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EFFECT OF DISSOLVED WASTE PURE WATER SACHETS ON THE STRENGTH PROPERTIES OF ASPHALT PAVEMENT / MIXES

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Abstract : The dissolved pure water sachet emulsion, achieved at the ratio 1:3 of pure water sachet and DPK at a temperature of about 120°C was added to the optimum bitumen content designed for a HMA mixes. In carrying out this laboratory study, two major steps were used, that is, (i) Conversion of PWS to blendable state with bitumen and (ii) evaluation of bitumen/dissolved pure water sachet blend for asphalt pavement mixes as both partial replacement and addition to the designed optimum binder content. The maximum bitumen content was first determined using the Marshall Design method which was found to be 6% for wearing course of a heavily traffic road. This was followed by the determination of the dissolved pure water sachet quantity which could be used to replace some quantity of bitumen for the same traffic level. (8). Fifteen percent 15% of the dissolved pure water sachet to total mix of bitumen (i.e., 1% PWS and 5% bitumen) had no adverse effect on the desired Marshall stability for the heavily traffic road. However further addition of dissolved pure water sachet (PWS) to the optimum binder content to determine how much more of the PWS for the heavily traffic was found to be about 2%, which is about 25% addition to total mix. The respective Marshall Stability values of 1,400kg for unmodified bitumen binder, 1,150kg at 15% partial replacement and 1,200kg at 25% additions to optimum binder content for the dissolved pure water sachet were recorded, while the corresponding flows of 2.6mm for unmodified bitumen binder, 3.2mm for partial replacement and 2.7mm for additions to optimum binder content were obtained, when the samples were subjected to Marshall test.

1.0 INTRODUCTION

Growth in population and the demand for safe and cheap drinking water in Nigeria has resulted in the generation of pure water sachets waste. These are mainly polythene products. The use of thin plastic bags to pack and to carry water including house hold articles has become a common practice all over the world. Once the packaging objectives has been satisfied no other meaningful alternate usage is been considered, hence the resultant problems it's creates, which is of great concern and challenge particularly in big cities of the country.

Keywords : Dual purpose kerosene, optimum binder content, dissolved pure water sachet, Marshall Stability, design parameters

The disposal of the pure water sachets either in small or large quantity has become a major source of worry in the country, because of its non-decaying nature and the menace it causes in the environment; its blocks drainages, its serves as breeding ground for mosquitoes, its flies about directionless e.t.c.

In order to find solution to these challenging problems, attempt is been made in this paper to find out if this waste material will blend effectively with bitumen hence its use in highway construction industries for the production of asphaltic pavement which will be able to maintain its premium quality and asphaltic quality. It worthy to say that presently in Nigeria bitumen of varying grades are the main binder for pavement works, in other that this waste material be use as binder in pavement mixes either partially or wholly certain reformation and transformation has to take place. This reformation and transformation will draw out the viscosity of the pure water sachets either singly or in solution. The blending of these two dissimilar polymer required transformation of the pure water sachet to a blendable state with bitumen. (1)

However, successful utilization of this blend would mean

a. An addition, to existing list of probable bituminous material and the accompany literature as new contribution to existing data on same,

b. Free environment from flying pure water sachets, which before now are among the main source of non- degradable environmental nuisances and impediment to free flow of water in drainages

c. Reduction in the consumption rate of bitumen, which is substantially an avenue for foreign reserve depletion.

This paper is aimed at evaluating the modification of optimum bitumen content in partial replacement with polythene, in the production of asphaltic pavement mixes with a view to conserve the fund available for bitumen as well as simultaneously making the environment to be more pollution free and globally HSE compliant.(2)

2.0 METHODOLOGY

2.1 Material Characterisation

Test was conducted on aggregates, bitumen and pure water sachet, to determine the suitability or other wise of these materials, the test includes.

For aggregates

- Grading test
- Aggregate indices (Flakiness and Elongation)
- Crushing value

For bitumen and pure water sachet

- Density test
- Penetration test
- Specific gravity test

Table-1 presents the materials used for the study indicating their respective sources and preliminary physical properties while table-5 to table 10 the obtained results of the conducted test.

