A Comparison of Marshall Properties of Cold Asphalt Mixes in Use in Nigeria

S. S. Kolo[1] and Y. A. Jimoh[2]
[1]Department of Civil Engineering, Federal University of Technology, Minna, Niger State, Nigeria,bukysayo123@yahoo.com
[2]Department of Civil Engineering, University of Ilorin, Ilorin, Kwara State, Nigeria, dryajimoh@yahoo.com.

Abstract
This study present the Marshall properties of the cold mix asphalt produced with the DPWS modified bitumen compared with those of the commercial cold mixes in use in Nigeria. The following stability and flow results were obtained after careful laboratory experiments on four types of cold Asphalt mixes (DPWS, Portland Emco, Carboncor and UPM). The DPWS modified cold mix asphalt gave a stability of 5.8kN and flow of 4mm were obtained when using the normal hot mix method of testing, while stability of 9.58kN and flow of 4.5mm were obtained when air dried method was used. The Portland Emco shows stability of 2.21kN and flow of 3.95mm when it was subjected to test using the normal hot mix method of testing, while a stability of 4.37kN and a flow of 4.85mm were obtained air dried method was used. The Carboncor shows stability of 4.27kN and flow of 5.5mm when it was subjected to test using the normal hot mix method of testing, while a stability of 9.79kN and a flow of 5.5mm were obtained when air dried method was used. The UPM could not be tested for stability when it was subjected to test using the normal hot mix method of testing, but using the air dried method a stability of 1kN and a flow of 6.85mm were obtained. This shows that the DPWS modified cold asphalt has a good strength when subjected to laboratory load condition as compared to other commercially available cold asphalt mixes.

Keywords:
Marshall Properties, Stability, DPWS, Cold Asphalt

1. Introduction

Asphalt is a mixture of mineral aggregate and binder usually bitumen. Bitumen is a heavy, dark brown to black mineral substance, one of several mixtures of hydrocarbons and has ability of binding mineral aggregates together to form asphalt (James and Nobel, 2006). Bitumen is a strong, versatile weather and chemical-resistant binding material which adapts itself to a variety of uses. Bitumen binds crushed stone and gravel (commonly known as aggregate) into firm, tough surfaces, termed asphalt, for roads, streets, and airport run-ways. (Asphalt Institute, 1997).

Asphalt has been produced in the hot mix (HMA), at 160^{o}C temperature with sophisticated equipment for decades (Bindra, 2001). This high temperature serves to decrease viscosity and moisture during the manufacturing process, resulting in a very durable material though the risk of production is very high. HMA is most commonly used for high-traffic areas, such as busy highways and airports (Gurcharan, 2004). The recent evolution in road technology has made it possible to produce asphalt in warm and cold forms (APAA, 1994).

Warm mix asphalt concrete (WAM or WMA**)** reduces the temperature required for manufacture by adding bitumen emulsions, waxes, or zeolites. This process benefits both the environment and the workers, as it results in less fossil fuel consumption and reduced emission of fumes. In cold mix asphalt concrete, the bitumen is emulsified in soapy water before mixing it with the aggregate, eliminating the need for high temperatures altogether (Noble, 2005). However, the asphalt produced is not nearly as durable as HMAC or WAM, and cold mix asphalt is typically used for low traffic areas or to patch damaged HMAC. The cold technology is new in the market and there is need to verify and clearly understand its properties before adopting it for the use in Nigeria. Cold mix asphalt is produced at temperature of about 60^{o}C and laid at ambient temperature; it does not produce hazardous gases which mean it is environmentally friendly and can be stored for a very long time.

The possible gain of producing cold mix asphalt with Disposed Pure Water Sachet (DPWS) modified bitumen include:

(i) an addition, to existing list of probable bituminous materials, and the accompanying literature as new contributions to existing data on same.
(ii) to generate a model that will assist designers on better ways by which bitumen mixture can be produced with some hitherto wastes of packaging product.
(iii) free the environment from polyethylene bags wastes, which are among the main sources of non-degradable environmental nuisance and impediment to free flow of water in drainages.
(iv) in economic terms, reduce the consumption rate for the bitumen, which is substantially an avenue for foreign reserve depletion.
(v) to reduce the rate of oxidation of bitumen, since it may act as buffer solution in the chemical degradation of bitumen on exposure to the open atmosphere of a completed road pavement; and
(vi) eventually create job opportunities through the collection of polyethylene bags wastes leading to meaningful participation in a 'waste to wealth' programme.

