International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

The Study of the Mechanical Behavior of Bitumen Modify with A Polymer

[1.] Fokwa Didier
Assistant Professor
Department of Civil Engineering
Advanced teacher's training college for technical education
Douala, Cameroon.

[2.] Tchemou Gilbert
Lecturer
Department of Civil Engineering
Advanced teacher's training college for technical education
Douala, Cameroon.

[3.] Ngouffo Koukougnang René [*]
PhD Student
*Corresponding
Department of Civil / Mechanical Engineering
Industrial Engineering Faculty of Douala
Douala, Cameroon.

[4.] Mbe Jacob
Student
Department of Civil Engineering
Advanced teacher's training college for technical education
Douala, Cameroon.

[5.] Tetuh Raymond
Student
Department of Civil / Mechanical Engineering
Industrial Engineering Faculty of Douala
Douala, Cameroon

[6.] Fomethe Anaclet
Professor
Department of Physics
Faculty of Science
University of Dschang, Cameroon.

[7.] Talla Piere Kisito
Professor
Department of Physics Faculty of Science
University of Dschang, Cameroon.

***Abstract*:- Face with degraded roads and the demand for more tarred roads that are constantly expensive and with waste Polyethylene terephthalate (PET) plastic that is also an environmental problem. This work aims to study the mechanical behavior of bitumen mixed with PET white and blue polymer, and a mix of the two wasted plastics bottles. The several samples of bituminous concrete constituted 32 % of gravel 6/10, 15 % of gravel 4/6 and 53 % of stone sand 0/4, mixed with varying percentage of PET 4%, 6%, 8%, 10 %, 12% , 14% and binder bitumen 80/100 content of 6%. The different experiments carried out for several tests shown that the maximum value of resistance is obtained at 10 % of polymer (waste blue plastic bottle) comparatively to white and mixed white and blue. The increasing resistance of blue plastic is due to admixture like dye during it manufacturing process.**

Keywords: Polyethylene terephthalate (PET), binder bitumen, wasted white plastic bottles, wasted blue plastics bottles.

I. INTRODUCTION

Daily increasing of waste due to the rapid growth in population and industrialization has turned to rapid urbanization. This explosion into an urban way of live will necessitate enormous resources and supply of constructions materials to build the infrastructures such as airports, tarring roads, waste disposal constitute of non-biodegradable like PET plastic waste bottles from Tangui, supermont, Brasseries Tampico which forms the highest plastics that causes environmental pollution, floats, gutter blockages in towns and also give high cost of waste dispersal and recycling. The early degradation of road is due to the fatigue of the bitumen used, its high cost and its scarcity. Many researchers [1-12] look for alternative product or ways to modify the bitumen in favor of the customers and the environmental protection. The present work aims to analyze the possibility of using wasted drinking plastic bottles in manufacturing plastic-bitumen concrete. PET researchers like [1] obtained a maximum PET of 16.7% waste with reduction in penetration value, strength ratio TSR while [12] had a higher stability value at 0.4% of PET. [2] Also used calcium carbonate ($CaCo_3$) as fillers and water PET bottles shows that the mixture is more resistant to permanent deformation. [6] used PET oligomer waste to modify petroleum asphalt cement and had increase in resistance to disaggregation and durability of asphaltic mixture making it suitable for paving and [7] Used mixed PET plastic waste and had 10 to 12% by weight of bitumen and observed that there are improvement in penetration, ductility, softening point and viscosity. Some authors have used polyethylene and molten SBS polymer on the stability of the butime [13]; the polymer (95% plastomer) called PR PLAST S for the recycling of recycled concretes [14]; recycled polymers (polyethylenes, polypropylenes, polyether polyurethanes and truck tire rubbers) to modify the properties of bitumen [15]. Others have used plastic bags [16] on the consistency and stability of butime; high density polyethylene for the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

modification of a 35/50 butime [17]; waste from PET bottles to evaluate Marshall properties as well as density of asphalt mix [18-19].

The authors have observed that all researchers have not considered the colours of the waste drink bottles , so we decided to use the blue, white, mixed (blue + white) for the study that are the waste plastic PET bottles that cause environmental pollutions. At this end, three types of wasted plastic are considered: the white, the blue and their mix (white plus blue), in respective percentage of 4, 6, 8, 10, 12, 14 % PET in bituminous concrete through the several tests, analyses and interpretations of results. The studies of materials that fit with the bituminous concrete requirements were carried out.

