UTILIZATION OF SHREDDED WASTE PLASTIC BAGS AND WASTE SUGAR CANE ASH IN BITUMEN AND BITUMINOUS MIX FOR IMPROVED ROAD PERFORMANCE

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Abstract
With the expansion of road network in Kenya, care should be taken to construct road pavement that will last their designed life if not to outlive it. Bitumen is a major component in road construction material providing its ability to sustain traffic road. Bituminous paved road fail or get damaged if it is no longer able to sustain traffic or other environmental loading. They fail through poor road maintenance, pot-hole development, overloading among other factors. Convectional bitumen can be modified using waste sugar cane ash (WSCA) and shredded waste plastic bags (SWPB) to improve its mechanical properties as well as solving the disposal issue.The main objective of this study is to understand the fundamental behaviour of modified bitumen, evaluate its mechanical property, and determine optimum mix proportion of the waste to modify bitumen.The modified bitumen and aggregates used in this study were taken through the standard tests to ascertain their suitability in road construction. Marshall Stability test was conducted to determine bitumen optimum content, stability and flow on the modeled briquette. The results gotten from the modified bitumen and aggregates were within the recommended standard specifications. The optimum bitumen content is 5.4% and a stability of 12600N. Penetration index (ranges 61-68) and softening point (51.3 – 57.8). The aggregates strength (20.6%), water absorption (0.69%) and weathering (2%).The modified bitumen has the ability to withstand high temperature, heavy load and this will minimize the development of rutting and cracking of the wearing course reducing seepage through the pavement surface. It is recommended that the convectional bitumen commonly used in Kenya 80/100 should be modified using WSCA and SWPB to make it a better binder for road construction.

Key words: Convectional Bitumen, Modified bitumen, shredded waste plastic bags, waste sugar cane ash, mixed design, road design life

1.0 Introduction

A road pavement is composed of stable layers constructed on earth mass to distribute load of vehicles over a wide area of the underlying sub grade soil and permitting deformation with elastic on allowable range and to provide adequate surface (Gupta *et al.*, 2010). They constitute subgrade, sub base, base course and the wearing course. All the layers should be properly designed and constructed to prolong the life of a pavement.

A number of the roads in most countries of the world are surfaced using hot bituminous mixtures which is a mixture of aggregate materials bound together with bitumen. Different grades of bitumen like 30/40, 60/70 and 80/100 among other penetration indices are available on the basis of their penetration values and are used depending on the climatic conditions of an area. However road conditions are not static because of continuing development in vehicles and tyres design often increasing the stresses that are applied on them. From observation and literature review, there is an increase in the vehicles volume in our roads that may sometimes increase load applied by the traffic sometimes beyond limits of the empirical data on which designs are based (John Hodges, 2002).

Hot bituminous mixture is a combination of aggregates and bitumen. The aggregates act as the skeleton while the bitumen provides the muscles to the skeleton to hold together. The skeleton must carry the weight while the muscles must be strong enough to hold the skeleton in place but still be flexible enough; this is known as mix design. Mix design is the proportion of the aggregates to be used and the amount of bitumen to be added. These proportions are established by testing various combinations in the laboratory until one is found that meets the entire requirement. The bitumen must be liquid enough to mix and coat aggregates at a higher and reasonable temperature but solid enough at normal temperature to act as the glue for the pavement.

Sampling and testing are required to determine whether the quality of materials is in reasonably close conformance with the planned specification. With a well graded material, all the different size aggregates particles will position themselves within the total matrix in a way to produce a tightly knit layer of maximum possible density, when compacted correctly and it is better able to carry and spread load imposed on it than a poorly graded material. The aggregates used should also be taken through the standard tests like crushing, abrasion, impact, soundness test, to ensure their suitability in road construction. The materials used in the construction of roads in a given country, should be locally available so that it can be affordable and manageable. The materials used for the base, sub base and aggregate for the wearing course, are locally available while bitumen is currently being imported. In the effort of constructing durable roads, all the road layers should be constructed using high quality material.

