50	-	35	OK
Elongation Index	24.70	-	25	OK
Aggregate Crushing value (%)	26.22	-	30	OK
Aggregate Impact value (%)	28.89	-	35	OK

Oxide Composition of Carbide Waste

The test on the Percentage of Oxide composition of Carbide Waste is shown in Table 3. It was observed that Calcium Oxide (CaO) have the highest percentage of 51.599%. It is very essential in mineral filler and also significant in performance of asphalt. Calcium oxide increases the complex shear and modulus of stiffness of mastic asphalt. Consequently, this in turn improves the stripping to moisture attack, rutting resistance at elevated temperature, minimize pavement ravelling and improve aging resistance. Ferric oxide (Fe₂O₃) also aids in absorption of excess oil in bituminous mixture (Ahlich, 1991). Aluminium oxide (Al₂O₃) helps in creep recovery, which means better resistance to permanent deformation among the modified asphalt cements, regardless of the stress level (Mubaraki, et al., 2016). Large amount of silicon oxide (SiO₂) can cause stripping of HMA pavements because silica reduces the bond strength between the aggregate and binder (Yasreem, et al., 2011).

Table 3: Oxide Composition of Carbide Waste Using XRF

Element	Concentration (Weight %)
Na ₂ O	0.000
MgO	1.000

Element	Concentration (Weight %)
Al ₂ O ₃	11.532
SiO ₂	7.879
P ₂ O ₅	5.082
SO ₃	3.286
Cl	3.082
K ₂ O	3.102
CaO	51.599
TiO ₂	2.066
Cr ₂ O ₃	0.000
Mn ₂ O ₃	0.000
Fe ₂ O ₃	10.320
ZnO	0.000
SrO	1.052

Marshal Test for Modified HMA

The mix was prepared and the marshal test was conducted in other to determine the properties of the modified HMA to ascertain its possibility for highway construction.

Stability

The variation of stability with carbide waste content are as presented in Figure 2. Figure 2 indicated that stability of the carbide waste replacement increases initially, reaches a maximum value and then decreases with increase in carbide waste content. This behaviour was equally observed by (Murana & Sani, 2015) when bagasse ash was used to partially replace



cement in HMA. The study also agrees with the work of (Taih, 2011), (Awwad & Shbeeb, 2007) and (Sabina, et al., 2009) who study the effect of additives in HMA. Consequently, stability of CW replacement in hot-mix asphalt has a higher stability value of 7.60kN which is higher than that of the control hot-mix. Bituminous mixture is an inconsistent, non-uniform, multi-phased

composite material. Therefore, excessive CW may not disperse uniformly, while coagulate together to form weak points inside the mixture. As a result, stability decreases at high CW contents. This result shows that the mixture using CW as replacement, result in higher performance than the control mixture.

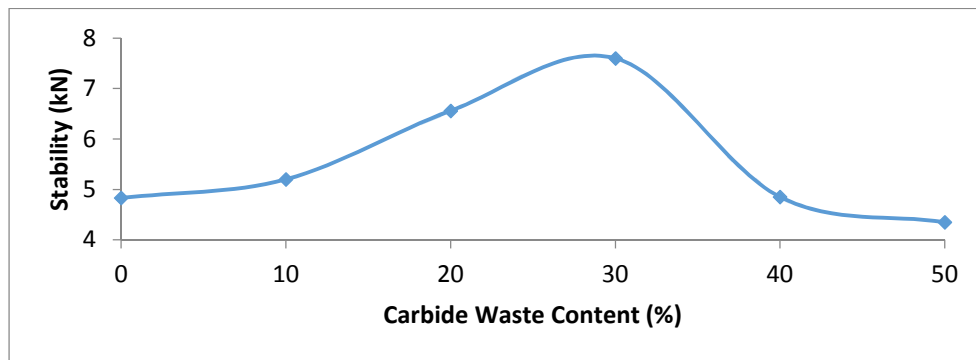


Figure 2: Variation of Stability with Carbide Waste Content

Flow

The variation of flow with CW content is shown in Figure 3. It was observed that the flow value decreases after adding CW content to the mixture. This was equally observed by (Bindu, 2012) the influence of additives on the on the characteristic of stone matrix asphalt. This also agrees with the result of (Aliyu, et al., 2015) who noted that reduction in flow suggests that polymer content has increased effect on the internal

friction of the mix. This is as a result of high CaO content present in carbide waste which tend to stiffen the asphaltic concrete, the asphaltic concrete becomes less flexible and the resistance to deformation increases resulting in a low flow value. However, these values are all within the limits specified by (Federal Ministry of Works and Housing, 2016) that stipulated that the flow value should lie between 2-4mm.