II. MATERIALS AND METHODS

A. Materials

The materials used for the study are: Aggregates and stone dust from mile 8 Mankon– Cameroon rock quarry, bitumen 80/100, waste plastic polyethylene terephthalate (PET) bottles of Tangui, brasseries, Tampico, supermont drinks of two colors, blue and white.

1) Characteristics of materials

The table 1 bellow gives the composition of various components of the composites.

Table I: Various components of the composites.

Components	Quantity
Percentage of the Gravel 6/10	**32 %**
Gravel 4/6	**15 %**
Crushed Sand 0/4	**53 %**
Specific density of sand	**2.67**
Sand equivalent SE	**80 %**
Finess modulus	**3.6**
PET waste shredded plastic bottle size range	**1.25-5mm**
Specific gravity of the PET waste shredded plastic bottle	**1.38**
Softening point	**170°C**
Specific gravity of the bitumen	**1.1**
Softening point of the bitumen	**45°C**
Penetration point	**88mm**
Flash temperature	**230°C**
Fire point	**250°C**

2) Fabrication of modified bituminous concrete sample: dry method

Place the mould in position and oil it with glycerin. Make sure that the fabrication position is near the oven and the fire heater. Record the lab temperature. Measure the various aggregates that has pass through sieve analysis and abrasion test cleanliness of 1200g composed of 32% gravel 6/10, 15% gravel 4/6 and heat it at 170°C .Weigh the percent of shredded PET 4%, 6%, 8%, 10 %, 12% , 14% and spread inside the gravel, turn until it coat to the gravel. Add the sand at the same temperature and Heat the weighed bitumen on another fire at160°C then, quickly remove the aggregates from the oven and mix well in the bitumen when it is still hot at temperature 160°C, pour it in the mould and ram it on each side 75 blows. Take cool piece of cloth and round the mould till it cold at room temperature. Use sample extruder to remove the sample from the mould.

B. Methods

1) Grain size analysis of sand and gravel (NF p 94-056 April 1996)

Dry sample was weighed and recorded. The sample was then poured into a set of Sieves and sieved. The set of sieves were placed on the mechanical agitator that did the sieving. Cumulative weight passing and retained through each sieve was recorded. The percentage passing and retained for each sieve was calculated as a percentage of the total sample weight. Fineness modulus was obtained. The results show the presence of coarse aggregates.

2) Sieves analysis of polymer (PET)

Scredded pieces of white and blue waste plastic bottles and sheared to color. Through the sieve analysis select size < 5mm (look Fig. 1).

Fig. 1: White and Blue PET polymers.

3) Specific density test

Select the various aggregates trough the designer size and with pycnometers come out with the specific density of each aggregate.

4) Los Angeles abrasion

From aggregate sample collected from sieve analysis, 5100g was weighed and washed. Sample was placed in an oven at 105°C to dry for 24 hours. Aggregates were sieved through a column of sieves ranging from 0.08mm to 10mm of diameter classified from top to bottom. Aggregates were corresponding to the aggregate classes 6/10. 5000g of material was weighed and labelled. Repeat twice as above to obtain a total of 3 samples each weighing 5000g. Samples were labelled A, B and C respectively. Sample B was heated to about 160°C in oven. 50g Shredded plastic was spread over hot aggregate (160°C) from oven. Both heated aggregate and plastic were manually mixed in a hot mixing pot for about 1 to 2 minutes to enable aggregate to blend with the plastic. Sample was removed from hot pot and placed in a bowl and allowed to cool at room temperature. 5000g of sample was weighed (note: The original weight of the aggregate of 5000g from the above step is increased as a result of the added plastic) .Repeated with sample C adding 100g of shredded plastics. Sample A was placed in the Los Angeles Abrasion machine with 11 balls of 400g each. The machine was switched on ran 500 turns for approximately 17 minutes. Material was removed from the machine into a container avoiding the possible losses of aggregates. Steel balls were removed and the sample was placed in a bowl and weighed.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

The sample was washed with the sieves of meshes 1.70 mm in orders to eliminate particles of less than 1.70 mm. (material passing→ degraded, material retained→ intact). The washed sample was then placed into the drying oven at 105˚C to dry for 24 hours.
Then the sample was removed from the oven and weighed and the Los Angeles Abrasion was calculated. The results show that the polymer increases the resistance of gravel.
Abrasion coefficient for the coated aggregates with PET ranging from 12.64 to 7.54 with is less than 15%. It implies that the Los Angeles is very good.