Bitumen is more complex than other conventional civil engineering materials such as steel and concrete when it comes to stress-strain relationship. At low temperatures and short loading, it is elastic; when the temperatures are high and with long loading, it is viscous (soft) and in the intermediate, it is visco-elastic (Emeritus, 2002). This makes bitumen to undergo relatively rapid chemical changes that causes many desirable properties such as flexibility, durability to degrade or lost altogether. A typical failure of a pavement is characterized by cracking, rutting, consolidation of pavement, shear failure, lack of cohesion in different layers, formation of waves and corrugation, allowing water to ingress to the underlying layers (Gupta *et al*., 2010). This could be caused by factors such as the volume and the type of traffic, inadequate thickness of the pavement, environmental factors, soil factors, poor workmanship, and maintenance strategy adopted, among other factors. To prolong the lifetime of any given road, it should be the effort of every government to keep roads in perfect condition through routine maintenance and by improving the quality of materials being used to construct them.

The mechanical properties of bitumen can be improved by mixing it with polymer, tar, rubber, cement and chemicals like sulphur and manganese making it a better binder (Sreejith, 2010, Emeritus, 2002). When cement or lime is incorporated in bitumen, it enhances its adhesive property, strength of the mix and its resistance to water damage. If a small amount of lime or cement approximately 1-2% by mass of aggregate is added in the mix, a chemical reaction takes place between either additive, and the bitumen results in formation of compounds that are absorbed by negatively charged aggregate surface and this will improve adhesion and render the aggregates less vulnerable to stripping (Gupta *et al*, 2010). A study on utilization of cement dust on bituminous mixture, indicated that cement dust has considerable effect on the bitumen making it act as a much stiffer grade of bitumen compared to conventional one (Prithvi, 2007). This improves pavement performance including fracture behavior and assist in promoting stripping resistance (Vivian, 2006, Konsta, 2002).

The abundance of waste materials like plastic bags and waste sugar cane ash has necessitated the need to carry out research to determine their suitability as modifiers in construction of bituminous roads to check reduction in deterioration of pavement in form of rutting, potholes, and low-temperature cracking and in the same time saving the environment from pollution (Journal, 2009).

The current study will focus on studying the effect of using waste sugar cane ash (WSCA) and shredded waste plastic bags (SWPB) on the mechanical performance of bitumen and bituminous mixtures. First, the effect of plastic bags on bitumen and bituminous mixtures will be analyzed, followed by the effect of WSCA and finally the effect of WSCA and SWPB combined. Both modifier are expected to alter the mechanical properties of the bitumen thus improving the lifetime of a pavement and also reduce environmental pollution

1.2 Problem Statement

Maintenance of roads in Kenya has been given less priority compared to building of the news ones like many other countries in Africa (Wilson, 2001). This can be witnessed by the way roads in Kenya deteriorate so much before repairs are carried out. This is characterized by the fact that, most of the feeder roads are only accessible during the dry seasons. Lack of maintenance has left over 50% of paved roads in Africa in poor condition, while more than 80% of the unpaved main roads, their condition would be considered just fair (Wilson, 2001).

Deterioration of roads due to formation of potholes resulting from delayed maintenance, weak bituminous material, poor compaction and rutting among other factors, is a common occurrence in roads in Kenya. Kenya being a tropical country with temperatures ranging between 0^{o}C to 50^{o}C (Gichaga, 1987), causes bitumen to soften when hot and stiffens when cold resulting in cracking when temperatures drops and increase in traffic intensity resulting in overloading of the roads causing the ground temperature to rise resulting in ruts and cracks development . All this allow water to ingress to the underlying layers breaking the bond between the bitumen and the aggregate resulting in formation of potholes. Poor roads create traffic hazards, damage vehicles, cause accidents, and ties up traffic causing daily loss of tens of thousands of labour hours of drivers and passengers as well as increasing fuel consumption leading to air pollution. If not repaired on time, they lead to eventual collapse of a road.