2. Materials and Method

Table 1 shows the material used to produce the cold mix asphalt with the DPWS modified bitumen and the other types of cold asphalt sourced from the market in Nigeria. Their source and physical properties as well as their compositions are briefly indicated in the table.

2.1 Marshall Test and Characterization of the Properties of the Mixes.

2.1.1 Marshall test Specimens Production.

Test samples were produced according to AASHTO 1990 of mix design for bitumen mixes. In this test, some amount of aggregates,

Table 1 Cold mix asphalts used for the study.

S/No	Sample	Description/Characteristic	Sources	Designation
1	DPWS-Modified Bitumen cold asphalt.	Black in colour. A mixture of aggregates and binder (pure water sachet and bitumen emulsion)	Study	SDPWS
2	Carboncor cold-mix asphalt	Black in colour. A mixture of aggregates, carbon shale and bitumen emulsion	Carboncor Nigeria, Sauka Kahuta, Niger State, Nigeria	Scarb
3	Portland Emcor Cold-mix Asphalt	Black in colour. A mixture of aggregates and bitumen emulsion	Portland Paints and Products, Lagos, Nigeria.	Sportland
4	UPM Cold-mix asphalt	Black in colour. A mixture of aggregates and bitumen emulsion	UPM Company,Uyo, Akwa Ibom State, Nigeria	Supm

not less than 1,200g in weight was placed in the Marshall mould and compacted with the 75 blows on each side of the specimen, using 4.54kg compacting rammer falling through 457mm unto the top and bottom of each specimen. The mould containing the material was removed from the compacting machine and then taken to the extruder and the compacted sample was extruded out of the mould. The density of the compacted material was achieved after 24hours of cooling, by weighing in air and suspended in water. The numerical differences in the two weights are the volume. As stated earlier four different materials were used for this study as listed in Table 3.1. For each material, 6samples were produced totaling 24 samples. The density is calculated by dividing the weight in air by the volume. Three samples of each material were placed in water basin, heated to 40 ℃ for the duration of 30 minutes that the sample continued to be in it while three samples of each material were air-dried for 3 days. All the samples were then placed in the Marshall Stability testing machine to measure the load at failure i.e. the Marshall stability; while the rate of deformation (flow) was read directly from flow gauge. The stability read from the gauge was appropriately corrected.

2.1.2 Extraction, Sieve Analysis and Specific Gravity

i) The percentage bitumen/binder content is the amount of binder present in an asphalt mixture which is otherwise known as extraction test. This is important because other relevant result relies on the bitumen content of the mix. The percentage bitumen content of the various samples was determined as follows:

Percentage bitumen by weight of total mix =

$$\frac{\text{Wt of sample before extraction} - \text{Wt of sample after extraction} \times 100}{\text{Wt of sample before extraction}} \quad (1)$$

Percentage bitumen by weight of aggregate =

$$\frac{\text{Wt of sample before extraction} - \text{Wt of sample after extraction} \times 100}{\text{Wt of sample after extraction}} \quad (2)$$

ii) In sieve analysis, a sample of a dry aggregate of known weight is separated through a series of sieves with progressively small openings. Once separated, the weight of the particles retained on each sieve is measured and compared to the total sample weight. Particle size distribution is then expressed as percentage retained by weight on each sieve size. The results are usually in tabular or graphical format

Percentage retained on any sieve =

$$\frac{\text{Weight of aggregate} \times 100}{\text{Total aggregate weight}} \quad (3)$$

Cumulative percentage retained on any sieve = sum of percentage retained on all coarser sieves.

iii) The specific gravity of the aggregate was determined to know how heavy or light the aggregates are. The mix asphalt was obtained already in its mix state. However only clean aggregates are needed for specific gravity test. Hence only extracted was also used for the specific gravity. The sample was soaked in distilled water and later surface dried and weighed in air. The specimen was then oven dried for 24 hours at 100 - 110 ℃ and re-weighed in air again. The specific gravity was calculated by dividing the weight of the oven-dry sample in air by the difference between the saturated sample weights in air and water. The computational data and expression for the purpose of calculation are as follows:

If

Weight of cylinder	= A
Weight of cylinder + Sample	= B
Weight of cylinder + Sample + Water	= C
Weight of cylinder + Water only	= D
Therefore, Specific Gravity	= (B-A)/{(D-A)-(C-B)}

3. Results and Discussion

3.1 Results

a) Graduation Distribution (Sieve Analysis)

Figure 1 shows the gradation result for all sampled cold mix asphalt:

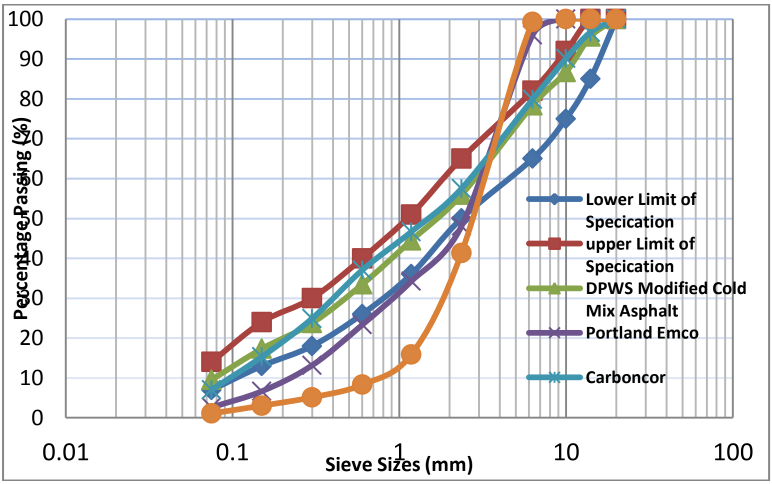

Fig 1: Combined gradation results for all the sampled cold mix asphalt

b) Bitumen Content

The bitumen contents of the samples were calculated as follows (Table 2):

Table 2: Determination of Bitumen content for all samples

Samples	Experim-ental Asphalt	Portland Emco	Carboncor	UPM
weight of sample before extraction, g, (A)	988	1178.7	1008.8	1063.3
weight of sample after extraction, g, (B)	906	1067.0	906.7	969.6
weight of bitumen, g, (C) = A – B	82	110.8	102.1	93.7
% bitumen by weight of total mix = C/A X 100	8.3	9.4	10.1	8.8
% bitumen by weight of aggregate = C/B X 100	9.1	10.4	11.3	9.7

c) Specific Gravity

The table below shows the specific gravity of the various cold mix asphalt samples (Table 3).

Table 3: Specific gravity of the various samples

Material	Experimental Asphalt (g)	Portland Emco (g)	Carboncor (g)	UPM (g)
Wt of cylinder (A)	185.5	114.10	126.90	97.50
Wt of Cylinder + Sample (B)	323.6	208.40	217.8	161.7
Wt of cylinder + Sample + Water (C)	940.7	421.80	428.30	386.20
Wt of cylinder + water only (D)	858.9	362.4	374.9	346.0

Specific Gravity g/m^3 = (B-A)/((D-A)-(C-B))	2.45	2.59	2.42	2.68

Table 4: Comparison of test results for normal asphalt method of testing

Property	Cold mix Asphalt				Standard specification (FMW, 1997)for hot mix wearing course
	Experimental Asphalt	Portland Emco	Carboncor	UPM	
Bitumen content (%)	8.30	9.40	10.10	8.80	5.0 - 8.0
Stability (kN)	5.80	2.21	4.27	-	≥ 3.5
Flow(mm)	4.0	3.95	5.5	-	2 - 4
Voids in total mixture (%)	10.79	17.43	17.97	32.90	3 - 5
Voids filled with bitumen (%)	51.76	49.74	46.31	30.45	75 - 82

d) Strength Properties

Table 4 shows the stability and flow values for the various cold mix asphalts and the standard specification. Some tests could not be done on some samples of UPM due to the poor nature of the sample. Table 5 shows the same set of results for tests conducted with air-dried asphalt.

Table 5: Comparison of test results for air-dried asphalt method of testing

Property	Cold mix Asphalt				Standard specification **(FMW, 1997)** for hot mix wearing course
	Experimen-tal Asphalt	Portland	Carboncor	UPM	

Bitumen content (%)	8.3	9.40	10.10	8.80	5. - 8.0
Stability (KN)	9.58	4.37	9.79	1.00	≥ 3.5
Flow(mm)	4.5	4.85	5.5	6.85	2 - 4
Voids in total mixture (%)	12.30	16.18	21.27	29.65	3 - 5
Voids filled with bitumen (%)	49.02	51.98	41.74	33.96	75 - 82

3.2 Discussion of results

i) Sieve Analysis

The sieve analysis chart as presented in Figure 1, for the four asphalt samples under consideration, shows that the DPWS modified cold mix asphalts gradation comprised of adequate fines and coarse particles and lies perfectly within the grading envelop as specified by the Nigerian General Specification (FMWH, 1999), this situation also applies to Carboncor cold asphalt. The Portland Emco cold asphalt gradation shows too much fines particles while the coarse particle was found sparsely in the mix. The UPM Cold asphalt, from physical observation and the sieve analysis contains a single type of aggregates on sieve 2.36mm with no fines and no coarse particles making the binding of the asphalt difficult.