2.2 Methods for the study

The approach that was used for the laboratory works was at two major stages: -

(1) Conversion of the pure water sachet to blending state with bitumen and

(2) Evaluation of the bitumen - pure water sachet blend for asphalt pavement mixes for wearing course. Various test were conducted on the materials to determine the suitability or other wise of aggregates, bitumen and pure water sachet, these test includes (4)

For aggregates

- Grading test
- Aggregate indices (Flakiness and Elongation)
- Crushing value

For bitumen and pure water sachet

- Density test
- Penetration test
- Specific gravity test

2.2.1 Conversion of Pure Water Sachet to miscible state with bitumen

Preparing the pure water sachet solution was achieved by first heating the solvent in a mixing bowl, to a temperature of about 40ºC, and then pouring the pure water sachet into the mixing bowl which contained some quantity of the solvent (DPK.) in the ratio of 1% of pure water sachet to 3% of solvent, the volume of the solvent is immaterial since the temperature at which asphalt is produced most of this solvent would have evaporated. The mixture was then returned to the hot plate, adequately covered and raised to a temperature of 80ºC. It .was again removed from the hot plate for stirring. The mixed content, that is the solvent and the pure water sachet are then returned to the hot plate and covered for further heating to a temperature of about 120ºC. This process was continued until a semi liquid mixture was achieved. (3)

2.2.2 Laboratory trial mixes

In order that optimum binder content be determined, different sizes of aggregate were mix together as specified by Nigeria General Specification (Road and Bridges) (1997). The best proportion was determined See table-2. With this mix, it is aimed that the optimum binder content will be determined by varying the amount of binder that is been added to aggregate mixture, the binder content that gives the best properties after testing was adopted as the optimum binder content. The aggregates and filler were mixed together (after confirmation of their respective standard see table-6 and table-7) as determined by the job mix formula, See table-2 below for the required grading as obtained in the sieve analysis and place on hot plate and various amount of bitumen was added in percentages. Tests were conducted on the resulting samples (see test result in table-3) and 6% of bitumen was found to have the best asphaltic properties and was therefore adopted as the optimum binder content for this work. See fig-7.

Table-1 : Materials for study

Serial No	Material	Description / Characteristics	Sources	Remarks
1	Polyethylene	It is colourless, density is between 0.91 – 0.94g/cm^3, its melting temperature is between 110 – 160ºC. It is flexible and is not easily dissolved by petroleum products.	Life fresh pure water manufacturing company in Chanchaga, Minna, Niger State	Package water sachet in dry form
2	Bitumen	It is black in colour, having a penetration between 60dmm - 700dmm at temperature of 25°C, is density ranges between 0.95 to 1.00kg/lit	P.W. (Nig) Ltd, Vom Plateau State.	60/70 Bitumen Penetration
3	Solvent	DPK (Dual Purpose Kerosene)	P.W. (Nig) Ltd, Vom Plateau State.	D.P.K
4	Aggregate	Must be hard enough to withstand wheel abrasion.	P.W. (Nig) Ltd, Vom Plateau State.	Igneous rock
5	Water	Tested and fit for consumption	P.W. (Nig) Ltd, Vom Plateau State.	Bore-hole, satisfies WHO standard
6	Bucket	Cylindrical Shape and made of metal	P.W. (Nig) Ltd, Vom Plateau State.	Metal