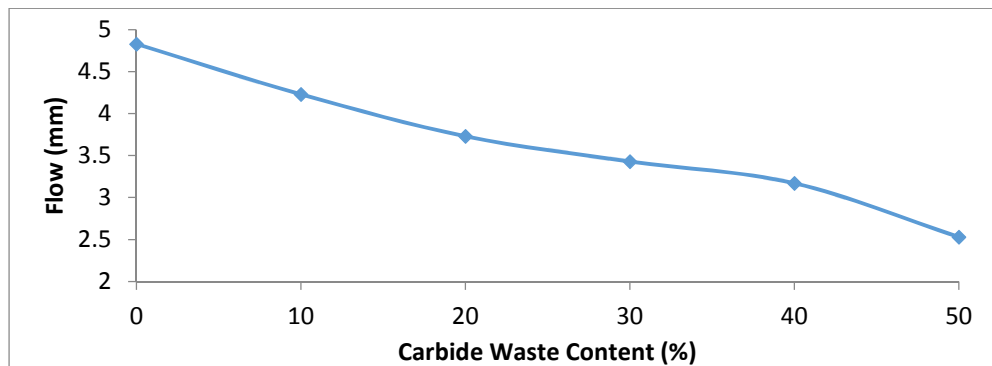


Figure 3: Variation of Flow with Carbide Waste Content



Bulk Density

The variation of unit weight with carbide waste content is shown in Figure 4. The behaviour of the bulk density is elastic in nature, as the carbide waste content is increasing; there was a corresponding increase in the values of bulk density. This trend was equally observed by (Nwaobakaba & Agwunwamba, 2014) when periwinkle shell ash was used as filler in HMA. The study shows similar pattern with (Aliyu, et al.,

2015) and (Taih, 2011). This may be due to different specific gravities of the aggregates and a much lower specific gravity of carbide waste and they will penetrate into the aggregate and a proper coating is formed over it. Bearing in mind that better mix design is achieved with higher specific gravity. The highest value of 2.46 g/cm^3 was obtained at 30% CW content and lower values of 2.43 and 2.4 g/cm^3 were recorded at 40 and 50% CW content.

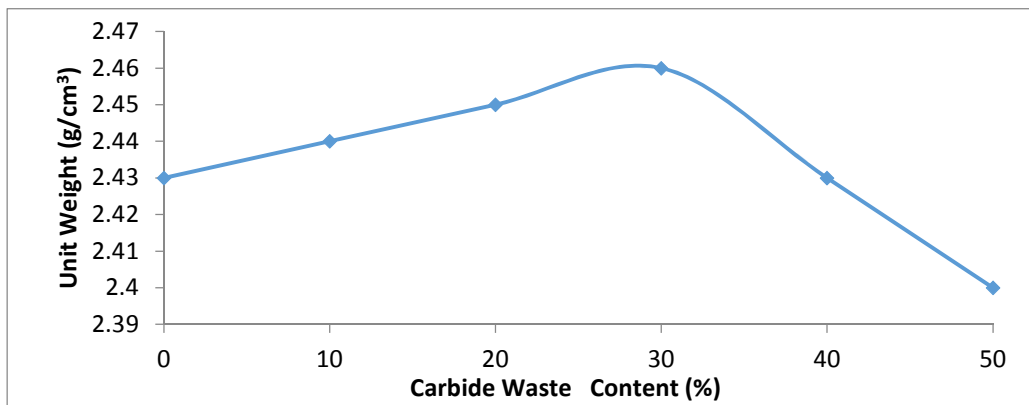


Figure 4: Variation of Unit Weight with Carbide Waste Content

Void in the Mineral Aggregate

The variation of void in the mineral aggregates (VMA) with CW content is shown

in Figure 5. It can be observed that VMA decreases by the addition of CW to the mixtures.