5) Softening point of bitumen and bitumen plus plastic

Heat he bitumen 80/100 between 75˚C-100˚C, stir it, heat the rings and fill it with bitumen , cut the excess with the knife, put the steel ball in position in the brass ring at the centre of bitumen and put the thermometer in the right position (Fig. 2). Then heat the bitumen until the steels fall at the bottom of the water bath, record the average temperature. Percentages (White, Blue and mixed).

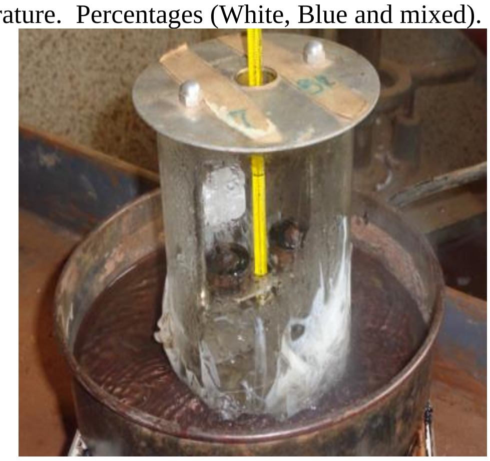

Fig. 2: Softening apparatus.

6) Penetration at 25 ºC of bitumen and bitumen plus PET in %

Heat he bitumen 80/100 between 75˚C- 100˚C, stir it, fill the cup it with bitumen, allow it to cool at ambient, immerge the cup in water bath at 25˚C, remove the cup, put the penetrometer at least three measurements of the surface of the sample and record the average reading.

7) Flash point and fire point of bitumen and pet plastic

The flash point is taken as the temperature at which the thermometer reads at the time of the flame application that causes the material to ignite. Fill the material up to the mark and place it on pen- sky, insert the thermometer, stir it, light the test flame and supply heat at a rate not least than 5˚C per minute till the flash ignite.

8) Marshall stability of bitumen and bitumen plus PET

The determination of the various resistances of samples passes through the Marshall apparatus (Fig. 3). Measure the average height, the average diameter, the weight of each and identify it. Each sample is introduced in the hot water bath at 60˚C for 30 minutes. Remove it, weight it and test it in the machine.

Fig. 3: Marshall Apparatus

9) The flow value of bitumen and bitumen plus PET

The determination of the various flows of samples passes through the Marshall apparatus. Measure the average height, the average diameter, the weight of each and identify it. Each sample is introduced in the hot water bath at 60˚C for 30 minutes. Remove it, weight it and test it in the machine.

10) Normal Duriez test of bituminous concrete.

The sample is placed in the mould on the automatic press at the pressure of 180 KN for 5 minutes, then the plate comes back automatically to the initial position which enable us to dismantle the sample after cooling for 4 hours. The samples are numbered and the weight recorded with the geometrical measurement to control the sample. The apparent volumic mass Mva from the geometrical measurement is calculated. The Sample is wax at 70˚C. Determine the apparent volumic mass by weighing the sample in water. Conserved half the sample in air and in water at 18˚C for 7 days then introduce the sample to the machine for compressive test and read the results. Determine the real volumic mass of bituminous concrete and calculate the percentage of compacity.
We concluded that the sample of bituminous concrete can be used for tarring the road because the result is within the range of 91<C %< 95 (**NF EN 12591**).

11) Comparative estimated cost of bitumen required to tar 1km of road

The details costing for the complete realization of constructing and tarring one kilometer of road will not be detailed in this project since the only difference in the cost is in the application of the final layer using bituminous concrete as the surface dressing with compacted volume.

