JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Investigation on the Effect of Recycle Asphalt Pavement, Crumb Rubber Modified Bitumen and Cow Dung Ash (CDA)/Ordinary Portland Cement (OPC) Blend As Filler in Asphalt Production

Adamu Aminu Salihu[1], Mohammed Mustapha Musa[2], Bilkisu Danjuma[3]
[1,3]Department of Civil Engineering Technology, Nuhu Bamalli Polytechnic, Zaria
[2]Department of Civil Engineering, Ahmadu Bello University, Zaria

Corresponding author: adalgefans@gmail.com (+2348035309151)

Abstract

This paper presents the possibility of utilizing reclaimed asphalt, used automobile tires and cow dung ash, which are mostly regarded as waste. These materials could be used in construction of new roads and for roads rehabilitation. Reclaimed Asphalt Pavement (RAP) was used to replaced Virgin aggregate, Crumb Rubber (CR) from waste automobile tires as modifier for bitumen and a blend of Ordinary Portland cement OPC and Cow Dung Ash as filler. 30% Reclaimed asphalt of total aggregate, 15% Crumb Rubber of total binder content, and a blend of 25% Cow Dung Ash/75% Ordinary Portland Cement of total mix, and 5.2% Crumb Rubber Modified Bitumen content were recommended for optimum performance. Loss of marshal stability was investigated on mix with the recommended optimum CRMB. The mix revealed good performance with only about 17% loss of stability after 24 hours of immersion in hot water bath, as against about 24% marshal stability lost reported in previous studies for conventional Hot Mixed Asphalt (HMA).

Keywords: Cow Dung Ash, Reclaimed Asphalt, Crumb Rubber, Ordinary Portland Cement, Green Hot Mix Asphalt

1.0 Introduction

1.1 Preamble

Efforts are being made worldwide in the area of recycling waste material from road maintenance and rehabilitation. Removed deteriorated asphalt pavement is now being reclaimed and recycled, especially in the developed countries (Sadeeq, et al., 2014). The essence of recycling of waste material is to reduce the cost of construction as well as to help conserve the environment. This study investigated the effect of three waste materials for the production of Hot Mix Asphalt (HMA) in roads construction. The materials are, Reclaimed Asphalt (RA), Crumb Rubber (CR) and Cow Dung Ash

(CDA). Possible utilization of these materials will contribute to the proper management of solid waste and sustainable roads construction (Salihu et al., 2021)

1.2 Reclaimed Asphalt Pavement (RAP)

RAP is generated when asphalt pavement is removed for the purpose of reconstruction, resurfacing or obtaining access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated with bitumen (Sadeeq et al., 2014). In Nigeria, this material is usually dumped by the roads side as waste. This results to environmental nuisance; polluting roads side and usually inhibiting side drains for water. Previous studies revealed that, reclaimed asphalt can be re-used for roads construction (e.g. Joel, 2010; Vicroads, 2011; Abiola, et al., 2014; Delfosse, et al., 2014). Since the process of production of virgin aggregate is expensive and environmentally unsustainable, construction and rehabilitation of roads using reclaimed asphalt is expected to be more economical and environmentally sustainable (Kennedy et al., 1998; Salman, 1998).

1.3 Crumb Rubber (CR)

The growing number of cars produced in the world is enormous. It was established previously that about 1.4 billion tires are sold worldwide each year (Mousavi, et al., 2012; Davide, 2013). In Nigeria, alone, approximately 15 million scrap tires are currently in existence (Aisien, et al., 2011). The management of waste-tire rubber is very difficult, because it is generally non-biodegradable even after long-period of landfill treatment (Guneyisi, et al., 2004). One important area for the possible utilization of waste tire is on highway construction and rehabilitation (Teleb, et al, 2008). Crumb Rubber is a materially that are used as partial replacement for bituminous binder. It is obtained after shredding waste tires to smaller sizes. Crumb rubber is added to bituminous binder in a specified proportion to produce what is known as Crumb Rubber Modified Binder (CRMB). CRMB was extensively used in advanced countries for a very long time (Epps, 1994; Heitzman, 1992).

