International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 8 Issue 08 Series. III || Aug 2019 || PP 35-40

Stability of Polymer Modified Asphaltic Concrete

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ABSTRACT: *Recent increases in road traffic, coupled with insufficient maintenance in developing countries have contributed immensely to accelerated and continuous deterioration of the road network. Polymer modified binders have been shown to improve adhesion, cohesion, stiffness and general stability of bituminous materials. This paper reports an investigation on the performance of high density polyethylene (HDPE) as additive bitumen modifier on the permanent deformation of asphalt concrete. Marshall design parameters were used in the study and Marshall stability method was also used in determining the stability characteristics. The research was carried out in three stages. The first stage involved the mix design of the control specimen without addition of polymer. In the second stage, filler was removed completely (about 9%) and substituted with equal amount of polyethylene. The third stage involved the replacement of some percentage of bitumen (about 1.5%) with equal percentage of polyethylene. Marshall mix design technique was used to determine the optimum binder content and to test the modified mixture properties. Tests were carried out to determine specific gravity of aggregates, bulk density, air void and stability characteristics. Results obtained from the three samples were compared based on Marshall design criteria. The results indicated that by substituting 1.5% by weight of bitumen with equal amount of polyethylene, both stability and air voids were increased. Hence, the Marshall stability for modified mix is higher than the control mix*

KEYWORDS: *Asphalt Concrete, Bitumen, Polymer Modified Binder, Polyethylene, Stability.*

Date of Submission: 20-08-2019 Date of acceptance: 02-09-2019

I. Introduction

Under the effect of heavy traffic loading, high temperatures and water damages, specific requirement are needed to control the quality of highway pavement materials in order to increase its durability. The major road deterioration occurs due to extraordinarily high temperature, and excessive lack of solar isolation during summer and heavy loading [1]. The increase in road traffic during the last two decades in combination with an insufficient degree of maintenance due to shortage in funds has caused an accelerated and continuous deterioration of road network [2]. A high– performance pavement calls for resistance to high – temperature rutting and low – temperature cracking [3].

The term asphalt is applied to a black cementation material with varying consistency at room temperature from solid to semi – solid. It can be poured when heated to the temperature of boiling water. It is present in most crude petroleum from which refining process separates it [4]. Asphalt concrete consists of a binder and graded aggregate. Asphalt cement has diverse applications and is commonly used in flexible highway and airport pavements owing to their adhesion properties and visco-elastic properties [5]. Several factors influence the performance of flexible courses, e.g. the properties of the components (binder, aggregate and additive) and the proportion of these components in the mix. Bitumen can also be modified by adding different types of additive [6, 7]. Polymer is one of these additives. The excessive use of polymers (plastics, polyethylene, nylons etc) in our day to day life has made solid waste management especially in urban areas a major problem. Annual waste generation in the world is about 1.3 billion tons and these waste most times are non-biodegradable. These plastics are made of toxic pollutants with the potential to cause great harm to the environment [8, 9].

The addition of polymer typically increases the stiffness of the bitumen and improves its temperature susceptibility. Increased stiffness improves the rutting resistance of the mixture in hot climates and allows the use of relatively softer base bitumen, which in turn, provides better low temperature performance. Polymer modified binders also show improves adhesion and cohesion properties [10, 11]. The polymers used in modifying bitumen are classified as plastomers, or elastomers. Plastomers include ethylene vinyl acetate, polyethylene (un-stabilized and stabilized) and various compounds based on polypropylene [12]. They increase the viscosity and stiffness of bitumen at normal service temperatures. However, they do not increase the elasticity of bitumen significantly and on heating, they do not perform satisfactory. Elastomers (rubbers) include natural rubber, polybutadiene, polysoprene, isobutene–isoprenecopolymer, polychloroprene, styremebutadiene copolymer and stryrene – butadienestyrene block copolymer [13].They describes the ability of a material to return to its original shape when a load is removed. These polymers increase the bitumen viscosity rather than elastomeric strengthening. The use of polymers as modifiers will greatly reduce their environmental pollution.

II. Materials And Methods

2.1 MATERIALS

The materials used are aggregate, bituminous material, mineral filler, and polyethylene is used as an additive.