III. RESULTS AND DISCUSSION

A. Sieves analysis and Los Angeles results

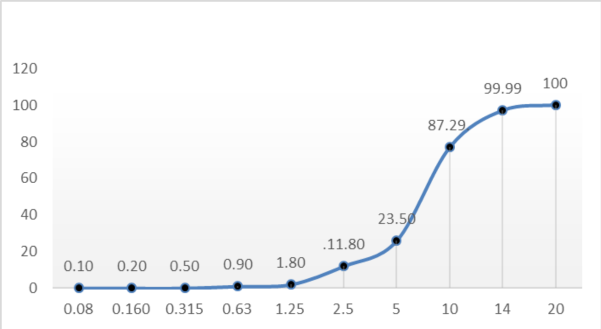

Fig. 4: Sieve analysis % of aggregates passing.

The results of fig. 4 mainly show the presence of coarse aggregates. Table 2 gives us the references of Los Angeles and Fig. 5 the variation of the coefficient of Los Angeles according to the% of plastic.

Table II: Reference for L A (AFNOR 1985)

Reference values	
Los Angeles coefficients	Appreciation
< 15	Very good
15 to 25	Good
25 to 40	Weak
> 40	Poor

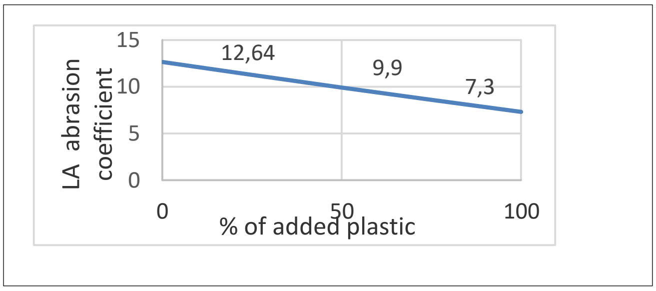

Fig. 5: Graph–LA Test- varying percentage of added plastics

Abrasion coefficient for the coated aggregates with PET ranging from 12.64 to 7.30 with is less than 15 %. It implies that the Los Angeles is very good.

B. Softening point of bitumen and bitumen plus plastic results

The recorded values are seen on the table 3 below and the graph (Fig. 6).

Table III: Softening values of modified bitumen with PET in %

Softening Point of each sample							
Designation	Percentage of PET polymer						
	O %	4%	6%	8%	10 %	12 %	14%
White plastic	45	45. 50	46. 02	46. 50	46. 70	47.0 5	48.02
Blue plastic	45	46. 05	47. 25	48. 00	49. 21	51.5 0	60.14
(White + Blue) plastic	45	45. 75	46. 62	47. 25	47. 85	48.5 2	54.01

From the above table 3, the curves of the various softening points of the bitumen modified by the waste plastic bottles are obtained.

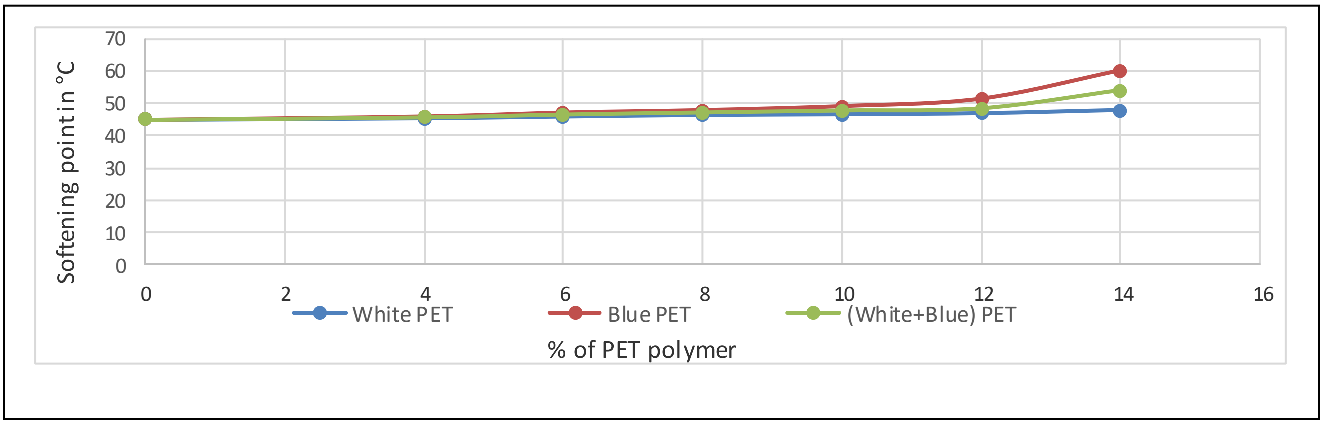

Fig. 6: Curve of softening points for various % of polymer.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