With a growing economy, there is an ever increase in generation of waste both biodegradable and non-biodegradable. Managing the waste has been a challenge as is clearly witnessed by heaps of both waste on the road sides, estates, and places that are not designated for dumping. Plastic bags little our environment while waste sugar cane ash is easily blows away by wind needing a lot of water to hold it during its disposal.

1.3 Overall Objective

The main objective of the study is to gain understanding of the fundamental behaviour of bitumen modified with waste sugar cane ash and shredded waste plastic bags, quantify its beneficial effects, and determine its mechanical properties.

1.4 Specific Objectives

To determine the optimum mix proportions of SWPB and WSCA to modify conventional bitumen to improve on its viscosity, seepage, penetration grade, adhesiveness, durability and strength.Compare the effect of WSCA, SWPB, and WSCA & SWPB combined on bitumen and bituminous mixtures. Suggest practical treatment methods to improve stripping resistance of conventional bitumen.

2.0 Material, Methodology and Results Analysis

The material that were used included coarse and fine aggregates collected from aristocrat quarry in Mlolongo, bitumen from the Ministry of Public works, shredded waste plastic bags from Kariobangi light industries and waste sugar cane ash from Mumias sugar Company.

3.0 Sieve Analysis

The particle size distribution of a sample aggregates and fillers were determined by sieving. A representative weighed sample was passed through BS test sieves of different sizes in millimeters and microns and each weight retained in each sieve was weighed and then divided by the total weight to give a percentage retained on each sieve. The cumulative percent of aggregate retained in each sieve was calculated by adding up the total amount of aggregate that is retained in each sieve and the amount in the previous sieves. The cumulative percent passing of the aggregate was found by subtracting the percent retained from one hundred percent. The values are then plotted on a graph with cumulative percent passing on the y-axis and logarithmic sieve size on the x-axis. The results are used to determine compliance of the particle size distribution with applicable specification requirements.

3.1.1 Sieve Analysis Results

A mix design was carried out through trial and error method to determine the proportions of different aggregates and how they should be mixed together for a strong blend. The mix proportions were 55% quarry dust, 23% size 10/6 aggregates and 22% size 14/6 aggregates. A graph was drawn as indicated below to ensure the combined curve passes through the maximum and the minimum curve.

AGGREGATES					
Sample no	Nominal Size	Description and Source	TRIAL MIX- MEDIUM BLEND		
			Total Wt.	%	Wt.
2	14/6	Aggregates	1100	22	242
3	10/6	Aggregates	1100	23	253
4	0/6	Quarry dust	1100	55	605
1	Filler	OPC	1100	0	0

SIEVE ANALYSIS % PASSING									
Sample Number	1	Cement	0/6	10/6	14/6	THEO.	DESIGN MIX		
% in Mix 100	**0**	**0**	**55**	**23**	**22**	COMBINED	SPEC.		Actual Grading
Sieve Size (mm)						GRADING			
20	100	100	100	100	100	100	**100**		100
14	100	100	100	100	84.6	97	**90**	**100**	95
10	100	100	100	95.4	10.4	79	**70**	**90**	78.3
6.3	100	100.0	99.4	43.5	0.0	65	**55**	**75**	62.4
4	100	100.0	88.5	0.0	0.0	49	**45**	**63**	49.4
2	100	100.0	70.9	0.0	0.0	39	**33**	**48**	39.2
1	100	100.0	44.5	0.0	0.0	24	**23**	**38**	24.7
0.425	100.0	100.0	27.7	0.0	0.0	15	**14**	**25**	15.6
0.3	100.0	100.0	22.2	0.0	0.0	12	**12**	**22**	13.4
0.15	100.0	100.0	16.6	0.0	0.0	9	**8**	**16**	10.1
0.075	90.0	97.6	13.7	0.0	0.0	8	**5**	**10**	8.5