2.1.1 AGGREGATE

The aggregate used in this study is crushed aggregate. The aggregate was dried to a constant weight and separate them by sieving into the desired size fractions. Normally, all material passing the No. 8 sieve, except mineral filler, which may be added as a separate ingredient, makes up one size fraction. The following size fractions are recommended as generally adequate for the course of this research 15mm, 12.5mm, 9.5mm, 6.3mm, 2.8mm, 1.25mm, 0.6mm, 0.30mm. 0.15mm, 0.075mm.

Asphalt Cement (Bituminous Material). The asphalt cement 40/50 was used in this research. Some basic laboratory tests were conducted on the bitumen to evaluate its physical properties and they are: softening point, flash point, ductility, penetration and specific gravity.

2.1.2 POLYMER (POLYETHYLENE)

The term “polymer” means a combination of a large number of similar small molecules or “monomers” into large molecules or “polymers”. A molecule of polyethylene is a long chain of carbon atoms, with two hydrogen atoms attached to each carbon atom. They are light in weight and have good mechanical properties so it can be added to asphalt in order to enhance its mechanical properties. Factors that influence the flow behaviour of polyethylene melts can be grouped into external and internal variables. External variables include temperature, pressure, time, stress and flow geometry whereas internal variables cover molar mass and molar mass distribution, molecular architecture and nature of the chain.

2.2 METHODS

2.2.1 MINERAL FILLER

0/5mm stone dust was used in this study as filler.

Preparation of sample (mixes)

The performance of an asphalt mixture is a function of right determination of proportion of aggregate and asphalt and air.

2.2.1.1 MARSHAL METHOD

The concepts of the Marshal method of designing bituminous paving mixtures were formulated by Bruce G. Marshall, formerly a Bituminous Engineer with Mississippi State Highway Department. Marshallspecimens prepared with various asphalt cement content were tested to determine Marshall properties. These tests have been standardized by the American Society of Testing and Materials. It may be used for both laboratory design and field control of asphalt hot mix paving. The test is performed on each specimen in accordance with procedure described by ASTMD1559.[10] Principal features and procedure of the tests are as follows:

The specific gravity of the blended aggregate is found by:

$$G_{sb} = \frac{100}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \dots \frac{P_n}{G_n}} \qquad 1$$

Where

G_{sb} = bulk specific gravity of the blend

$P_1, P_2 \dots P_n$ = respective percents of aggregates 1, 2, etc and

$P_1 + P_2 + \dots P_n = 100$

$G_1 + G_2, \dots G_n$ = respective specific gravities of aggregate 1,2etc .

2.2.2 DETERMINATION OF THE BULK DENSITY

The bulk density of a specimen is taken as the ration of its dry weight in air to its bulk volume in accordance with standard test method of as ASTM D2726.[10] And it is estimated by:

$$G_{mb} = \frac{W_A}{W_{SSD} - W_w} \qquad 2$$

Where:

G_{mb} = Bulk density of the compacted specimen

W_A = Weight of specimen in air (gm)

W_{SSD} = Weight of saturated surface dry specimen
W_w = Weight of specimen in water (gm)
Specific gravity of material (S.G.M)

$$G.M = \frac{100}{\frac{\%Bit}{S.G,Bit} + \frac{\%Aggt}{S.G.Aggt}} \qquad 3$$

2.2.3 VOID ANALYSIS

There are two voids assessments that were made: are voids in mixed aggregate (V.M.A) and voids filled with Bitumen. Both of the void analysis is expressed as percentage and they are calculated as following:

i. Voids filled with Bitumen:

This is an expression of the mixed aggregate, which were filled with bitumen, it is calculated from;

$$\text{Void filled with Bit} = \frac{\text{VolumeofBit}}{\text{Volumeinmixedaggregate}} \times 100 \qquad 4$$

ii. Voids in mixed aggregate:

Thisdetermination is recommended by the asphalt institute and is determined from the bulk specific gravity of the compacted specimen and the bulk specific gravity of the aggregate.