The softening point at 25˚C is 45˚C and it is between 42˚C and 48˚C, which characterises 80/100. In general the softening point increase with added percentage of polymer but differently with the type of polymer. Comparing this result with the Materials (ASTM 946) it is within the range 42 to 48

C. Penetration point of bitumen and bitumen plus plastics

The both mixture of bitumen and plastic at different percentages (White, Blue and mixed), give the following values (Table 4).

Table IV: Penetration values of various percentage of polymer.

Penetration Point of each sample							
Designation	Percentage of PET polymer						
	0%	4%	6%	8%	10%	12%	14%
White plastic	88	86	75	70	65	58	55
Blue plastic	88	86	80	72	65	61	57
(White + Blue) plastic	88	87	85.6	75	70	65	60

Then the curves of the various penetration points of the bitumen modified by the waste plastic bottles are given below Fig. 7.

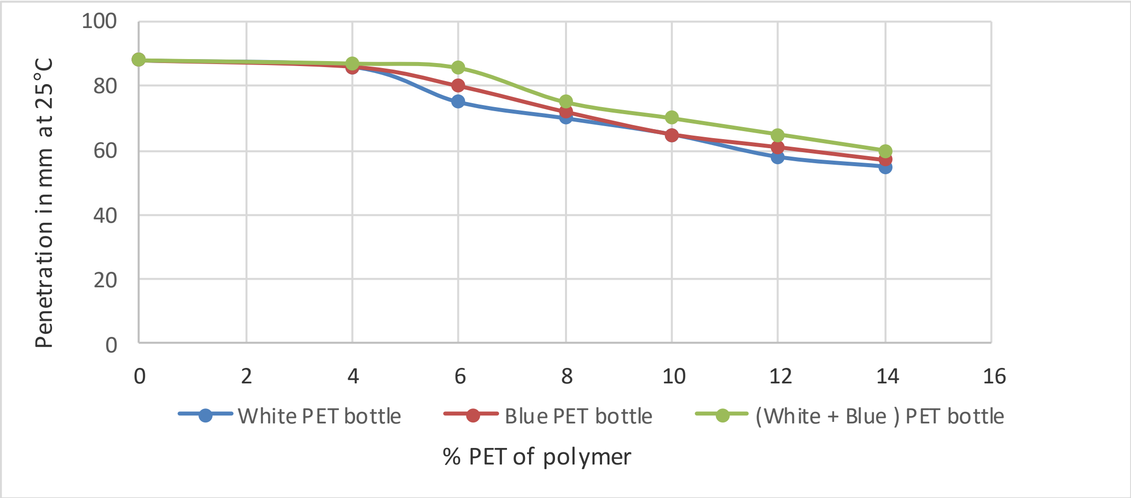

Fig. 7: Bitumen polymer penetration at 25ºC

The penetration point at 25˚C is 88mm proud the presence of bitumen 80/100 and generally decreasing with adding of plastic polymer. Comparing this result with the Materials (ASTM 946) it is within the range 80 to 100.

D. Flash point and fire point of bitumen and pet plastic

The average of the temperature of the flash point of bitumen is equal to 230˚C. The heating continuous until the material ignite and burn for at least 5 seconds. The temperature recorded at that time is 250˚C which represent the fire point.

E. Marshall Stability of bitumen and bitumen plus PET

Table V: Value of stability in KN of various samples

Value stability of each sample in KN						
Designation	Percentage of PET polymer					
	4%	6%	8%	10%	12%	14%
White plastic	11	14.10	16	15.02	12	10
Blue plastic	15.2	18.3	19	19.3	17.7	16.1
(White + Blue) plastic	13.4	16.2	17.5	18.3	16	15

From the above table 5 the various curves (white, blue and white + blue plastic bottles) were obtained Fig. 8.