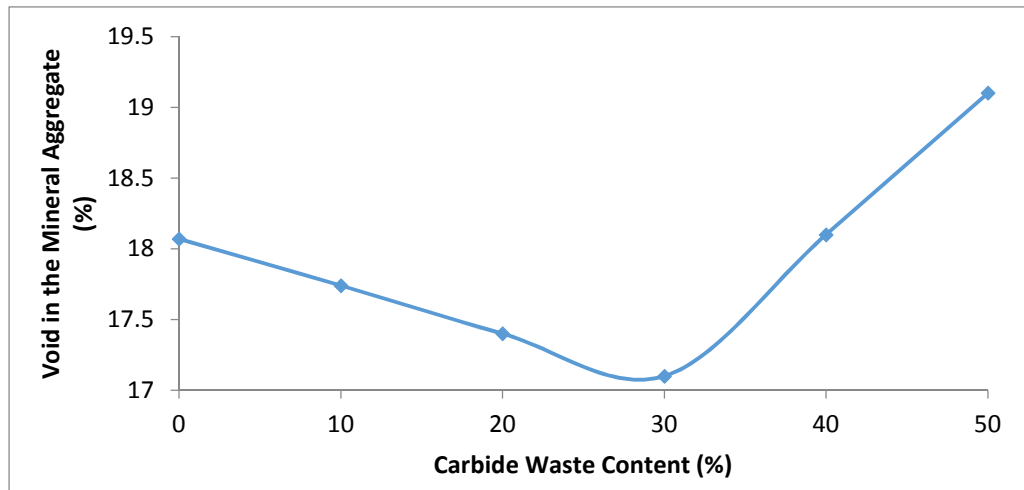


Figure 5: Variation of VMA with Carbide Waste Content



This trend was equally observed by (Nwaobakaba & Agwunwamba, 2014) when periwinkle shell ash was used as filler in HMA. This also showed a similar trend to that of (Noor, et al., 2011) as VMA decreased to 17.5% at 2.5% before showing an increased pattern. Modified mixture has a lower VMA compared to non-modified mixtures and thus positively influence the rutting resistance of these mixtures as indicated by (Awwad & Shbeeb, 2007). This may be due to the decrease of bulk specific gravity as indicated by equation for VMA. But all the results are within the specification range

which also supports the use of these additives.

Void Filled with Bitumen

The variation of void filled with bitumen (VFB) with carbide waste content is shown in Figure 6. VFB of the mixtures have an increase after adding carbide waste into the mixture. VFB which represents the volume of the effective bitumen content in the mixture is inversely related to air voids and hence as air voids decrease, the VFB increases. This trend was equally observed by (Okobia, 2016) evaluation of sawdust ash as mineral filler in asphalt mixture.