Table-2 : Material Proportions

***AGGREGATE*:- COARSE 25% FINE 75%**

Imperial Bs Sieve	**Metric BS Sieve**	**Percentage Passing**				**Range of matrial per sieve**				**Blend**	**Av.**	
		Quarry		**Mineral**		**Quarry**		**Mineral**				
Nos	**Nos**	**1/2''**	**3/8''**	**Dust**	**Filler**	**1/2''**	**3/8''**	**Dust**	**Filler**	**Total**	**Spec**	**Specification**
						20%	**5%**	**70%**	**5%**			**Range**
3/4"	20mm	100.00	100.00	100.00	100.00	20.00	5.00	70.00	5	100.00	100.00	100 - 100
1/2"	14mm	98.09	100.00	100.00	100.00	19.62	5.00	70.00	5	99.62	92.50	85 - 100
3/8"	10mm	46.15	98.22	100.00	100.00	9.23	4.91	70.00	5	89.14	83.50	75 - 92
1/4"	6.3mm	6.64	45.56	100.00	100.00	1.33	2.28	70.00	5	78.61	73.50	65 - 82
No 7	2.36mm	4.46	3.00	72.78	100.00	0.89	0.15	50.94	5	56.98	57.50	50 - 65
No 14	1.18mm	3.72	2.37	47.58	100.00	0.74	0.12	33.30	5	39.17	43.50	36 - 51
No 25	600μm	2.92	2.01	29.87	100.00	0.58	0.10	20.91	5	26.59	33.00	26 - 40
No 52	300μm	2.28	1.18	18.77	100.00	0.46	0.06	13.14	5	18.65	24.00	18 - 30
No 100	150μm	1.75	0.00	11.72	100.00	0.35	0.00	8.20	5	13.55	18.50	13 - 24
No 200	75μm	1.22	0.00	6.78	98.00	0.24	0.00	4.75	4.9	9.89	10.50	7 - 14

Table-3 : Summary of Marshall Test for unmodified Bitumen

Bitumen Content (%)	**Density g/cc**	**Void in Total mix VIM (%)**	**Void in mineral Aggregate VMA (%)**	**Void filled with Bitumen VFB %**	**Stability Adjusted (kg)**	**Flow (mm)**
5.00	2.27	6.58	18.00	62.44	997.00	2.20
5.50	2.28	5.79	18.08	68.69	1212.00	2.40
6.00	2.29	4.58	18.15	74.93	1454.00	2.60
6.50	2.31	2.94	17.88	83.17	1327.00	3.30
7.00	2.29	2.97	19.02	83.44	908.00	3.70

Table-4 : Partial replacements for bitumen in asphalt mix production

Serial Number	Bitumen		Dissolved Pure water sachet		Total Binder Content in grms	
	%	grms	%	grms	%	grms
1	6	72	0	0	6	72
2	5	60	1	12	6	72
3	4	48	2	24	6	72
4	3	36	3	36	6	72
5	2	24	4	48	6	72
6	1	12	5	60	6	72

Table-5 : Flakiness and Elongation Index Test Data

		SIEVE SIZE(mm) (Flakiness Index)				SIEVE SIZE(mm) (Elongation Index)			
		25.4-19.1	19.1-12.7	12.7-9.5	9.5-6.6	25.4-19.1	25.4-19.1	25.4-19.1	25.4-19.1
A	Total Weight of sample (gm)	513	1528	65	14	513	1528	65	14
B	Weight Passing (gm)	53	122	4	4	32	310	26	6
C	Flankiness / Elongation Index B/A X 100%	10.3	8	6.2	28.6	6.2	20.3	40	42.9
	Average (%)	13.3				27.4			

2.2.3 Bitumen replacement tests

The addition of dissolved pure water sachet to bitumen was done in percentages. The bitumen was being reduced by certain percentage and dissolved pure water sachet was added to make up the already determined optimum binder content of 6%. See Table-4 for the bitumen mix replacement test schedule. Asphalt samples were produced using this schedule while the corresponding standard Marshall testing parameters were subsequently determined. For this purpose l,200gms of total mix was used. For test conducted on bitumen and PWS see table-8 to table-10.

Table-6 : Aggregate Impact Value and Crushing Value Test Data

		SIEVE SIZE 14mm crush rock (Impact Test)			SIEVE SIZE 25.4mm crush rock (Crushing Test)			SIEVE SIZE 10mm crush rock (Crushing Test)		
		1	2	3	1	2	3	1	2	3
A	Weight of Material (gm)	743	700	691	3000	3000	3000	3208	3200	3100
B	Weight of Material Passing Sieve No 7 (2.36mm) (gm)	71	68	68	463	450	445	818	820	825
C	Aggregate Crushing Value B/AX 100%	9.6	9.7	9.8	15	15.2	14.8	25.5	25.6	26.6
	Average (%)	9.7			15			26		