1.4 Cow Dung Ash (CDA)

Due to much construction activities going on around the world, the demand for Ordinary Portland Cement (OPC) had risen continuously. This is in addition to heavy CO_2 emission during cement manufacturing process. CO_2 is the major contributor to ozone layer depletion, hence global warming. Identification of more sustainable cement replacement materials in Hot mixed asphalt would be a welcomed development. The possible utilization of Cow dung ash as cement replacement is investigated in this study. Cow Dung ash is obtained by control burning of the Remnant of Cow defecation. This ash has high specific surface area and pozzolanic in nature (Tsado, et al, 2014).

2.0 Materials and Methods

2.1 Materials Used in the Investigation

Materials used in this study were 60/70 penetration grade bitumen (virgin binder), shredded automobile tire (crumb rubber), Fresh Coarse Aggregate, Reclaimed Asphalt, Ordinary Portland Cement and Cow Dung Ash. The Reclaimed Asphalt was obtained from the site of an ongoing roads rehabilitation project along Kaduna-Kano Road (37 km from Kaduna) in Kaduna State, Nigeria. The fresh aggregate, was obtained from a stone quarry belonging to a Nigeria-based construction company (Mothercat Limited) at Katsina. Ordinary Portland Cement (OPC), produced by the BUA Cement Company of Nigeria, was used in the mix. The Cow Dung was obtained from a farm at Dutsen Abba town, Zaria Local Government area of Kaduna State, Nigeria. The Crumb

Rubber was produced from waste car tires, obtained from local vulcanizer at Zaria City, Kaduna State, Nigeria.

2.2 Experimental Methodology

The first step in the production of Hot mixed asphalt is the appropriate mix design strategy. The objective of the mix design is to determine the best blend through several trial mixes. Marshal Mix design method was adopted (ASTM D1559). Investigation was conducted on Asphalt Briquettes, prepared by using Reclaimed Asphalt/Fresh Aggregate, Crumb Rubber/Bitumen binder and Cow Dung Ash/Ordinary Portland Cement blend as filler.

2.2.1 Particle Size Distribution of the Aggregate

Particle size distribution tests were carried out on the Reclaimed Asphalt (RA) and the fresh virgin aggregate, in accordance with the general Specifications for Roads and Bridges, Federal Ministry of Works and Housing, Nigeria (FMWH, 1997). The results obtained were presented in Table 1.0, placed together with the gradation limits of the FMWH (1997). It is clear from the result that both the Reclaimed Asphalt (RAP) and the virgin aggregate, failed to fit within the envelope of the FMWH (1997). Based on a separate recent investigation (Sadeeq, et al., 2014), 30% RAP and 70% fresh aggregate proportions were found to satisfied the FMWH (1997) requirement. This was therefore adopted.

2.2.2 Partial Replacement of OPC with CDA

Ordinary Portland Cement (OPC), stone dust, slag dust, hydrated lime and fly ash are the commonly used filler material in asphalt mixes. These filler materials are not readily available at affordable cost. Consequently, research efforts have gone into waste materials in the construction industry exploring alternative materials at affordable cost. Such materials include industrial, domestic and agricultural waste (Abarshi, 1988). The mineral fillers used in this study are Ordinary Portland Cement (OPC) and Cow Dung Ash (CDA). Mineral filler in Hot Mixed Asphalt (HMA) consists of very fine inert mineral matter that is added to the hot mix asphalt to improve its density and strength. Filler is generally selected on the basis of its ability to increase the stiffness of the binder or improve adhesion between the binders and aggregate (Overseas Roads Note 19, 2002). Typical mineral filler completely passes a 0.060mm (No. 30) sieve with at least 65 percent of the particles passing the 0.075mm (No. 200) sieve. In this study, 10% mineral filler of total mix was adopted based on the previous studies (Sadeeq et al, 2014). Five trial blend mixes with the dosages of 0%CDA/100%OPC, 25%CDA/75%OPC, 50%CDA/50%OPC, 75%CDA/25%OPC and 100%CDA/0%OPC were subjected to various laboratory tests. The chemical composition of OPC and CDA are presented in Table 2.0.

