Available online at www.uofk.edu
Proceedings Vol. 1 pp. 22-27
Annual Conference of Postgraduate Studies and Scientific Research
17-20 February 2012-10-17 Friendship
Hall, Khartoum

The Use of low density Polyethylene carry-bags waste in Hot Asphalt paving mixtures

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Abstract: This paper reports an investigation on the effect of shreded low density polyethylene (LDPE) as a bitumen modifier on the permanent deformation of asphalt concrete using Marshall Design parameters. The parameters assessed include the compacted hot-mix density, the percentage of air voids in the mixture, and in the mineral aggregate, the percentage of voids filled with bitumen, in addition to Marshall Stability and flow. The effect of LDPE on some physical properties such as penetration, softening point and ductility was also investigated. Bitumen was mixed with the LDPE 2 - 10% by weight of bitumen at 160-180°C and it was found that Marshall Samples prepared with the modified binder provide the specification limits and that using higher percentage of plastics waste causes the polymer to separate from the blend. A modified technique was developed where the stone aggregate was coated with molten LDPE(10-25%) , the plastics waste coated aggregate (PCA) was then used as the raw material for flexible construction. PCA shows better binding properties. It has less wetting property with much less voids and higher Marshall Stability value.

Keywords: *Low density Polyethylene; modified bitumen; aggregate; Hot-mix; PMB and PCA.*

1. INTRODUCTION

Today the availability of the waste plastics is enormous, as the plastic materials have become part of daily life. They either get mixed with Municipal Solid Waste and/or thrown over land area. If not recycled, their present disposal is either by land filling or by incineration. Both the processes have certain impacts on the environment. Under this circumstance, an alternate use for the waste Plastics is needed.Thinner polythene carry bags are most abundantly disposed of wastes, which do not attract the attending rag pickers for collection for onward recycling, for lesser value Bitumen is a useful binder for road construction. Different grades of bitumen like 30/40, 60/70 and 85/100 are available on the basis of their penetration values [3]. The steady increase in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature demand improved road characteristics. Any improvement in the property of the binder is also the need of the hour. these polythene/polypropylene bags are easily compatible with Bitumen at specified conditions. The waste polymer bitumen blend can be prepared and a study of the properties can throw more light on their use for road laying.

2. Objectives

- Environmentally: Utilization of waste plastics especially polyethene carry bags which is a very hot issue nowadays.
- Economically: Saving: The bitumen (imported from other countries) required can be reduced depending upon the percentage of polymer added.
- Increasing roads durability: The new engineering properties gained by polymer modification keep road life for longer time.
- Technically: To study the effect of adding polyethylene on the hot mix asphalt.

- To identify the best mechanism of adding the polyethylene to the mixture to achieve better mixture properties.

-To determine the optimum percent of asphalt and polyethylene in the hot mix asphalt.

3. Materials and Methods

Bituminous material: Asphalt binder 60/70, 85/100 were used in this research. The laboratory tests performed to evaluate the bitumen properties were: Specific Gravity, Ductility, Flash and fire Points, Penetration and Softening point. The properties of asphalt binder, which are presented in Table 1, Table 2 are within the specification of penetrated asphalt grade 60/70, 85/100 respectively.

Table (1). International Properties of used asphalt binder grade 60/70 Specification

Test	Result	Unit	Specification Minimum	Maximum
Penetration	64	0.1 mm	60	70
Softening point	55	C^0	46	57
Ductility	100	cm	-	100
Flash point	235	C^0	250	-
Fire point	316	C^0	-	350
Specific gravity	1.02	____	1.01	1.06

Table(2). International Properties of used asphalt binder grade 85/100 specification

Test	Result	Unit	Specification Minimum	Maximum
Penetration	95	0.1 mm	85	100
Softening point	47	C^0	45	52
Ductility	100	cm	-	100
Flash point	243	C^0	225	-
Fire point	314	C^0		350
Specific gravity	1.03	____	1.01	1.05

Aggregate

The coarse and fine aggregates (1/2",3/4",3/8",3/16",sand) used were brought from El -Sleet(North Bahri) and Gbal Toria (West Omdurman).The filler used was calcium carbonate obtained to supplement the fine materials size in hot mix asphalt (HMA) mixture design. The laboratory tests performed on coarse aggregates were: Los Angeles Abrasion (ASTM C131 – 81), Aggregate Impact Value, Sieve Analyses (ASTM C136-84) Water Absorption, Specific Gravity (ASTM C127 – 88), The tests for fine aggregates were: sieve Analyses (ASTM C117 – 87) Specific Gravity (ASTM C128 – 88) and Water Absorption, while for filler the test was Specific Gravity only.