These tests are in according to BS 812 also see page 271 of Nigerian General Specifications (Roads and Bridges) Volume II 1997

Table-7 : Density Test Data for 60/70 bitumen

S/No	Description of Materials	Test No 1	Test No 2	Test No 3
1	Weight of Bitumen + Can(Ml)	2960	2959	2962
2	Weight of Empty can (M2)	1813	1813	1813
3	Weight of Bitumen Only(M3) M1-M2	1147	1146	1149
4	Volume of can (M4)	1178	1178	1178
5	Density of Bitumen (M1-M2)/M4	0.974	0.973	0.975
	Average Density of Bitumen Kg/litres	0.974		

Table-8 : Penetration Test Data.

Test No	Time At Sseconds	Penetration Reading	Bitumen Type	Remarks
1	5 seconds	66mm	60-70	Temperature is at 25°C
2	Sseconds	70mm	60-70	Temperature is at 25°C
3	Sseconds	68mm	60-70	Temperature is at 25°C
4	5seconds	65mm	60-70	Temperature is at 25°C

Table-9 : Specific Gravity Test Data for Bitumen and Polyethylene

MATERIAL	**BITUMEN 60/70**		**PURE WATER SACHET**	
No. OF PICYNOMETER (gm)	**1**	**2**	**1**	**2**
Mass of Picynometer A (gm)	467	467	467	467
Mass of Picynometer + Sample B (gm)	559	554	558	560
Mass of Picynometer + Sample + Water C (gm)	1277	1277	1263	1265
Mass of Picynometer + Water Only D	1276	1276	1276	1276
Specific Gravity B – A (D - A) - (C - B)	1.01	1.01	0.88	0.89
Mean Value S.G	1.01		0.89	

Table-10 : Specific Gravity Test Data for aggregates

MATERIAL	**1/2"**		**3/8"**		**DUST**		**M/ FILLER**	
No. OF PICYNOMETER	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Mass of Picynometer A	469	469	469	469	469	469	469	469
Mass of Picynometer + Sample B	1046	1011	1058	1068	1142	1168	726	720
Mass of Picynometer + Sample + Water C	1640	1619	1648	1653	1697	1713	1424	1419
Mass of Picynometer + Water Only D	1281	1281	1281	1281	1281	1281	1276	1276
Specific Gravity B - A (D - A) - (C - B)	2.65	2.66	2.65	2.64	2.62	2.62	2.32	2.29
Mean Value S.G	2.66		2.65		2.62		2.31	

AVERAGE SPECIFIC GRAVITY FOR THE ABOVE :- $\frac{(20/2.66)+(5/2.65)+(70/2.62)+(5/2.31)}{100} = 2.60$

Table-11 : Marshall Stability to determine the polyethylene content and other properties while varying polyethylene and bitumen as binder P.R.F. 1.75kgf/Div

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R		
				Weight			Density		Volume Total			Void					Stability		S	
Specimen Number	% of polythene to bitumen	Ratio of Polythene to bitumen	Bitumen By Weight of Total Mix	Air	Water	Bulk Volume	Bulk	Maximum Theoretical	Bitumen	Aggregate	Void	Void in Total Mix	Void in mineral Aggregate	Void men with Bitumen	Specimen Height	Correction Factor	Measured	Adjusted	Flow	
		%	%	GMS	GMS	CC	GM/M3	GM/M3	%	%	%	%	%	%	mm		KG	KG	MN	INS
0	0	00:06	6	1193	672	621	2.3	2.4	14	83	3.6	4.2	17	79	64	1	750	1313	3	
1	17	01:05	6	1184	665	519	2.3	2.4	14	82	3.2	4.2	18	82	64	1	660	1155	3.2	
2	33	02:04	6	1184	660	524	2.3	2.4	14	82	4	5	18	78	64	1	640	1075	3.4	
3	50	03:03	6	1175	650	525	2.2	2.4	14	81	4.9	5.9	19	74	64	1	540	907	3.5	
4	67	04:02	6	1148	633	515	2.4	2.4	14	81	5.3	6.3	19	73	64	1	500	875	3.5	