Table 1.0: Particle Size Distribution for RAP and Fresh aggregate Compared with FMWH Specification

Sieve Size (mm)	Percentage Passing		FMWH Specification (FMWH, 1997) (%)
	RAP (%)	Fresh Aggregate (%)	
25	-	100	-
19.00	100	99.1	100
12.50	84.2	82.8	85 – 100
9.50	70.0	72.7	75 – 92
6.30	47.0	58.6	65 – 82
2.36	21.5	42.1	50 – 65
1.18	12.8	34.1	36 – 51
0.60	7.7	27.8	26 – 40
0.30	3.9	19.9	18 – 30
0.15	1.8	9.9	13 – 24
0.075	0.6	6.0	7 – 14

Table 2.0 Typical Chemical composition of OPC and CDA

Chemical Constituents	Composition in OPC	Composition in CDA (%)
SiO_2	18.78	79.22
Al_2O_3	2.87	5.62
Fe_2O_3	4.03	2.98
Cao	54.66	3.71
MgO	3.46	1.88
SO_3	1.13	0.19
IR	9.69	1.65

LOI	4.83	4.25

(Sources: Thej Kumar, et al, 2015)

2.2.3 Crumb Rubber Modified Binder (CRMB)

60/70 penetration grade bitumen was used in this study as the virgin binder. This material is widely used in Nigeria for the production of Hot Mix Asphalt (HMA). Based on a recent research (Salihu, et al., 2021), 15% Crumb Rubber of total binder content was found to be sufficient in the Asphalt-Rubber mixture. Therefore, this proportion was considered appropriate and adopted for the investigation.

Four laboratory tests were conducted to investigate the physical properties of Crumb Rubber Modified Bitumen and is presented in Table 2. The tests include penetration grade test, ductility test, softening point test and specific gravity test.

Table 3.0 Physical Properties of the Crumb Rubber Modified Bitumen

Property	Test Method	Result Obtained	Standard Value (ASTM)
Penetration at 25ºC	ASTM D5	65	60-70
Ductility, cm	ASTM D113	108	Min 100
Softening Point, ºC	ASTM D36	62.3	4.52
Specific Gravity	ASTM D70	1.04	1.03-1.06

2.2.4 The Marshal Test Preparation

The Marshall Mix design is used to determine the optimum bitumen content of dense-graded AC with 25.4 mm maximum nominal aggregate size. A total of 75 marshal briquettes were prepared for the test and conducted in accordance with ASTM D 6926-04 (2010). The material for the briquettes includes Reclaimed Asphalt/Virgin Aggregate, Crumb Rubber Modified Bitumen and Ordinary Portland Cement OPC/Cow Dung Ash CDA. The aggregate, consist of 30% Reclaimed Asphalt Pavement and 70% Virgin aggregate (Sadeeq et al., 2014; Salihu et al., 2021). The Crumb Rubber Modified Bitumen content was varied from 4.0 to 6.0% at 0.5% interval. 10% filler of total mix was adopted, with Cow Dung Ash replacing Cement in the proportion of 0%CDA/100%OPC, 25%CDA/75%OPC, 50%CDA/50%OPC, 75%CDA/25%OPC and 100%CDA/0%OPC of the total mix.

3.0 Discussion

3.1 Marshal Stability Test Results

The Marshal test plots were presented from Figure 1.0 to 6.0 respectively. For each of the five mixes, test samples were prepared for five different bitumen content, 4.5%, 5.0%, 5.5%, 6.0% and 6.5%, with three samples for each fraction. Fig, 1.0 shows the plots of the marshal stability against bitumen content. The stability values increase with increasing bitumen content up to maximum value, then decreases with increasing bitumen content. The maximum values of the stability are 9.0, 8.4, 7.5, 6.7 and 6.7kN for 0%CDA/100%OPC, 25%CDA/75%OPC, 50%CDA/50%OPC, 75%CDA/25%OPC, 100%CDA/0%OPC mix respectively. The specification limit for marshal stability is that it should not be less than 5kN. This implied that all the mixes satisfied the minimum standard requirements for stability.