Table (3). Properties of used aggregate

	Coarse Aggregate	Fine Aggregate	Filler
Specific Gravity (SG)	2.78	2.92	2.912
Water Absorption	2.65%	2.0%	2.3%
Impact Test %	%17		
Corrosion percentage: Loss Angeles Test	30.6%		

Low density Polyethylene

It is the most popular plastic in the world. Polyethylene is semi-crystalline materials with excellent chemical resistance, good fatigue and wear resistance and a wide range of properties. It has a very simple structure. 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; provide good resistance to organic solvents with low moisture absorption rates. The mechanical and physical properties are shown in Table 4:

Table (4). Thermal and physical test of low density polyethylene

Physical properties	Metric value
Density	0.917 - 0.932 g/cc
Thickness	12.7 - 150 microns
Melt Flow	0.180 - 60.0 g/10 min
Thermal Properties	Metric value
Melting Point	107 - 121 °C
Crystallization Temperature	95.0 - 104 °C
Vicat Softening Point	85.0 - 107 °C

The percentages of polyethylene (LDPE), that were added to the asphalt mixture and designed after determining the optimum bituminous material content (% of mixture weight), were 2 , 3 , 5, 7, 10 % (by weight of bitumen content) in PMB(polymer modified bitumen) method and 10,15,25% in PCA(polymer coated aggregate) method. Three samples for each percent polyethylene were prepared and tested.

Sample preparation

The performance of an asphalt mixture is based on the determination of the correct proportion of aggregate and asphalt and air, which are measured by volume [3]. To determine the optimum bituminous content that would produce asphalt concrete mixtures with strength and durability properties that meet the MPWH specifications,

18 samples each of 1200 gram in weight were prepared according to the proposed mix design. Three samples were used to prepare asphalt mixtures with one-bitumen content. The average values of three samples for the unit weight, Marshall stability and flow properties for each binder content were determined. Seven binder contents were considered (4,4.5, 5, 5.5, 6 and 6.5%). All examined asphalt concrete mixtures were prepared in accordance with the standard 75-blow Marshall design method for designing hot asphalt concrete mixtures, designated as (ASTM Designation: D 1559-89) using automatic compaction.

PMB (Polymer modified bitumen) method

Polyethylene carry bags were cut into pieces using a shredding machine. It was sieved and the plastic pieces passing through 4.75mm sieve and retaining at 2.36mm sieve were collected. These plastic pieces were added slowly to the hot bitumen of temperature around 160-180C. The mixture was stirred well using mechanical stirrer for about 20-30 minutes. Polymer-bitumen mixtures of different compositions were prepared and used for carrying out various tests. Two grades of hot modified bitumen 60/70 and 85/100, were added to the weigh aggregate (1200g)with different types (1/2",3/4",3/8",3/16",sand,filler and ratios (15%,20%,20%,30%,10%,5%) respectively. The percentage of addition of modified bitumen to the aggregate are 4, 4.5, 5, 5.5, 6, 6.5 % .Three blocks (test samples) of each percentage were prepared and compacted with the compactor machine and used for carrying out hot mix Marshall tests.

PCA (polymer coated aggregate) method

In this method, initially the aggregates were heated to around 170°C. Then the plastic wastes, in the form of small pieces (passing 4.75 mm sieve – normally with a thickness of 60 micron and below) were added to the heated aggregate. This had enabled to give a uniform coating of plastics waste over the aggregates. To this hot plastics coated aggregates, the hot bitumen was added. A uniformly coated mix blocks were obtained. These were used for carrying Marshall Tests.