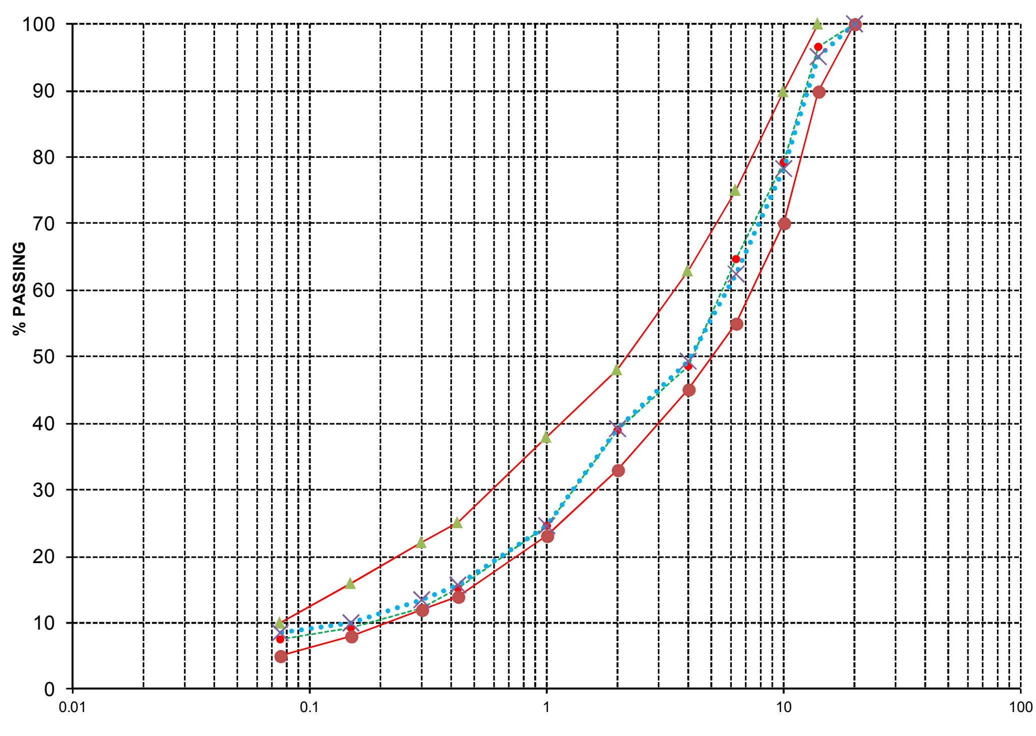

Figure 1: Proposed theoretical blending of aggregates

3.1.2 Discussion

A particle size distribution analysis is a necessary classification test for aggregates in that it presents the relative portions of different sizes of particles. From the above sieve analysis, it is clear that the aggregates are properly blended. Proper mixing of aggregates before being mixed with hot bitumen will ensure that the right sizes of voids are maintained giving strength to the wearing course enabling it to withstand the load of the traffic once it has been laid. There was no need for the additional of fines as the aggregates collected had enough fines. From the graph, the combined aggregates curve gives a coarse blend that is economical as it consumes less binder.

3.2 Aggregates Test Results

The aggregates were tested for crushing value, flakiness index, Los Angeles Abrasion test, aggregates impact value, soundness test, specific gravity and water absorption. The results were tabulated as follows

Table 1: Summary of aggregates test results

Summary of aggregates tests	Test Value	Standard specification
Aggregate Impact value	10.10%	10.10%
Aggregate crushing value	20.60%	30%
Los Angeles Abrassion Test (LAA)	17.10%	35%
Flakiness Index for 14/6aggregates	9.70%	35%
Flakiness Index for 10/6 aggregates	13.60%	35%
Sulphate soundness test	2%	12%
Water Absorption	0.691	2
Specific gravity of aggregates	2.63	

The test value of the aggregates being used in this project is less than the recommended parameters thus suitable for road construction. (Chief Engineer, 1981).

3.3.1 Bitumen

Bitumen grade 80/100 was passed through the standard bitumen test like Penetration test, ductility test, viscosity test, ring and ball softening point test, specific gravity, among other test. It was later modified with waste sugar cane ash (WSCA) and shredded waste plastic bags (SWPB) in different proportions as indicated in the table below. The modified bitumen was passed through the bitumen standard test to determine its suitability on road construction and their results recorded as shown below.