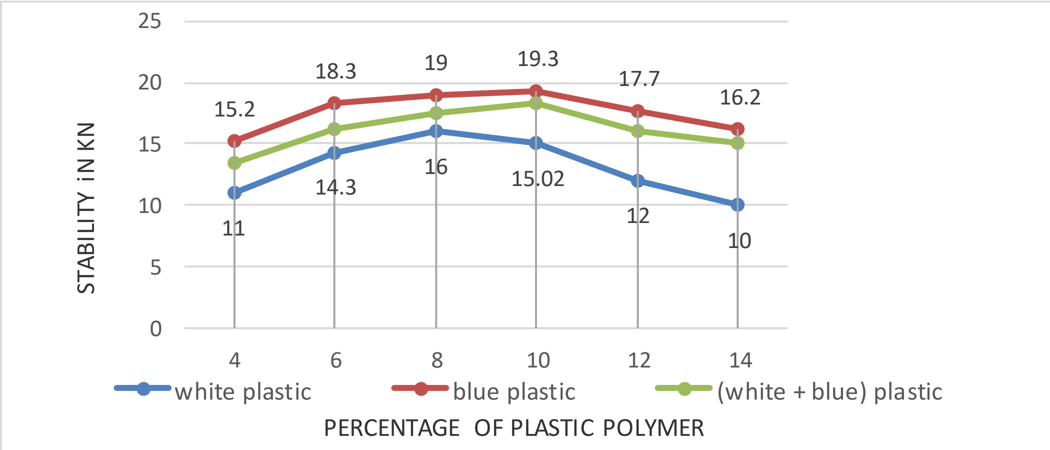

Fig. 8: Curve of Marshall

The experiment with white waste plastic bottles has the lowest resistance while the blue waste plastic bottle has the highest value of Marshall Stability test of 19.3KN at 10% of PET. That let us to search why the strength of the blue plastic was higher than the white. We discovered that the additive or colorant added to the plastic as dyes or pigment increase the resistance of the PET.

F. The flow value of bitumen and bitumen plus PET

The various flows were recorded following by theirs curves.

Table VI: The flow value of various samples in mm

Flow value of each sample in mm						
	Percentage of PET polymer					
Designation	4%	6%	8%	10%	12%	14%
White plastic	2.52	3.00	3.40	3.60	3.80	4.44
Blue plastic	2.30	2.50	2.52	2.53	3.40	3.80
(White +Blue) plastic	2.48	2.51	2.52	2.80	3.50	4.20