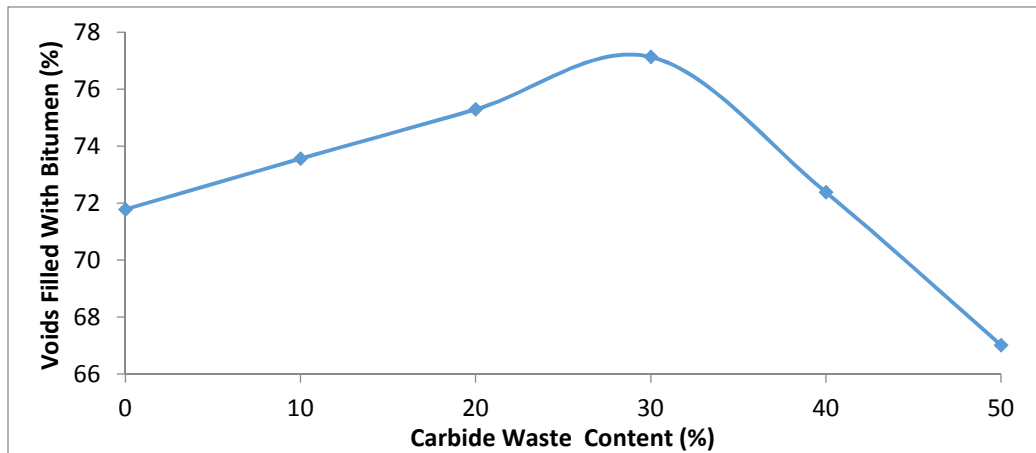


Figure 6: Variation of VFB with Carbide Waste Content

Percent Air Void

The variation of percent air void (Pa) with carbide waste content can be seen in Figure 7. It shows that as the carbide waste content increases air void decrease at some point it begins to rise. This trend was equally observed by (Nwaobakaba & Agwunwamba, 2014) when periwinkle shell ash was used as filler in HMA. This also follows a similar trend to the work of (Mohammad, 2012). This may be due to the networking effect of the carbide waste within the mix

(lower Gmb correlates to higher air voids). The mixture with carbide waste has lower air void compare to the control mixtures. However, the air voids of mixtures are located within the specification range of 3% to 5% (AASHTO T 312, 2009). Excessive air voids in the mixture would result in cracking due to insufficient bitumen binders to coat on the aggregates, while too low air void may induce more plastic flow (rutting) and bitumen bleeding.

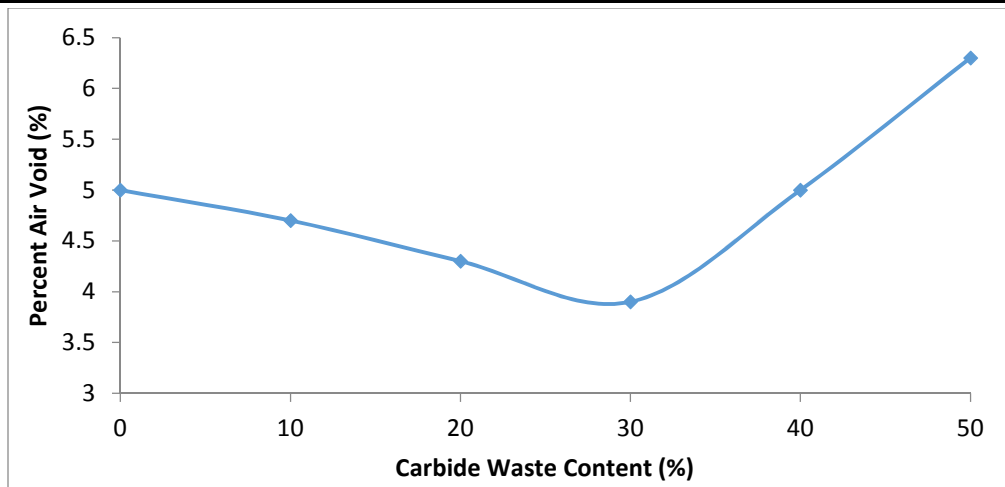


Figure 7: Variation of Percent air Void with Carbide Waste Content

Determination of Optimum Carbide Waste Content

The optimum carbide waste content (OCWC) was obtained from the following Figures 2, 4 and 7. Modifier content corresponding to the maximum stability, maximum unit weight and the average of the limits of percent air void were obtained to be 29%, 29% and 25% respectively. OCWC was then determined to

be 27.67% of the total mass of modified HMA from the average of the three modifier content obtained above. This OCWC was then used to deduce the values of stability, flow, unit weight, VMA, VFB and Pa at OCWC from Figures 2 – 7 and the values are all in conformity with the specified limits by (Federal Ministry of Works and Housing, 2016) for wearing course as shown in Table 4.

Table 4: Optimal conditions (parameters) of the modified HMA

Property	Optimum Carbide Waste Content (27.67%)	(Federal Ministry of Works and Housing, 2016)	Remarks
Optimum Stability (kN)	7.60	Not less than 3.5kN	Ok
Optimum Flow (mm)	3.43	2-4mm	Ok
Optimum Percent Air Void (%)	3.90	3-5%	Ok
Optimum Void Filled with Bitumen (%)	77.13	75-82%	Ok

CONCLUSION

The result of the experimental study shows that:

1. From the test result carried out on the constituent material, the test values all meet with the standard limit specification. Therefore, materials are suitable for use in HMA production.
2. The result of oxide composition for CW shows that it has high percentage of calcium oxide (CaO). For this reason, it can be used as an additive in HMA production.
3. While increasing the percentage of CW content for the replacement, the OCWC content was determined to be 27.67%



of the total mineral filler. Other properties such as stability, flow, VMA, VFB and Pa are all within the specification (Federal Ministry of Works and Housing, 2016).