Void in mixed aggt = (100 – volume of aggt) 5

Where

$$\text{Volume of Bitumen} = \frac{\text{Bitumencontent} \times \text{BulkDensity}}{\text{S.G.Bit}} \qquad 6$$

$$\text{Volume of Aggregate} = \frac{100 - \text{Bitumencontent} \times \text{BulkDensity}}{\text{S.G.Bit}} \qquad 7$$

2.2.4 EVALUATING AND ADJUSTING MIX DESIGNS

In the process of developing a specific mix design, often it is necessary to make several trial mixes in order to satisfy the design criteria of the particular design method that are used. Where the trial mixes fail to meet the design criteria, it is necessary to modify or in some cases, redesign the mix. Certain adjustments in the gradation of the aggregate blend, within the specification limits, are required to correct the deficiency. The objective should be for adequate stability and maximum durability.

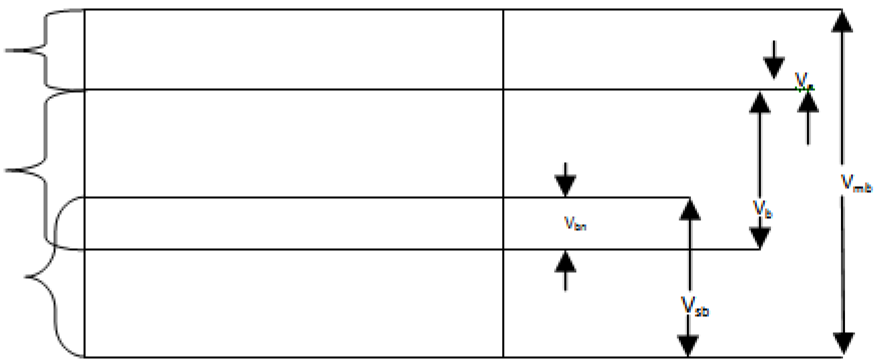

Figure 1 Density – Voids relationships of a compacted specimen of asphalt paving mix.

Where;
V_{mb}= volume of compacted specimen
V_a = volume of air voids
V_b = volume of asphalt
V_{sb} = volume of aggregate (by bulk specific gravity)
W_b = weight of asphalt
W_s = weight of aggregate

$$\text{Density of compacted specimen} = \frac{W_b + W_s}{V_{mb}} \qquad 8$$

$$\text{Voids in miner al aggregate} = \frac{W_{mb} - W_{sb}}{V_{mb}} \qquad 9$$

$$\text{Voids in compacted specimen} = \frac{V_n - (V_{sb} - V_{ba} + V_b)}{V_{mb}} \qquad 10$$

III. Result And Discussion

The selected mix design is usually the one most economical and satisfactory meeting all established criteria, mixes having abnormally high values of Marshall stability and abnormally low flow values are often less desirable because pavements of such mixes tend to be rigid or brittle and may crack under heavy traffic.

3.1 Marshall Stability

From Marshall design criteria the stability for heavy traffic should range from 750kg for minimum and above for maximum and, flow should also range from 20mm for minimum and 40mm, for maximum. Table 1, 2 and 3 show respectively the Marshall stability values for control and the modified mixes against filler and asphalt content.

Therefore from the result analysis it could be seen that the whole result from the three samples are in the specified limit. Sample “C” forms the most economical and satisfactory result since its flow is the less one and its stability is within the design criteria. Sample “B” is the least result among the three results because its flow is too high to compare with the other two samples and this is due to the increment in the bituminous material and the filler removal.

3.2 ECONOMIC ANALYSIS

As it is known that highways are economic venture. Therefore, the demand is becoming more and more important that the proposed highway improvement or new construction programmes must be most economical. That the benefits derived from the proposed programme must be more than the cost incurred on it. Hence it requires careful economic analysis to determine the comparative advantages of various proposals of design and construction programmes.