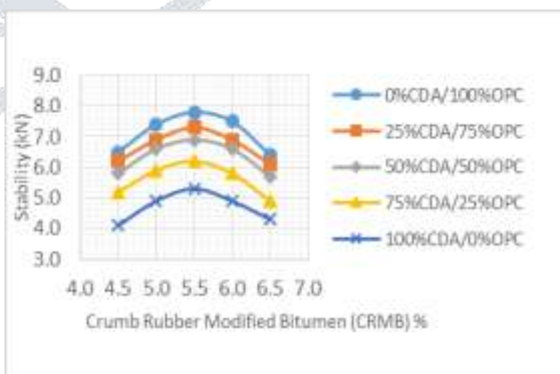

Fig. 1.0 Stabilty against binder content

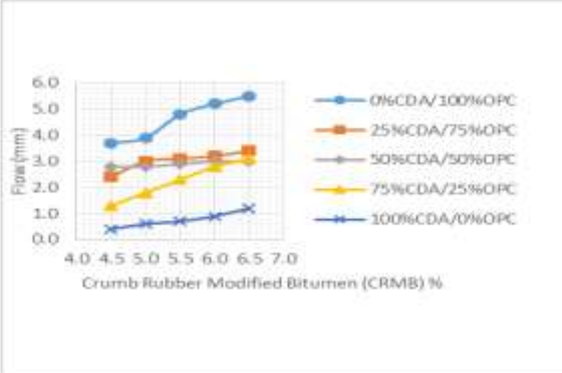

Fig. 2.0 Flow against binder content

Fig. 2.0 show the plots of flow against bitumen content. The results indicated that, increasing the bitumen content leads to linear increase in the flow values. The minimum specication limits for flow is 2.0. The use of Asphalt with flow value greater than 2.0 may result to rutting. This implied that the optimum value for CDA is 5%. This is because, the mixes with 7% and 10% CDA lead to flow values that are not acceptable.

The relationship between compacted density and bitumen content is presented in Fig. 9.0. It was found that as the CDA content of the filler increases, the value of the compacted density decreases. This may be attributed to the higher air voids created by the substittion of Ordinary Portland Cement with Cow Dung Ash.

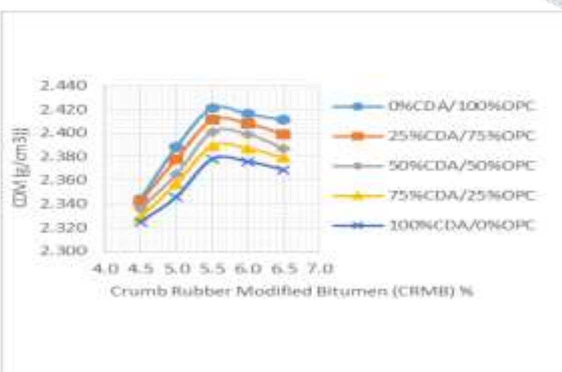

Fig. 3.0 CDM against binder content

Fig. 10.0 shows that the void in mix increases with increasing bitumen content. Likewise increase in CDA result to increase in the percentage air void. This is in aggreement with the earlier observation made from the CDM plots in Fig 9.0, confirming that the addition of CDA as partial replacement for OPC as mineral filler result to increased in air void. However, all point were above the lower limit of 3% air void in mix specified in Asphalt Institute (Asphalt Institute, 1984).

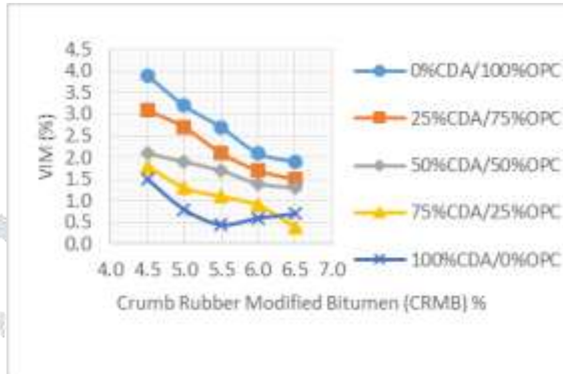

Fig. 4.0 VIM against binder content

Voids in mineral aggregates is the volume of intergranular void space between the aggregate particles of a compacted paving mixture. It include the air voids, and the volume of asphalt not absorbed into the aggregate. The plots of the VMA against bitumen content are presented in Fig. 11.0. It is observed from the plots, that for all the consdered mixes, the VMA increase with increasing bitumen content. The control specimen has the least value of VMA. The increase in the VMA as a result of the addition of CDA may be attributed to the increased absorption of bitumenn content by the filler.