4. Results & Discussion

Depending on the specifications of the pure bitumen Sample of grade 60/70 stated by the Ministry
Of Roads and Bridges, it was found that the modified samples results(Table 5&6) ,lies within the threshold of the standards for the following tests:

i. Penetration test 60-70 ,85-100
ii. Softening point 35-75^{0}C
iii. Ductility MAX 100 cm
iv. Flash point MIN 450 ^{0} F (232^{0}C)
v. Fire point MAX 675 ^{0} F (357^{0}C)

Table (5). Bitumen sample (60/70) modified with LDPE %

Test	2%	%3	%5	%7	%10	Unit
Penetration	66	44	45	61	7	0.1mm
Softening point	49	50	66	52	100	C^0
Ductility	100	100	85	68	14	cm
Flash point	290	310	330	260	298	C^0
Fire point	380	373	357	321	360	C^0
Specific gravity	1.03	1.03	1.03	1.02	1.02	____

Table (6). Bitumen sample (85/100), modified with LDPE%

Test	2%	%3	%5	Unit
Penetration	79	69	33	0.1mm
Softening point	50	58	62	C^0
Ductility	100	88	69	cm
Flash point	310	272	310	C^0
Fire point	370	330	320	C^0
Specific gravity	1.05	1.05	1.05	____

It is observed that the softening point increased by the addition of plastic waste to the bitumen. Higher the percentage of plastic waste added, higher is the softening point. The influence over the softening point may be due to the chemical nature of polymers added. The increment in softening point leads to reducing bleeding and withstanding high temperature climate.
The penetration values of the blends are decreasing depending upon the percentage of polymers and the type of polymer added. The increase in percentage of polymer decreases the penetration value. This shows that the addition of polymer increases the hardness of the bitumen. Therefore Lower penetration value; withstands higher load.one of the positive & important results obtained was that the grade 85/100 changed to 60/70 penetration which means technical and economical benefits.
The ductility is decreasing by the addition of plastic waste to bitumen. The decrease in the ductility value might be due to interlocking of polymer molecules with bitumen.
Flash and fire point of plain bitumen is 235-320^{0}C. From the experimental results it is observed that the inflammability of the blend is decreasing as the percentage of polymer increases. The blend has developed better resistance to burning. The polymer bitumen blend road surfaces will be less affected by fire hazards.this enhances handling and storing conditions.

Evaluation and adjustment of Mix Design

The overall objective of the mix design is to determine an optimum blend of different Components that will satisfy the requirements of the given specifications (Table7).

Table (7). Hot-mix standard design criteria

property	Value
Stability, KG	<1000
Air Voids, %	3-5
VMA, %	16-20
Flow, mm	2-4
Unit Weight, g/cm3	2.45>

The optimum modifier content is selected as the content that satisfies the following:
* Maximum Bulk Density
* Maximum Marshall Stability
* Minimum Flow
* The minimum AV (air voids) or the closet percentage to AV content of 4%
* Maximum VMA(voids in mineral aggregate) content