Crushed Stone Specific Gravity 2.60 60/70 & Polyethylene Specific Gravity 0.95

3.0 RESULT PRESENTATION AND DISCUSSION

Pure Water Sachet (PWS) Modified Asphalt Mixes at Constant 6% Optimum Binder Content. Samples produced from the modified bitumen shows a relative comparison to the control in terms of density, voids, flow and stability with an implication of a stable condition of most of these properties at their relative peak and sag values. (See Figures-1 - 6). Having considered these properties with respect to relative Standards (Nigerian General Specifications, 1997) it can be observed that the replacement of bitumen with PWS in the production of asphalt is acceptable up to 1% of total mix (i.e. Bitumen 5% and PWS 1%) in the ratio of 1 :5 for the stability for heavily traffic road. It therefore implies that about 1 5% by weight of bitumen can be saved with the inclusion of PWS in the production of asphaltic pavement for a wearing course. The inclusion of PWS will improve such properties as oxidation period of bitumen by reducing time of bitumen oxidation period, because bitumen loses its binding properties easily with present of water with time whereas dissolved pure water sachet does not oxidize neither does it decompose at normal temperature and weather.(6)

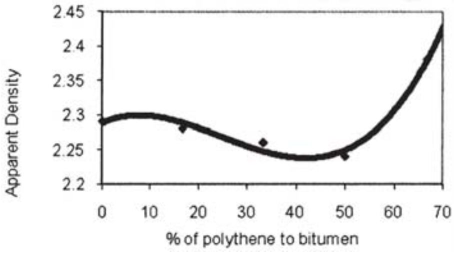

Figure-1 : Variation of apparent density with % pure water sachet to bitumen

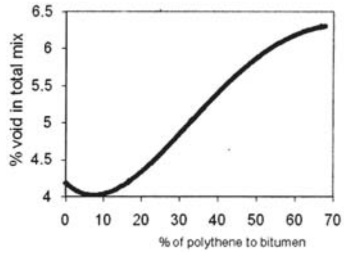

Figure-2 : Variation of Void in total mix with % pure water sachet to bitumen

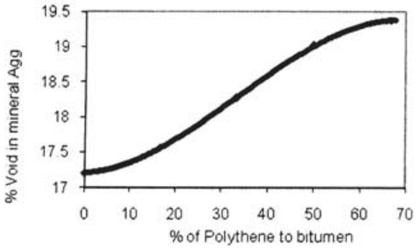

Figure-3 : Variation of Void in mineral Aggregate with % pure water sachet to bitumen

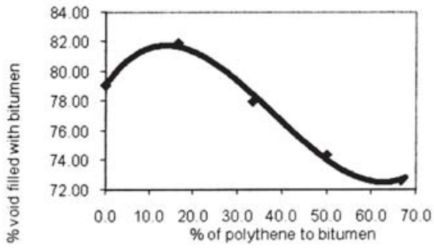

Figure-4 : Variation of Void filled with bitumen with % pure water sachet to bitumen

An inspection of Figure-6 for the Marshall Stability results indicate the amount of dissolved pure water sachet that can successfully replace bitumen in the production of asphaltic pavement without actually affecting its traffic load supporting (stability) properties. The dissolved pure water sachet does not add to the resistance against traffic loads. The apparent density curve shown in Figure-1 for the bitumen and dissolved pure water sachet as the binder also shows that at about 14% replacement, the density dropped and rose again at about 50% replacement thus, indicating the density is appreciated up to the 14% replacement. This may be explained by the differences in the specific gravity of the two binding component. Also, the swelling at first instance of the PWS during the conversion without any gain in weight is another reason for the gradual drop in the density as the dissolved pure water sachet proportion increases.

Figure-2 shows the variation of void in total mix (VIM) with % of dissolved pure water sachet to bitumen. The indication of this curve is that bitumen ratio reduction in the mix at the inertial point has no effect on the voids since it has been replaced by dissolved pure water sachet. But on further replacement it was noticed that VIM increased. Also presented in Figure

3 is the Void filled with bitumen (VFB) curve. It shows the maximum void that can be filled with the modified bitumen, which is about 18% replacement after which there is a drop in value indicating that the mix is permeable to water.