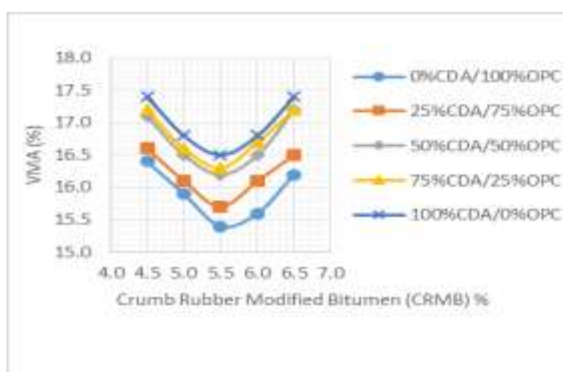

Fig. 5.0 VMA against binder content

The relationship between VFB and bitumen content is presented in Fig. 12.0. It is observed from the plots that VFB increases with increasing bitumen content. The values of the VFB for all the mixex containing CDA are lower than the control mix (100% OPC), implying that the addition of CDA reduces VFB values.

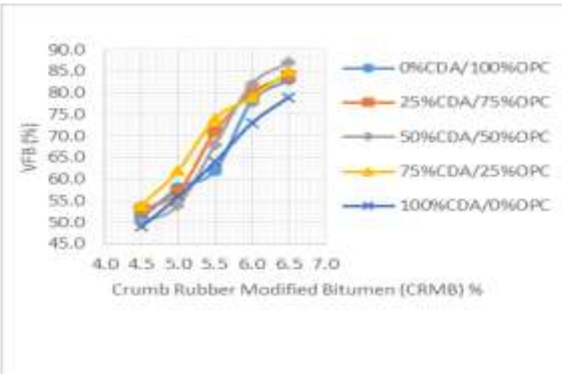

Fig. 6.0 VFB against binder content

3.3 Optimum Crumb Rubber Modified Bitumen Binder (Asphalt-rubber)

From the graph of stability, CDM and VFB above, the following data were obtained

CRMB at maximum stability = 5.0%

CRMB at max unit weight = 5.0%

CRMB at 4% Air Void = 5.5%

Therefore,

Optimum CRMB content = (5+5.5+5)/3 = 5.2%

3.4 Indirect Tensile Strength of HMA

The indirect tensile strength test was developed to determine the tensile properties of cylindrical concrete and asphalt concrete specimen through the application of a compression load along a diametrical plane through two opposite loading heads. This type of loading produces a relatively uniform stress acting perpendicularly to the applied load plane, causing the specimen to fail by splitting along the loaded plane (Sadeeq et al., 2014). The essence of indirect tensile strength is to evaluate the maximum resistance of pavement to cracking. The test was subjected to a temperature of 30^{0}C. The adopted design mix with 25%CDA/75%OPC has the highest tensile strength of 1112 N/mm2, while the control mix with 0%CDA/100%OPC has the lower tensile strength of 1074 N/mm2. The result implied that the 25%CDA/75%OPC blend has more resistance to cracking than that of control with 100%OPC