4. From the result of Marshal Stability test carried out it shows that stability at optimum carbide waste content was obtained to be 7.6kN for the modified HMA which is higher than that of the control HMA that was obtained to be 6.9kN.

RECOMMENDATION

1. Based on results of tests, the partial replacement of filler with 27.67% carbide waste is recommended for use in HMA production.

REFERENCE

- AASHTO T 312, 2009. *Standard Method of Test for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor*. Washington DC.: American Association of State Highway and Transportation Officials.
- Ahlich, R., 1991. *The Effects of Natural Sands on Asphalt Concrete Engineering Properties*, 3909 Hall Ferry Road, Vicksburg, Mississippi: Department of the Army, Waterways Experiment Station, Corps of Engineers.
- Ahmedzadeh, P. & Sengoz, B., 2009. Evaluation of Steel Slag Coarse Aggregate in Hot Mix Asphalt Concrete. *Journal of Hazardous Materials*, 165(1-3), pp. 300-5.
- Al-Hadidy, A. & Yi-qiu, T., 2009. Effect of Polyethylene on Life of Flexible Pavement. *Construction and Building Materials*, 23(3), pp. 1456-1464.
- Aliyu, I. et al., 2015. *Polyethylene from Water Sachet as a Modifier in Hot Asphalt Mixture*, Zaria, Nigeria: Department of Civil Engineering, Ahmadu Bello University.
- ASTM D113, 2007. *Standard Test Method for Ductility of Bituminous Materials*. West Conshohocken, Philadelphia, PA: ASTM International.
- ASTM D2042, 2015. *Standard Test Method for Solubility of Bituminous Materials*. West Conshohocken, Philadelphia, PA: ASTM International.
- ASTM D2170, 2010. *Standard Test Method for Kinematic Viscosity of Bituminous Materials*. West Conshohocken, Philadelphia, PA: ASTM International.
- ASTM D36/D36M, 2009. *Standard Test Method for Softening Point of Bitumen, (ring-and-ball apparatus)*. West Conshohocken, Philadelphia, PA: ASTM International.
- ASTM D5, 2005. *Standard Test Method for Penetration of Bituminous Materials*. West Conshohocken, Philadelphia, PA: ASTM International.
- ASTM D6926-16, 2016. *Standard Practice for Preparation of Asphalt Mixture Specimens Using Marshall Apparatus*. West Conshohocken, Philadelphia, PA: American Society for Testing and Materials (ASTM) International.
- ASTM D92, 2005. *Standard test method for flash and fire points by Cleveland Open Cup Tester*. West Conshohocken, Philadelphia, PA: ASTM International.
- ASTM-D2726, 1992. *Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures*. Pennsylvania, USA: American Society for Testing and Material (ASTM).