Table 2: Summary of standard bitumen test results

S/No		Unit	state	Alone	Combined	Combined	Alone	Combined	Alone	Alone		Alone	Alone	Standard specification
% Ash			0.0%	1.0%	2.0%	1.0%	2.0%	1.5%	0.0%	3.0%	3.5%	4.0%	5.0%	
% of Plastics			0.0%	1.0%	1.5%	2.0%	2.0%	2.5%	2.5%	3.0%	3.5%	4.0%	5.0%	
Bitumen 80/100		Neat	Neat	99	96.5	97	98	96		97		96	95	60/70
Plastics		%	0	1			2			3		4	5	
Test done														
	WSCA	mm		79			67		62	58				
Penetration	SWPB	mm	87	75			65			61		55	51	60 - 70
	Combined	mm			68	65		36						
	WSCA	°C		53			55		56.6	57.3				
Softening point	SWPB	°C	48	55			57.3			61.4		65.2	66.6	48 - 56
	Combined	°C			57.8	54.3		55.4						
	WSCA	cm		89			68		55	34				
Ductility	SWPB	cm	100	49			41			36		23	16	100
	Combined	cm			45	43		27						
	WSCA	°C		250	250		250		250	250				
Flash fire point	SWPB	°C	250	250			250			250		250	250	250
	Combined	°C			250	250		250						
	WSCA			1.02			1.04		1.05	1.07				
Specific Gravity	SWPB		1.01	1.01			1.01			1.02		1.01	1.01	1-01 - 1.06
	Combined				1.08	1.06		1.01						
	WSCA			49			42		40	35				
RTFOT	SWPB		56	55			45			40		38	35	
	Combined				45	42		31						
	WSCA			70			58		50	45				
TFOT	SWPB		76	70			59			55		50	40	
	Combined				56	53		35						
	WSCA			0.2			0.3		0.2	0.2				
Loss in heating	SWPB		0.2	0.2			0.3			0.2		0.2	0.2	0.2
	Combined				0.3	0.2		0.2						

3.3.2 Discussion

It was noted that the penetration of the modified bitumen decreased from 75mm to 51mm with increase in percentages of shredded waste plastic bags from 1% to 5% and from penetration value decreased from 68 – 36mm using 1% to 3% waste sugar cane ash. The ductility decreased from 49 – 16cm with increase with shredded waste plastic from 89 – 34cm with increase with waste sugar cane ash.The softening point increased from 55 – 66.6°C with increase with shredded waste plastics bags and from 53 – 57.3°C with increase with waste sugar cane ash. There is higher increase with shredded plastic bags since it has a higher softening point than ash.

Waste sugar cane ash and shredded waste plastic bags blended well and the penetration, ductility and softening point of the binder decreased with increase of plastic bags and decrease of waste sugar cane ash. Modified binder whose penetration was within 60 to 70mm was selected and used for Marshall Test for testing the stability and flow of the mix. This will include bitumen modified using 2% and 3% proportion of SWPB, 2% and 2.5% WSCA and bitumen modified using 2% SWPB and 1.5% ash and 1% SWPB & 2% WSCA.

The proportions can be treated as the optimum mix proportions as their parameter fall within the specifications of 60/70 neat bitumen with a higher softening point making it withstand higher temperatures than neat bitumen type 60/70.

3.4 Marshall Stability Test

Marshall Stability is the maximum load required to produce failure when the briquette is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous material with good stability and flow.

Five different sample three sets each containing aggregates were added bitumen from 4.5% - 6.5% with an increment of 0.5% bitumen. The aggregates and the bitumen were mixed at a temperature of 160°C and put in a Marshall mould and compacted with 75 blows on each face. The briquette left to cool at room temperature. The bulk specific gravity were measured, and then put in a water bath, after 30minutes they were crushed using Marshall Stability machine. The load at which the briquette failed was noted and the flow and the results were recorded. The following graphs represent the results from the briquette prepared using the seven binders.