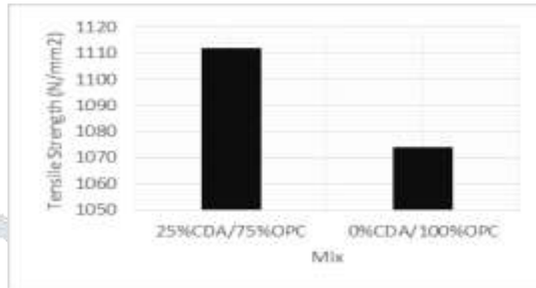

Fig 7. Result of Indirect Tensile Strength Test

3.5 Performance of the Prepared Hot Mixed asphalt

The performance of the HMA was investigated based on the loss of Marshal Stability. Ten Asphalt Briquettes samples were prepared using 30% Reclaimed Asphalt Pavement (RAP), 70% virgin aggregate, 25%CDA/75%OPC blend as a filler, 5.2% optimum Crumb Rubber Modified Binder; containing 15% Crumb Rubber (CR). All the ten samples were places in a water bath and maintained at 60^{0}C. Five of the briquette samples were subjected to Marshal Stability test after 30 minutes of immersion based on the ASTM D1559 specification. The average marshal stability of the samples was computed as 7.52kN. The remaining five samples were tested after twenty-four hours of immersion, and the average marshal stability of 6.25kN was obtained, representing 17% loss of stability. Comparing this result with what was reported in Taleb, et al. (2008), where an average of 24% loss of marshal stability was obtained for Marshal Briquettes when only conventional aggregate, bitumen binder and ordinary Portland cement where used. The reason for the low loss of marshal stability for the Green HMA is likely due to the following reasons.

a. Presence of hardened asphalt in the Reclaimed Asphalt Pavement (RAP),

b. Modification of the bitumen binder with Crumb rubber (CR).

These resulted to increase in the binder viscosity that lead the mix to be less sensitive to the effect of hot water as a result of the 24 hours immersion. In conclusion therefore, it is clear that the performance of the Green HMA is quite encouraging.

4.0 Conclusion

This paper presents laboratory-based study that was conducted to investigate the effect use of Reconstituted Reclaimed Asphaltic Concrete mix design with Cow Dung Ash (CDA) modified Ordinary Portland Cement (OPC) as filler and Crumb Rubber Modified Bitumen (CRMB) as binder in the production of Hot Mixed Asphalt (HMA), for green road construction and rehabilitation and maintenance. The following values are therefore recommended.

1. 30% Reclaimed asphalt as partial replacement for virgin aggreagate
2. 25%CDA/75%OPC blend of the total mix as filler.
3. The computed Optimum Crumb Rubber Modified Bitumen (CRMB) was 5.2% with 15% Crumb Rubber.

5.0 References

Abarshi, M. D. (1988). "Use of Billet Scales as Filler in Asphaltic Concrete" Unpublished MSc Thesis, Department of Civil Engineering, Ahmadu Bello University, Zaria.

Abiola, O. S., Mlango, S. M., Mdambuki, J. M., and Kupolati, W. K., "Use of Recycled Asphalt Materials for Sustainable Construction and Rehabilitation of Roads." Proceedings of the 2014 International Conference on Biological, Civil and Environmental Engineering (BCEE-2014), March 17th -18th. 2014. Dubai (UAE).

Aisien, F. A., Hymore, F. K., Ebeweele, R. O., (2011). "Application of Ground Scrap Tire Rubbers in Asphalt Concrete Pavement," Indian Journal of Engineering and Material Science. Vol, 13, pp 333-338.

Asphalt Institute, (1984). Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types, Manual Series No. 2, (MS-2).

ASTM D5 (2005). Standard Test Method for Penetration of Bituminous Materials. ASTM International, West Conshohocken, PA.

ASTM D36/D36M (2009). Standard Test Method for Softening Point of Bitumen, (ring-and-ball apparatus). ASTM International, West Conshohocken, PA.

ASTM-D1559. American Society for Testing and Materials. Annual Book of ASTM Standards, Section 4, Vol. 4.03. Philadelphia, PA.

ASTM C 136. (2005). Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate. American Society for Testing and Material. Philadelphia, PA.

ASTM D60 (2004). Standard Test Method for Elastic Recovery of Bituminous Materials by Ductilometer. ASTM International, West Conshohocken, PA.

ASTM D113 (2007). Standard Test Method for Ductility of Bituminous Materials. ASTM International, West Conshohocken, PA.

Austroads (1997). Specification Framework for Polymer Modified Binders. APRG19, Australian Road Research Board, Vermont South, Victoria.

Davide L. P. (2013). “Recycled Tire Rubber Modified Bitumen for Road Asphalt Mixture: A Literature Review. Construction and Building Materials. 49, 863-891.