- Awwad, M. & Shbeeb, L., 2007. The Use of Polyethylene in Hot Asphalt Mixtures. *American Journal of Applied Sciences*, 4(6), pp. 390-396.
- Bindu, C., 2012. *Influence of additives on the characteristics of Stone Matrix Asphalt*, Kochi, India: Cochin University of Science and Technology.
- Brennan, M. & O'Flaherty, G., 2002. Materials used in Road Pavements. In: C. O'Flaherty, et al. eds. *The Location, Design, Construction and Maintenance of Road Pavements*. Highways (Fourth Edition) ed. s.l.:Butterworth-Heinemann, pp. 118-162.
- BS 812 103.1, 1985. *Methods for Determination of Particle Size Distribution*. London, United Kingdom: British Standard Institution.
- BS 812 105.1, 1989. *Methods for Determination of Particle Shape, Flakiness Index of Coarse Aggregate*. London, United Kingdom: British Standard Institution.
- BS 812 105.2, 1990. *Methods for Determination of Particle Shape, Elongation Index of Coarse Aggregate*. London, United Kingdom: British Standard Institution.
- BS 812 110, 1990. *Methods for Determination of Aggregate Crushing Value (ACV)*. London, United Kingdom: British Standard Institution.
- BS 812 112, 1990. *Methods for Determination of Aggregate Impact Value (AIV)*. London, United Kingdom: British Standard Institution.
- BS 812 2, 1995. *Methods for Determination of Density, Water Absorption*. London, United Kingdom: British Standard Institution.
- BS EN 13043, 2003. *Aggregates for Bituminous Mixtures and Surface Treatments for Roads, Airfields and Other Trafficked Areas*. London, UK: British Standards Institution.
- Burak, S. & Ali, T., 2004. Use of Asphalt Roofing Shingle Waste in HMA. *Construction and Building Materials*, Volume 19, pp. 337-346.
- Chandh, K. & Akhila, S., 2016. A Laboratory Study on Effect of Plastic on Bitumen. *Int. J. Sci. Res.*, Volume 5, p. 1406-1409.
- Chen, W. & Richard-Liew, J., 2003. *The Civil Engineering Handbook*. Second Edition ed. s.l.:CRC Press, LLC.
- Chukwudebelu, J. A., Igwe, C. C., Taiwo, O. E. & Tojola, O. B., 2013. Recovery of Pure Slaked Lime from Carbide Sludge: Case Study of Lagos State, Nigeria. *African Journal of Environmental Science and Technology*, 7(6), pp. 490-495.
- Dunbabin, J., 1992. Potential Use of Constructed Wetlands for Treatment of Industrial Wastewater Containing Metals. *Science Total Environment Journal*, 111(2-3), pp. 151-168.
- Federal Ministry of Works and Housing, 2016. *General Specification for Roads and Bridge*. Lagos, Nigeria: Federal Highway Department (FMWH).
- Garber, N. J. & Hoel, L., 2009. *Traffic and Highway Engineering*. Fourth ed. Toronto Canada: University of Virginia, Cengage Learning.
- Geber, R. & Gomze, L. A., 2010. Characterization of Mineral Materials as Asphalt Fillers. *Materials Science Forum*, Volume 659, pp. 471-476.
- Grabowski, W. & Wilanowicz, J., 2008. The Structure of Mineral Filler and their



- Stiffening Properties in Filler-Bitumen Mastics. *Article in Materials and Structure*, 41(44), p. 793–804.
- Huang, B., Shu, X. & Chen, X., 2007. Effects of Mineral Fillers on Hot-Mix Asphalt Laboratory-Measured Properties. *International Journal of Pavement Engineering*, 8(1).
- Hunter, E. & Ksaibati, K., 2002. *Evaluating Moisture Susceptibility of Asphalt Mixes*, Laramie, Wyoming: Department of Civil and Architectural Engineering, University of Wyoming.
- Karlsson, R. & Isacson, U., 2006. Material-Related Aspects of Asphalt Recycling-State-of-the-Art. *Journal Material Civ. Eng.*, Volume 18, pp. 81-92.
- Khan, I. & Gundaliya, P., 2012. Utilization of Waste Polyethylene Materials in Bituminous Concrete Mix for Improved Performance of Flexible Pavements. *Indian journal of Applied Research (IJAR)*, 1(XII), pp. 85-86.
- Mageswari, M. & Vidivelli, B., 2009. The Use of Saw Dust Ash as Fine Aggregates Replacement in Concrete. *Journal of Environmental Research and Development*, 3(3), pp. 720-726.
- Manasseh, J., 2009. Effect of Carbide Waste on the Properties of Rice Husk Ash Concrete. *Global Journal of Engineering Research*, 8(1&2), pp. 57-65.
- Melotti, R. et al., 2013. A Preliminary Investigation into the Physical and Chemical Properties of Biomass Ashes used as Aggregate Fillers for Bituminous Mixtures. *Waste Management*, Volume 33, pp. 1906-1917.
- Menaria, Y. & Sankhla, R., 2015. Use of Waste Plastic in Flexible Pavements-Green Roads. *Open Journal of Civil Engineering*, Volume 5, pp. 299-311.
- Mohammad, A., 2012. *Use of Waste Plastic Blended Bitumen for Road Construction and Maintenance*, Bangladesh: Master of Engineering thesis, Bangladesh University of Engineering and Technology.
- Mohan, H. & Obaid, H., 2014. Laboratory Examination for the Effect of Adding Hydrated Lime on the Moisture Damage Resistance of Asphalt Concrete Mixtures. *Kufa Journal of Engineering*, 5(2), pp. 1-12.
- Mubaraki, M., Ali, S., Ismail, A. & Yusoff, N., 2016. Rheological of Asphalt Cement Modified with ASA Polymer and Al₂O₃ Nanoparticles. *Elsevier Journal of Advances in Transportation Geotechnics*, Volume 143, pp. 1276-1284.
- Murana, A. & Sani, L., 2015. Partial Replacement of Cement with Bagasse Ash in Hot Mix Asphalt. *Nigerian Journal of Technology (NIJOTECH)*, 34(4), pp. 699-704.
- NCHRP Project 9-45, 2010. *Test Methods and Specification Criteria for Mineral Filler Used in HMA*, s.l.: National Cooperative for Highway Research Program Project.
- Noor, H. Z., Kamaruddin, I., Napiah, M. & Tan, I. M., 2011. Rheological Properties of Polyethylene and Polypropylene Modified Bitumen. *International Journal of Civil and Environmental Engineering*, 3(2), pp. 96-100.
- Nwaobakaba, C. & Agwunwamba, J., 2014. Influence of Periwinkle Shell Ash as a Filler in Hot Mix Asphalt. *International Journal of Science and Research (IJSR)*, 3(7).
- Osuya, D. & Mohammed, H., 2017. Evaluation of Sawdust Ash as a Partial Replacement for Mineral