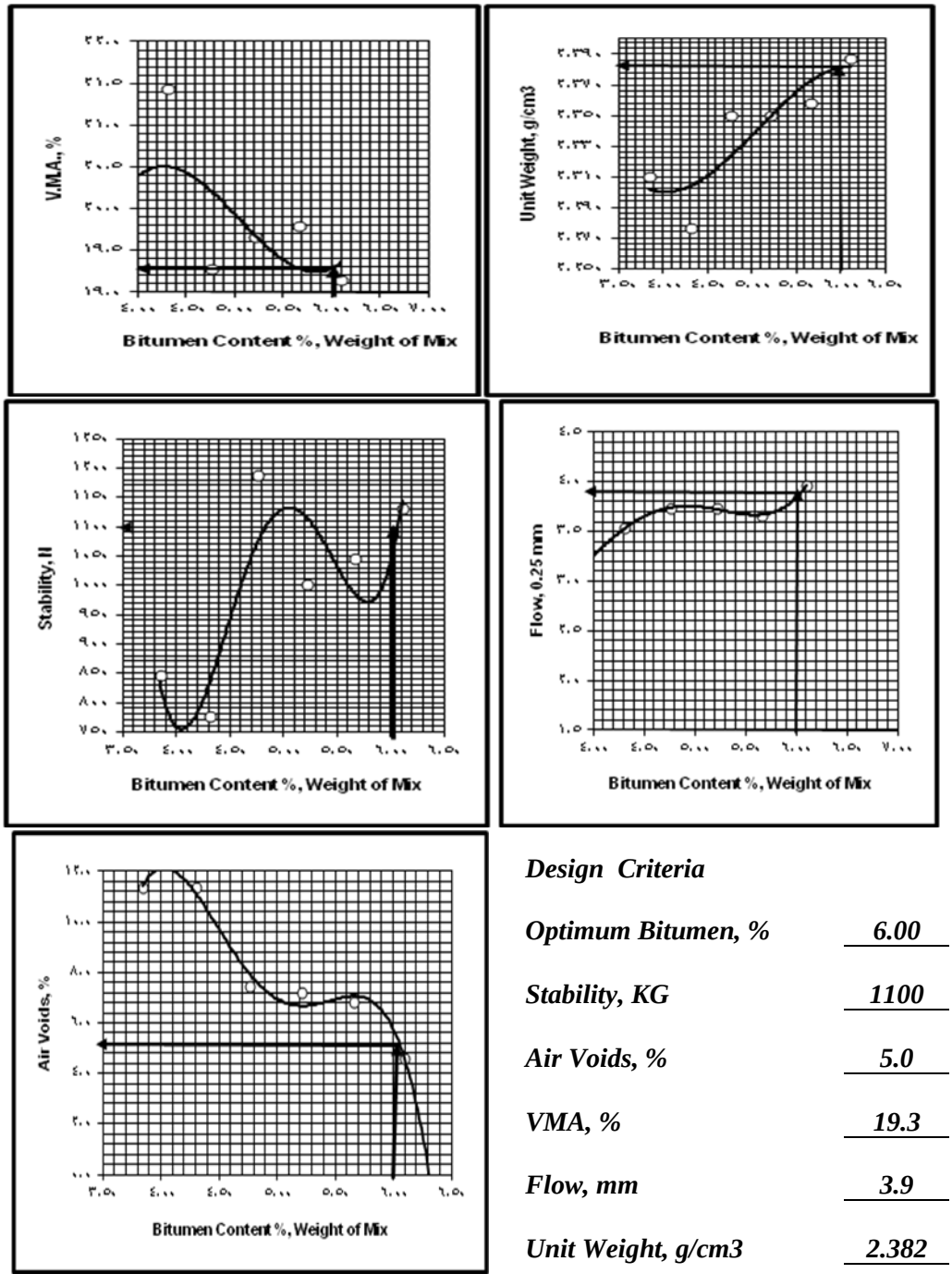
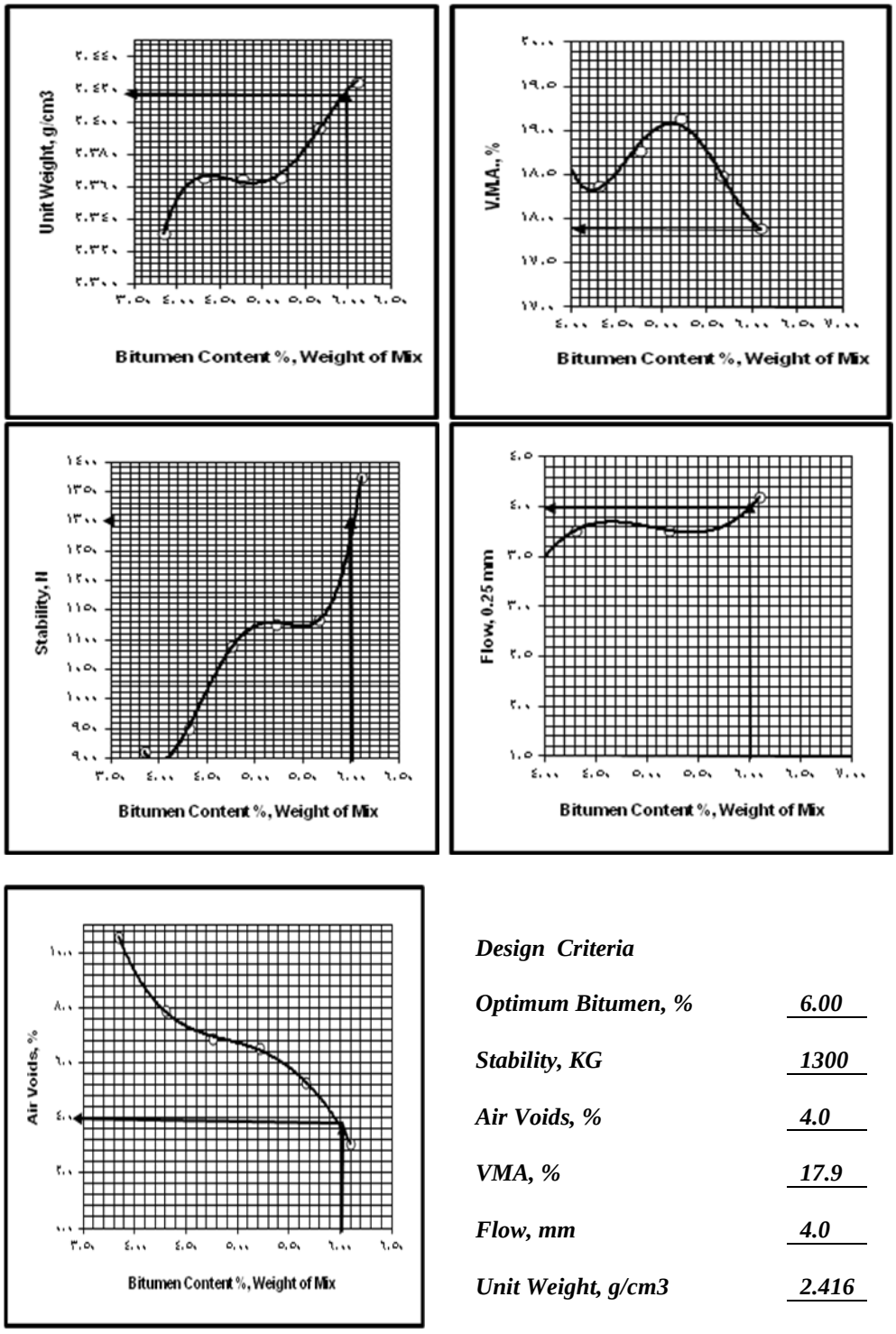