Delfosse, F., Drouadaine, L., Faucan, D. S., Largeaud, S., (2014). “Performance Control of Bituminous Mixtures with a high RAP Content,” Transport Research Arena, Paris, TRA.

Epps, J. (1994) “Use of Recycled Rubber Tires in Highways – A Synthesis of Highway Practice,” NCHRP Synthesis 198, National Cooperative Highway Research Program, TRB, National Research Council, Washington, D.C.

FAO Statiscal Database (2002). http://apps.fao.org. Retrieved on 10th January, 2015

Felix, A. A., Andrew, N. A., Adetayo, R. A. (2013). “Application of Recycled Rubber from Scrap Tire in the Removal of Phenol from Aqueous Solution,” The Pacific Journal of Science and Technology, 6(2)2013, 330-341.

FMWH (1997). General Specifications for Roads and Bridges. Volume II, Federal Ministry of Works and Housing, Nigeria.

Guneyisi, E., Gesoglu, M., and Ozturan, T. (2004). “Properties of rubberized concretes containing silica fume.” Journal of Cement and Concrete Research, Vol. 34, 2004, pp. 2309-2317.

Heitzman, M. (1992) “State of the Practice – Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier,” Research Report No. FHWA-SA-92-022, Federal Highway Administration, Washington, D.C., May.

Joel, R. M., Hugo, M. R. D. S., Silva, M. G. J., Liliana, P. F. A, Sara, R. M. F. (2010). “Pushing the Asphalt Recycling Technology to the Limit,” International Journal of Pavement Research Technology. 6(2), 109-116.

Kennedy, T. W., Tam, W. and Solaimanian, M. (1998). “Optimizing Use of Reclaimed Asphalt Pavement with Superpave System” Journal of the Association of Asphjalt Paving Technologies. 67, pp. 311-333.

Mousavi, H. Z., Hosseynaefar, A., Jaheed, V., Dehghani, S. A. (2012). “Removal of Lead from Aqueous Solution Using Waste Tire Rubber Ash as Adsorbent,” Brazillian Journal of Chemical Engineering, 27(1), pp 79-87.

NIDEP, “Recycled Asphalt Pavement Milling (RAP) Reuse Guidance,” March, 2013 (version 1.0). www.nj.gov/dep/dshw/rrtp/asphaltguidance.pdf. (Nov. 10, 2014).

Omatola, K. M., and Onojah, A. D. (2009) ‘Elemental analysis of rice husk ash using X – ray fluorescence technique.’ *International Journal of Physical Sciences.* Vol. 4 (4), pp. 189-193

Overseas Road Note 19 (2002). “A Guide to the Design of Hot Mix Asphalt in Tropical and Sub-tropical Countries, 2002.

Rodrigues, C. S. Ghavami, K.,m Stroeven, P. (2006) “Porosity and Water {Permeability of Rice Husk Ash Blended Cement Composites Reinforced with Bambou”. Journal of Material Scuence. New York. 41(21), 6925-6937.

Sadeeq J. A., Kaura J. M., Ochepo J. and Aliyu I. (2014) Recycling of Reclaimed Asphalt Pavement (RAP) with Riche Husk Ash (CDA)/Ordinary Portland Cement (OPC) Blend as Filler. Jordan Journal of Civil Engineering. Jordan University of Science and

Technology. 18(4), 473-481.

Salman, A. B. (1998). "Mechanistic Empirical Pavement Design Procedure for Geo-Synthetically Flexible Pavements" Unpublished PhD Dissertation. Virginia Polytechnic Institute and State University.

Taleb A, Ibrahim A., Omar A. and Husam A. Performance of Asphalt Mixes Containing RAP. Jordan Journal of Civil Engineering. 2(3), 218-227.

The Asphalt Institute. (2003). Performance graded asphalt binder specification and testing,SP-1.Lexington(KY).

Tsado T. Y., Yewa M., Yeman S., and Yewa F. (2014). "Comparative Analysis of Properties of some Artificial Pozzolana in Concrete Production'. International journal of Engineering and technology, IJET. Centre of Parofessional research publications. 4(5), 251-255.

Vicroads, "Use of Recycled Materials for Road Construction," Technical Note 107, September, 2011, Victoria.