- Filler in Asphaltic Concrete. *Ife Journal of Science*, 19(2), pp. 431-440.
- Pasandín, R. & Pérez, I., 2015. The Influence of the Mineral Filler on the Adhesion between Aggregates and Bitumen. *International Journal of Adhesion and Adhesives*, Volume 58, pp. 53-58.
- Paulsen, G., Stroup-Gardiner, M. & Jon Epps., 1987. *Recycling Waste Roofing Material in Asphalt Paving Mixtures*. Washington, D.C.: Transportation Research Record 1115, TRB, National Research Council.
- Rafi, M., Qadir, A. & Siddiqui, S., 2011. Experimental Testing of Hot Mix Asphalt Mixture Made of Recycled Aggregates. *Waste Manag. Res.*, Volume 29, p. 1316–1326.
- Recasens, R. M., Martinez, A., Jimenez, F. P. & Bianchetto, H., 2005. Effect of Filler on the Aging potential of Asphalt Mixtures. *Transportation Research Record: Journal of the Transportation Research Board*, Volume 1901, pp. 10-17.
- Sabina, K. et al., 2009. Performance Evaluation of Waste Plastic/Polymers Modified Bituminous Concrete Mixes. *Journal of Scientific & Industrial Research*, Volume 68, pp. 975-979.
- Selim, A., 1997. *Cost Effective/User Friendly Anti-Stripping Additives in HMA*, s.l.: Quartzite Quotes, Quartzite Rock Association.
- Taih, S., 2011. The Effect of Additives in Hot Asphalt Mixtures. *Journal of Engineering and Development*, 15(3), pp. 131-150.
- Widyatmoko, I., 2008. Mechanistic-Empirical Mixture Design for Hot Mix Asphalt Pavement Recycling. *Construction and Building Materials*, Volume 22, pp. 77-87.
- World Bank, 2003. *Thailand Environmental Monitor*, Thailand: A Joint Publication of the Pollution Control Department, Royal Thai Government. The World Bank, US Asia Environmental Partnership.
- Wu, S., Yang, W. & Xue, Y., 2003. *Preparation and Properties of Glass-asphalt Concrete: Key Laboratory for Silicate Materials Science and Engineering of Ministry of Education*, Wuhan 430070, P.R China: Wuhan University of Technology,.
- Yasreem, S., Madzlan, N. & Ibrahim, K., 2011. The Effect of Fine Aggregate Properties on the Fatigue Behaviour of the Conventional and Polymer Modified Bituminous Mixtures using Two Types of Sand as Fine Aggregate. *Journal of World Academy of Science, Engineer and Technology*, Volume 5, pp. 417-422.