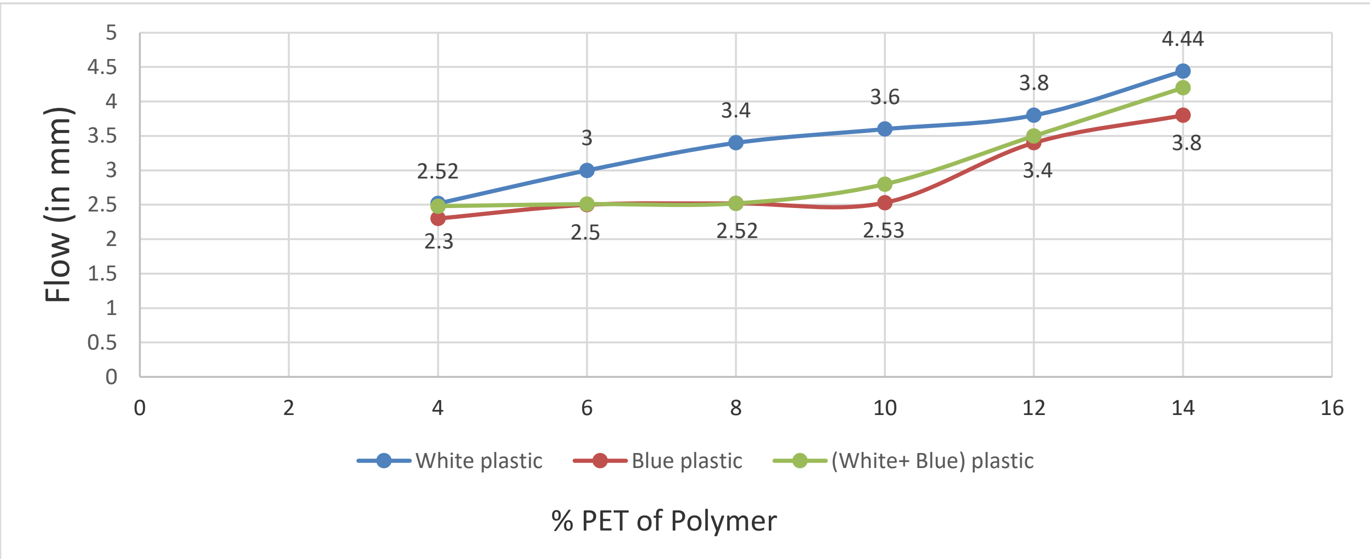

Fig 9: White, Blue and mix waste plastic bottle – Flow

The flow is increasing with the added % of binder but at certain at 12% of the bitumen is out of the range which is 2 to 4mm. At 10% the blue waste plastic has 2.53 while the white waste plastic is 3.6 mm (Fig. 9). The flow value of various samples in mm is given in Table 6.

G. Normal duriez test of bituminous concrete.

Table VII: Compaction stability table

Designation	**Weight 1 (g)**	**weight2 (g)**	**Diameter (cm)**	**Height (cm)**	**volume 1 (cm^3)**	**Mva (g/cm^3)**	**Mvr (g/cm^3)**	**C in %**
Bitumen	1202,5	1201	10,06	7,5	595,84	2,015	2,2	91,591
White plastic	1201,1	1200	10,06	7,5	595,84	2,014	2,16	93,239
Blue plastic	1200	1199	10,06	7,5	595,84	2,012	2,18	92,307
White + Blue plastic	1200,1	1200	10,06	7,5	595,84	2,014	2,15	93,673

We concluded of table 7 that the sample of bituminous concrete can be used for tarring the road because the result is within the range of 91<C %< 95 (**NF EN 12591**).

H. Comparative estimated cost of bitumen required to tar 1km of road

The details costing for the complete realization of constructing and tarring one kilometer of road will not be detailed in this article since the only difference in the cost is in the application of the final layer using bituminous concrete as the surface dressing with compacted volume.

Table VIII: Comparative saving cost for using 10% PET to tar 1Km road

ITEMS	BITUMEN (Tons)	PET Polymer (Tons)	Cost of bitumen from mercuria (FCFA)	Cost of PET bottles/Tons (FCFA)	TOTAL COST (FCFA)
Normal road	189	0	615 371	0	116 306 064
Bitumen	170.1		615 371	0	104 674 607.1
10%PET	0	18.9	0	200 000	3 780 000
Saving balance for 10%PET					7 851 456.9

The table 8 give comparative saving cost for using 10% PET to tar 1Km road. There is definitely an overall financial savings. For every fifteen kilometers of road tarred using modified waste PET polymer, one kilometer of road can be added. This may appear small, but any kilometer of paved road constructed in any locality has an enormous impact to the economy of that area. This technology is worth investing in and keeping our environment save.

CONCLUSION

The reduction of bitumen at 10% and replace with PET gives a good resistance compare to the specimen with pure bitumen 80/100.Care should be taken for the control of temperature during the fabrication and the placing of the bituminous concrete. The Blue Plastic polymer presented the highest resistance in compression and the Marshall compressive stability among them.

The Blue Plastic has the best flow among them due to his flow within the range [2 at 4 mm].The used of modified bituminous concrete will reduce the cost of the tarred road. The creation of jobs by using employers collecting the waste plastic bottles. Much research should be done for the determination of the best filler or colorant that increase the Marshall Stability resistance as compare to the white waste plastic bottles and the mixture of white plus blue plastic bottles.

ACKNOWLEDGEMENTS

Thanks are due to the Head of the Civil Engineering Department of Advanced Teacher's Training College for Technical Education (ENSET) of Douala-Cameroon for his help in various stages of the experimental work.