Figure (1). Marshall Test Results–Typical plots of PMB method (7% LDPE, 60/70 bitumen)



Design Criteria	
Optimum Bitumen, %	***6.00***
Stability, KG	***1300***
Air Voids, %	***4.0***
VMA, %	***17.9***
Flow, mm	***4.0***
Unit Weight, g/cm3	***2.416***

Figure (2). Marshall Test Results–Typical plots of PCA method (25% LDPE, 60/70 bitumen)

Both above mix design results passed effectively the international and local specifications.

From the above graphs, showing various typical relationships, it can be observed that:

- Density initially increases with asphalt content, since the fluid lubricates grain movement. Eventually, however, a maximum density is reached. Then density decreases, since the lighter asphalt replaces some of the aggregate, shoving the particle apart.
- Stability increases and then decreases on a curve similar to that for density, since the strength is mainly a function of friction between grains of aggregates and, therefore, of density.

- Flow increases along with asphalt content, as friction between particles decreases with thicker asphalt films.
- The percentage of air voids decreases as asphalt content increases, since the asphalt tends to fill all the void spaces.
- The percentage of voids in mineral aggregate is approximately opposite to the density curve, as the mass of aggregates is the main component of the total mass of the mix.
- The percentage of voids filled with asphalt also increases with asphalt content.

5. CONCLUSION

The generation of plastics waste is increasing day by day. The major polymers namely polyethylene show adhesion property in their molten state. The plastic coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of plastics waste. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many aspects.

6. Recommendations

- A serious step should be taken by the official authorities to apply the research.
- Researches should be continued with further efforts in the same field, specially the blending of different bitumen grades.
- Production of bitumen locally in order to reduce the imported amounts.
- Enhancement of quality control techniques regarding both, experimental and practical pavement side.

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