ii) Bitumen content

The bitumen content of the asphalt are presented on Table 2, this results show that all the asphalt did not comply with the Nigerian General Specifications (FMWH, 1999) recommendation for the hot mix. However, from the literature survey, a specification of 1% - 10% was found, making the DPWS asphalt and U.P.M to fall within the specified range while Portland Emco and Carboncor asphalt are slightly beyond the range of specification (Transportation Research Board, Washington DC. 2006)\

iii) Specific Gravity

Shown on Table 3, is the specific gravity of the aggregates that make up the asphalt. All of them are within the specification for crushed aggregates, as specified by BS 812 (1973)

iv) Marshall Test

Tables 4 and 5 show the strength properties of the various samples of cold mix asphalts at two different test methods as compared with standard for hot mix asphalts. Table 4 shows the strength properties for normal asphalt test method, while Table 5 shows air-dried asphalt method of testing. All the samples exhibited their highest stability values under the air-dried method.

v) Stability

The stability values of the various cold mix samples as seen on Tables 4 and 5 shows that DPWS Modified cold mix asphalt, Portland and Carboncor samples met the standard specification for hot mix and the UPM sample did not meet the standard specification. While the DPWS Modified cold mix asphalt and Carboncor samples had stability value far above the minimum requirement (see Table 4), the UPM sample stability value could not be tested, using the normal method, however 1KN was obtained when air dried.

vi) Flow

The flow values of the various cold mix samples as seen on Table 4 for the two different methods of testing (normal asphalt and air-dried asphalt methods) show that none of the sample had flow value is in the range of the hot mix standard specification but only in the normal asphalt method of testing. The Carboncor sample had flow values slightly above the range in all the methods of testing while the UPM sample had the highest flow value above the range for hot mix standard in the air-dried method of testing. The flow test could not be carried out on the UPM sample for normal asphalt method due to the poor nature of the sample.

vii) Voids in total mixture

From Tables 4 and 5, the percentage voids in total mixture of the samples were above the range of the hot mix standard specification in all the methods of testing.

viii) Voids filled with bitumen

The percentage voids filled with bitumen in all the cold mix samples were below the range of the standard specification for hot mix asphalt in all the methods of testing. All the above results suggest that there may be a need for new standard to be created for cold asphalt which is gradually gaining its way into the Nigerian market.

4. Conclusion and Recommendation

4.1 Conclusion

The tests conducted on all the sampled cold mix asphalt and the DPWS modified asphalt indicate that the properties of DPWS asphalt sample and Carboncor cold asphalt are closer to the standard in the Nigeria general specification. Closely following the DPWS asphalt and the Carboncor asphalt in term of properties and durability is the Portland Emcor asphalt and the least in term of properties and durability is UPM asphalt.

The average bulk density for DPWS asphalt was 1.93g/m^3 that of Portland Emco was 1.88 g/m^3; Carboncor had 1.74 g/m^3 while UPM had a bulk density of 1.6 g/m^3. The above values shows that the DPWS asphalt is the heaviest, closely followed by the Portland Emco and then by the carboncor asphalt while UPM is the least dense asphalt. It was also observed that Cold mix asphalt gain more strength in air than in hot water. This was evident from the result of stability obtained in Tables 4 and 5.

Furthermore judging from physical observation it was noticed that the aggregates in the UPM sample were not well distributed as their sizes were too close to each other. The samples could not meet all the requirements as contained in the Nigeria General Specifications for hot-mix asphalt. The best method of curing in cold mix asphalt is by air-drying asphalt. Surfaces with low flows and high stability will not deform easily but are likely to be brittle, while those with low stabilities and high flows deform easily under traffic. The stability is a function of both the inter-particle and the binder frictions.

4.2 Recommendation

Based on the laboratory tests and analysis obtained from the comparison of the various cold mix asphalts as compared with hot mix standard, the following recommendations were drawn,

- Aggregates for cold mix asphalt should be well distributed with different aggregate sizes. Air-drying should be used as a method of curing in cold asphalt. Cold mix asphalt is better used on medium and low traffic roads due to the time it takes before hardening.
- It is also recommended that new standard be introduced for cold mix asphalt instead of using the standard of hot mix asphalts because all the tested cold mix asphalt fell short of the HMA standard.

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