REFERENCES

[1] A. O. Sojobi, S. E. Nwabodo and O. J. Aladegbaye, ''Recycling of ploythylene terephthalate waste plastic bottles,'' Journal About Doi 101080/2331116-2015.1133480 February 2016.
[2] D. T. Mohamed and Z. H. Hussein, ''the use of pyrolysis polyethylene terephthalate (PET) as asphalt concrete mix,'' International Journal of Science, Engineering and Technology Research (IJSETR), Volume 3, Issue 11, November 2014
[3] G. Polaco, J. Stastna, D Blondi, and L. Zanzotto, ''Relation between polymer architecture and non-linear viscos-elastic behaviour of modified asphalts,'' Current Opinion in Colloid and Interface Science. 11. ISSN: 2231-5381. http://www.ijettjournal.org, pp. 230-245, 2006.
[4] J. S. Chen, M. C. Liao and C. H. Lin, ''Determination of polymer content in modified bitumen,'' Materials and Structures, Vol. 36, pp. 594-598 November 2003.
[5] J. P. Morgan and A. Muller, ''The shell bitumen industrial handbook survey,'' Publisher ASM International 320 pages, 1995.
[6] L.C Mendes, M.L. Dias, P.S.C Perira, L. M.B. Albuquerque, ''PET Oligomer waste to modify petroleum asphalt,'' Materials and Applications, Vol 3 pp. 575- 579, 2012.
[7] M. S. Ahmad and F. Mahd, ''Characterisation of bitumen with plastic waste (PET),'' IJTE, Vol. 3, Issue 2, Page 1260 Spring 2015.
[8] M. D. Earnest, ''Performance Characteristics of polyethylene terepthalate (PET) modified asphalt.Electronic,'' Theses and dissertation paper 1260 Http: // digital commons.georgiasouthern.edu/etd, 2015.
[9] M. Akinpelu, B. I. O. Dahumsi, O. Olafusi, O. Awogboro and Adedeji, ''Effect of polyethylene modified bitumen on properties of hot mix asphalt,'' ARPN Journal of Engineering and Applied Sciences, VOL. 8, NO. 4, April
[10] Reikizahia and Rabah Amel, ''Performance Evaluation of Polymer Modified Asphalt Mixtures,'' International Journal of ICT-aided Architecture and Civil Engineering, Vol.1, No.2, pp.33-50 June 2014.
[11] S. N. Nemade and P. R. A. V. Thorat, ''Utilization of polymer waste for modification of bitumen in road construction,'' Sci. Revs. Chem. Commun.: 3(4), pp.198-213 ISSN 2277-2669, 2013.
[12] T. B. Moghaddam and M. R. Karim, ''Properties of mixtures containing waste polyethylene terephthalate,'' Construction and Building Materials: pp. 236-242, 2012.
[13] U. A. kumar and P. V. V Satyanarayana , ''Comparison of Polyethylene and SBS Polymer Modified Bitumen Effect – A Case Study,'' International Journal of Engineering Trends and Technology (IJETT), Vol.22 Number 7- page 326, April 2015.
[14] B. Melbouci and S. Sadoun, ''Valorisation des bétons bitumineux recyclés et étude de leur renforcement,'' Invaco2: Séminaire International, innovation & valorisation en genie civil & materiaux de construction n° 1 P-185, 2011.
[15] M. Murphy, M. O'Mahony, C. Lycett and I. Jamieson, ''Bitumens modified with recycled polymers,'' Materials and Structures / Matériaux et Constructions, Vol.3,3, pp 438-444, 2000.
[16] H. Kowanou, D. A. Tchehouali, E. A. Sanya et A. K. Vianou, ''Effets de l'incorporation du fondu de déchets de sachets plastiques sur la consistance du bitume et la stabilité du béton bitumineux,'' Afrique Science 10(2), pp 39-52, 2014.
[17] W. Boughamsa and M. Belachia, ''Modification d'un bitume 35/50 par du Polyéthylène à Haute Densité,'' Invaco2: Séminaire International, innovation & valorisation en genie civil & materiaux de construction n°: 2 P-058, 2011.
[18] T. B. Moghaddam, M. R. Karim and M. Soltani, ''Utilization of waste plastic bottles in asphalt mixture,'' Journal of Engineering Science and Technology, Vol. 8, No. 3 pp 264 – 271, 2013.
[19] R. Choudhary, A. Kumar, and K. Murkute, ''Properties of Waste Polyethylene Terephthalate (PET) Modified Asphalt Mixes: Dependence on PET Size, PET Content, and Mixing Process,'' Periodica Polytechnica Civil Engineering, https://doi.org/10.3311/PPci.10797 , Février 2018.