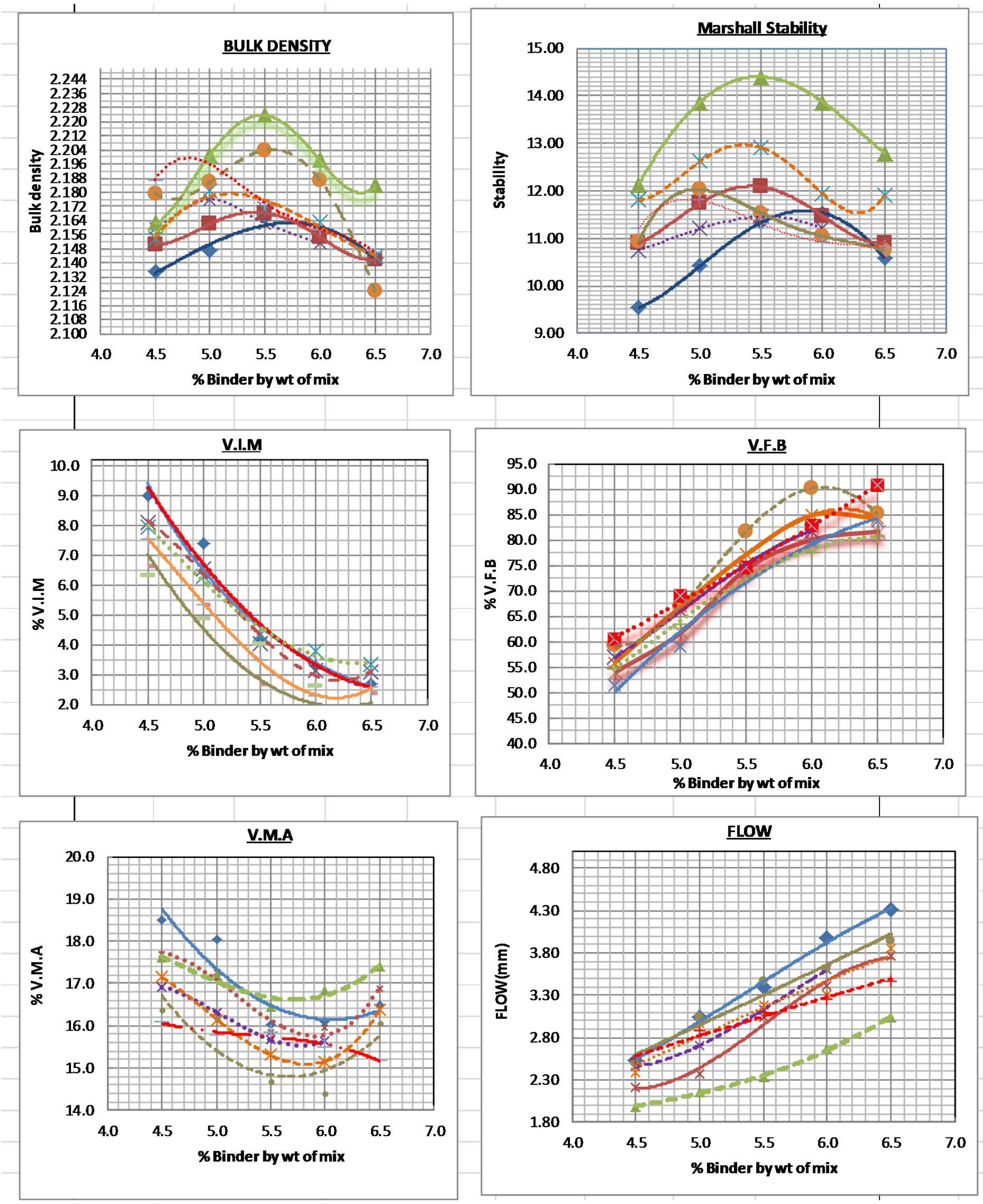

Figure 2: Marshall Stability test for neat and modified binder

Key	
	Neat Bitumen
	Modified with 2% plastics
	Modified with 3% plastics
	Modified with 2% Ash
	Modified with 2.5% Ash
	Modified with 2% Plstics & 1.5% Ash
	Modified with 1% Plstics & 2% Ash

3.4.1 Discussion

The results delivered from the graphs are tabulated below and they are all within the standard specifications of wearing course 0/14.