SAMPLE A
MARSHALL TEST DATA

Table 1.This sample A is used as control (guide)

Types Of Asphalt: Wearing Course

a	b	c	d	e	F	G	H	i	j	k	l	m	n	o	p	q	r	s
Mix Reference	Temperature	Bitumen content	Bitumen content $\frac{C \times 100}{100+C}$	Weight in Air	Weight in air after 1 hr. soaking	Weight in air after 1 hr soaking	Volume f - g	Bulk Density $\frac{e}{h}$	S. G. M. $\frac{100}{\frac{\%Bit}{S.G.Bit}+\frac{\%Aggt}{S.G.Aggt}}$	Volume of Bitumen $\frac{d \times i}{SG.Bit.}$	Volume of AGGT $\frac{(100-d)\,xi}{SG.AGGT.}$	Void in mixed Aggt. (100 – 1)	Void in mix 100 - (k+1)	Void Filled with Bit 100 x k/m	STABILITY	STABILITY CORP. RATIO	Corrected Stability	FLOW
	°C	P.H.A	%Wt.	gm	gm	Gm	ml	g/ml	gm/ml	%	%	%	%	%	kg		kg	0.1mm
				1200	1202	704.0	498	2.41	2.441	14.11	84.62	15.38	1.27	91.74	2414	1.04	2510.5	2.11
Av.			6.0															

MIX PROPORTION	**5/15mm =**	**27%**	
	0/5mm =	**38%**	
	N/Sand =	**20%**	
	Filler	**=**	**9%**
	Bit	**=**	**6%**

SAMPLE B

MARSHALL TEST DATA

Table 2.In this sample filler was removed completely and substituted with the same percentage of polythene

TYPES OF ASPHALT: WEARING COURSE

a	b	c	d	e	F	G	H	i	j	k	l	m	n	o	p	q	r	s
Mix Reference	Temperature	Bitumen content	Bitumen content $\frac{C \times 100}{100+C}$	Weight in Air	Weight in air after 1 hr. soaking	Weight in air after 1 hr soaking	Volume	Bulk Density	S.G.M. $\frac{100}{\frac{\%Bit}{S.G.Bit}+\frac{\%Aggt}{S.G.Aggt}}$	Volume of Bitumen $\frac{d \times I}{SG.Bit.}$	Volume of AGGT $\frac{(100-d)xi}{SG.AGGT.}$	Void in mixed Aggt. (100 – 1)	Void in mix 100 - (k+1)	Void Filled with Bit 100 x k/m	STABILITY	STABILITY CORP. RATIO	Corrected Stability	FLOW
	°C	P.H.A	%Wt.	gm	gm	gm	ml	g/ml	gm/ml	%	%	%	%	%	kg		kg	0.1mm
				1195	1195	685	510	2.343	2.441	13.72	74.39	25.61	11.89	53.57	750	1.0	750	2.94
Av.			6.0															

MIX PROPORTION	**5/15mm =**	**27%**	
	0/5mm =	**38%**	
	N/Sand =	**20%**	
	Polythene	**=**	**9%**
	Bit	**=**	**6%**

SAMPLE C

MARSHALL TEST DATA

Table 3.In this sample some percentage of bitumen were removed and replaced with the same percentage of polythene

TYPES OF ASPHALT: COURSE WEARING

a	b	c	d	e	F	G	H	i	j	k	l	m	n	o	p	q	r	s
Mix Reference	Temperature	Bitumen content	Bitumen content $\frac{C \times 100}{100+C}$	Weight in Air	Weight in air after 1 hr. soaking	Weight in air after 1 hr soaking	Volume f - g	Bulk Density	S. G. M. $\frac{100}{\frac{\%Bit}{S.G.Bit}+\frac{\%Aggt}{S.G.Aggt}}$	Volume of Bitumen $\frac{d \times I}{SG.Bit.}$	Volume of AGGT $\frac{(100-d)xi}{SG.AGGT.}$	Void in mixed Aggt. (100 – 1)	Void in mix 100 - (k+1)	Void Filled with Bit 100 x k/m	STABILITY	STABILITY CORP. RATIO	Corrected Stability	FLOW
	°C	P.H.A	%Wt.	gm	gm	gm	ml	g/ml	gm/ml	%	%	%	%	%	kg		kg	0.1mm
				1196	1190	700	490	2.441	2.441	10.72	85.70	14.30	3.5	74.97	1600	1.09	17.77	20
Av.			4.5															