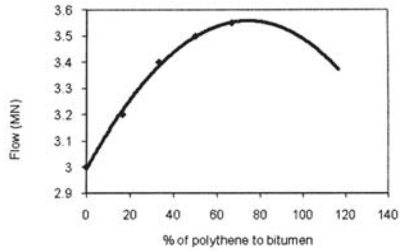

Figure-5 : Variation of Flow with % pure water sachet to bitumen

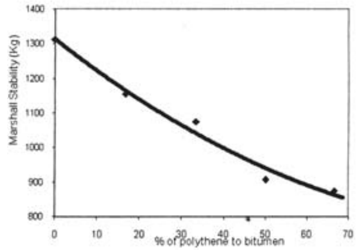

Figure-6 : Variation of Marshall Stability with % pure water sachet to bitumen

Figure 5 shows the variation flow with % of dissolved pure water sachet to bitumen. This indicates that the more the replacement of bitumen with dissolved pure water sachet in the asphalt mixes the more its potentials to deformation which has implication on the sliding of pavement when it is subjected to use by traffic.

Marshall Stability curve presented in figure 6 shows that the ability to carry heavy load as compared with that of figure 7 that has its peak at 1,400kg. But having a closer examination of this result and comparing with the specified standard, it shows that replacement of bitumen with dissolved pure water sachet can be done up to 15% and still maintaining stability of about 1,150kg, this figure is still far higher than the specified standard by Nigerian General Specifications (1997) which specified stability value of not less than 350kg for Nigeria roads. This implies that the capability of the resulting Asphalt mix can withstand heavy traffic loading of Category E and F which is equivalent to about 4,500vpd exceeding 30tons loaded weight. (5).

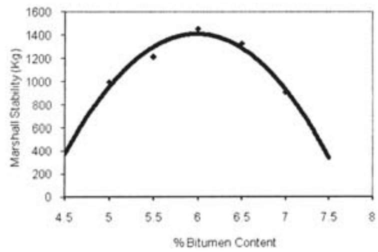

Figure-7 : Marshall Stability (Control)

4.0 CONCLUSIONS

Having considered the use of dissolved pure water sachet in the modification of bitumen in asphalt mixes production for road pavement works and pollution control, the following conclusions can be deduced. Test carried out on bitumen shows that it has a density of 0.974kg/lit, and an average penetration value of 67mm, thus implying 60/70 type of bitumen. The specific gravity of bitumen was also found to be approximately 1.00mg/m^3. The optimum bitumen content was found to be 6% of total mix; this was obtained after a range of bitumen content to total mix has been tested.

Samples were prepared by the job mix formula and were subjected to test using the Marshall Stability machine and such result as flow, stability, apparent density, void in total mix, void in mineral aggregates and void filled with bitumen was obtained.

While comparing the properties of the modified bitumen with ordinary bitumen, it was observed that the stability values of the produced asphaltic samples shows no appreciable difference in their values up to about 15% replacement but further addition in proportion of the emulsified pure water sachet up to 6 % by weight of total mix showed a gradual decrease in the ability of sample to sustain heavy traffic movement. Marshall stability test shows that, bitumen alone has Marshall Stability Value (MSV) of 1,400kg. It was also found that when replacement is being considered, it could be done up to 15% replacement of bitumen (i.e. addition of dissolved pure water sachet could be done up to 15%) and a good stability of 1,130kg was obtained, which is capable of carrying heavy traffic.(8). It therefore implies that about 15% by weight of bitumen can be saved, when partial replacement is been considered.

The addition of dissolve pure water sachet therefore helps in substantial maintenance of the stability or strength, fatigue life and other desirable properties of bituminous concrete mix. Even under adverse, water logging conditions it's reduces oxidation of the asphalt, therefore increasing the life span of the pavement. It was also noticed that the samples produced from the modified bitumen was lighter as compared to those samples produced from unmodified bitumen; this therefore implies that it can be use on a bridge deck where lighter load is often required.

It is therefore worthy to say that proper usage of the pure water sachet will reduce waste which is creating environmental pollution.

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