	Comparison of results							
	Neat Bitumen	2% plastic	3% Plastics	2% Ash	2.5% Ash	2% Plastic + 1.5% Ash	1% Plastic + 2% Ash	Standard Specification
Optinum Binder Content %	5.5	5.5	5.6	5.4	5.4	5.4	5.4	5.0 - 6.5
Stability (N)	11,300.0	12,050.00	14,400.0	11,450.00	12,600.0	11,600.0	11,500.0	9.0- 18.0
Flow	3.4	2.8	2.3	2.8	2.9	3.4	2.9	2-4
Voids in Mix	4.7	5.0	4.5	5.0	4.75	4.7	4.8	3-5
Voids filled with bitumen	16.4	16.4	16.3	16.4	16.3	16.6	16.3	min 13
Voids in mineral aggregates	72	70	70	7.3	72	72	72	65-75

It is clear from the above summary table that additional of shredded waste plastic bag (SWPB) and waste sugar cane ash (WSCA) increases the stability of mix. The more the waste materials are added to the neat bitumen, the more the stability increases. 2% of SWPB increases the stability by 6.6% while by 3% of SWPB rises by 27.4%, on the other hand 2% of WSCA increases the stability of the sample by 1.3% while 2.5% of WSCA increase it by 11.5%. The binder modified with SWPB and WSCA increases the stability but not as much as when the binder is modified by an individual modifier.

There is a higher drop in flow when shredded waste plastic bag is used as a modifier than when waste sugar cane ash is used. This implies the rate of deformation is lower in a mix where shredded waste plastic bags have been used than waste sugar cane ash. The reduced rate of deformation indicated softening point property of the binder has been improved thus the binder does not softens with increase in temperature as neat bitumen. Also an increase in stability indicates that the mix can withstand a higher loading than neat bitumen. The improvement of these two mechanical properties of the mix will bring about reduction in rutting and cracking thus prolonging the life of a pavement.

The optimum binder content (OBC) for the modified bitumen using shredded waste plastic bags is higher than the binder modified using Waste sugar cane ash. The binder modified using with WSCA is more economical to use in road construction as less binder is used.

4.0 Conclusion and Recommendation

4.1 Conclusion

From the above analysis and discussion in the previous page, the following conclusions can be made. The mechanical properties of bitumen is greatly changed once Shredded waste plastic bags and waste sugar cane ash has been added to it. The penetration and ductility are reduced while softening point increases.

There is a considerable increase in Marshall Stability value from 11300N to 14400N depending on the binder used. This implies that the modified bitumen is able to withstand a higher loading than the neat bitumen.

The flow value of the mix reduces with increase in additional of shredded waste plastic bags and waste sugar can ash varying between 3.4 to 2.3mm. This simulate that the deformation of mix is improved with increase of the additives up to a certain extent as discussed in this project. With increase in Marshall Stability and reduction in flow, the formation of rutting, potholing and cracking will be greatly reduced.Shredded waste plastic bag is a better modifier of bitumen than waste sugar cane ash as it is able to withstand higher loading. Bitumen with a grade of 80/100 can easily be converted to 60/70 easily in the field using either of the additives.

Above all the waste plastics and waste sugar cane ash which are a pollution menace can find they use in construction of roads in Kenya and thereby solving the problem to a certain extent

5.0 Recommendation

Based on this study the following recommendation can be made. Use of bitumen modified with either waste sugar cane ash or shredded waste plastic bag should be used in road construction in Kenya.

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