MIX PROPORTION	**5/15mm =**	**27%**	
	0/5mm =	**38%**	
	N/Sand =	**20%**	
	Filler	**=**	**9%**

Polythene = 1.5%

Bit = 4.5%

IV. Conclusion

In the bid for providing lasting solution to our highway pavement and the reduction of its cost, this research was carried out. When one considers the national expenditure on both new and rehabilitated pavement, when one considers the present zero residual life of most of our roads, it is important that alternative methods of Asphaltic concrete production like the one described in this project be utilized as quickly as possible. Accordingly, we should not settle for something simplistic in the interest of expediency. It is important that technical merit rather than tradition and ease of implementation drive the selection of the construction technique.

In this project, it has been established that polythene can be used as an additive in asphalted concrete production to enhance its performance. Polythene and bitumen are both thermoplastic and as such they are compatible. Some percentage of bitumen were removed and substituted with polythene and its stability and flow were within the Marshall design criteria.

References

[1]. Lamia A. A, Improvement of Marshall Properties of the Asphalt Concrete Mixtures Using the polyethylene as Additive, Eng. and Technology, Vol. 25(3), 2007, pp. 383–394

[2]. Mohammed T. A. and Lins S, The use of Polyethylene in Hot Asphalt Mixtures. American Journal of Applied Science, Vol. 3(6), 2007, pp. 390–396.

[3]. Chen J.S., Liao M.C. and Shaih M.S, Asphalt Modified by Styrene-butadiene-styrene triblock copolymer: Morphology and Model, J. Mater. Civil Eng. Vol. 14(3), 2002, pp. 224–229.

[4]. Neville A. M, Properties of concrete, 3rd edition Great Britain, Pitman Press Bath 1981.

[5]. Ait–Kadi .A., Brahimi .B. and Bousmine .M, Polymer blends for enhanced asphalt binders, Polymer. Eng. Sci. Vol. 36(12), 1996, pp. 1724–1733.

[6]. Subagio .B.S., Djnnaedi .K. and Busnial D.T., Development of stiffness modulus and plastic deformation characteristics of porous asphalt mixtures using tafpack super, Proceed. Eastern Asia Soc. Transportation studies, Vol.5, 2005, pp. 803-812.

[7]. Saez–Alvan L.D.P., Liedi B.B., and Edson D,M, Mechanical behaviour of Asphalt mixtures in regions of low temperature and attitude above 3800 meters, 2003 Int. Conf. Airports: Planning, Infrastructure & Environ. Rio Dc Janeiro–RJ–Brazil June 8–11 2003.

[8]. Syed S. A. S, Fazi E.J, Ahsan .N, Saeed .U. R and Kashif .M, Stability analysis of polymer modified binder asphalt, Conference paper, Environmentally Sustainable Development ESDev-VI, 2017.

[9]. Aymen .A, Khalil .A.M, Feras .A.A and Omar .S, Utilizing of polyethylene and plastic wastes for paving asphalt modification in Jordan, International Journal of Current Research, Vol.11, Issue 01,2019, pp 491-498.

[10]. CaH .O.V, Investigation of polymer modified asphalt by shear and tensile compliances. Material characterization for inputs into AASHTO 2002 Guide Session of the 2004 Annual Conf. Transportation Assoc Canada, Quebec City, Quebec.

[11]. ASTM Standard, Road and Paving Materials, Travelled Surface Characteristics, Annual Book of American Society for Testing and Materials Standard, Section 4,Vol. 0403 1989.

[12]. Hansen K.R., Robert B.M., Brian .P. and Anne S., Current and future use of non–bituminous components of bituminous paving mixtures. Committee on characteristics of Non–bituminous Components of Bituminous Paving Mixture: A2DD2. On-line pubs. trb.org/onlinepubs/millennium/00079.pdf.

[13]. Coplantz J.S., Yapp M.T., and Finn F.N, Review of relationship between modified asphalt properties and pavement performance. SHARP–A–631, Strategic Highway Res. Program, National Res. Council Washington, USA 1993.

Enem J. I" Stability of Polymer Modified Asphaltic Concrete" International Journal of Engineering Science Invention (IJESI), Vol. 08, No. 08, 2019, PP 35-40