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Effects of Polymer on Properties of Asphalt Concrete Mixture by Using Solid Waste

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Abstract: - The monolithic mixture of gravel, sand, and mineral powder is made up in part of the asphalt binder by bitumen. Due to its adhesive qualities and capacity to transform into a liquid at high temperatures and a solid at low temperatures, bitumen serves this purpose. Bitumen is the most susceptible of all the asphalt components to the impacts of traffic loads and climate conditions due to its thermoplasticity and low strength. Bitumen softening in warmer weather leads to road rutting, and winter brittleness causes low-temperature cracking. By using polymer additives such latex, terpolymers, and thermoplastics of the polyethylene type, bitumen properties such as durability of asphalt concrete can be improved. This trash also needs to adhere to two conditions. The first need is that it work with bitumen. Second, although perhaps not to the same extent as specific modifiers, it must provide bitumen the necessary positive qualities. According to the study, "recycled" polyethylene produced by processing plastic goods (such as films intended for agricultural use or packaging material) satisfies these criteria. Recycled polyethylene increases the viscosity, cohesive strength, and heat resistance of bitumen. The results of the experiments were used to create efficient polyethylene-based combinations that significantly reduced the amount of pricey specialty polymer modifiers needed to make bitumen. Recycling solid waste for use as aggregate (coarse, fine, filler) in asphalt mixtures is the aim of this research. It was the optimum asphalt ratio 4.883, so we use three percent (2, 3,4and5) % of polyethylene by the weight of optimal asphalt, due to increases the tensile strength and improves the durability of highway pavement in the binder layer. The purpose of using solid waste is to reduce cost and dispose of solid waste.

Keywords: modified bitumen, polyethylene, solid waste

I. INTRODUCTION

For a number of reasons, it is challenging to carry out trustworthy field performance comparisons on open roads. When test pavements fail, user costs and reconstruction costs are often very high, therefore there may be a disincentive to try out novel techniques and materials [1]. In the development of highways, runways, parking lots, and driveways, pavement is crucial. The most popular form of transportation in the world is paved, and total miles of paved roads are frequently used to gauge a nation's progress [2],[3]. Pavement is a strong layer-based framework for roadway engineering. The natural dirt is placed atop these layers (sub-grade). These layers' primary purpose is to distribute the applied vehicle loads to the underlying soil. The pavement's design should be able to produce a surface that rides well, has suitable skid resistance, is good at reflecting light, and emits little noise. The pavement's structural design can be divided into two categories based on its structural performance. Pavements fall into two categories: inflexible pavements and flexible pavements. The surface layer (surface course and binder course), base layer, and sub-base layer are the three categories into which the flexible pavement layers can typically be separated. The foundation layer and surface layer are normally constructed using different materials, and their placement during construction is done separately. Wheel loads are applied to flexible pavements by the aggregate coming into contact with the granular structure on a grain-to-grain basis. The flexible pavement behaves like a flexible sheet since it has less flexural strength. For firm pavement, concrete slabs are used to build the top layer (reinforced or non-reinforced). The concrete slab structure's stiffness and high modulus of elasticity can be used to provide the load carrying capability [4],[5],[6] .To assess the admixture qualities of the altered blends, a research center trial of, backhanded elasticity, held security was led on a compacted Marshall examples. The determination of polymer type should have minimal expense, tough, great attachment, and accessible. Various sorts of polymers are locally accessible, however one kind of polymer chose in this study polyethylene.

II. MATERIALS AND METHODS

A. *Asphalt Cement*

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The investigation used asphalt cement with a penetration grade of (40–50) that was purchased from AL-Kirkuk. (Table I) compares the physical features of asphalt with the real characteristics of this type of asphalt cement [7], [8], [9], [10], [11], [12], [13].

TABLE I The Asphalt Cement's Physical Characteristics

No.	Test	ASTM	Results	Requirements
1	Penetration 25°C, 100 gm, 5 sec, 1/10 mm	ASTM D5	47	40-50
2	Ductility (25°C, 5 cm/min.), Cm	ASTM D113	110	Min.100Cm
3	Ring &ball Softening Point, C°	ASTM D36 AASHTO T53	68	Min.65 C°
4	Flash Point, C°	ASTM D92 AASHTO T48	232	Min.230 C°
5	Rotational Viscometer at 135C°, cst	ASTM 4402 AASHTO T316	1830	Max.3000 cst
6	Dynamic shear ,Kpa	AASHTO T315	2.94	Min.1 Kpa
7	Storage stability, C°	ASTM D7173	1.5	Max.4C°

B. Aggregate

The aggregate used in this study, which brought from solid waste in Mosul. This type of total (solid waste) was generated from demolished buildings. The gruff and soft aggregates (solid squander) were sifted and in the legitimate extents to come upon the degree as needed (SORB/R9) specification [14]. Physical characteristics of solid waste aggregate are provided in (Table II), and the aggregate's gradation curve is shown in (Table III) and (Table IV).

TABLE II Aggregate Physical Properties (solid waste)

No.	Property(ASTM C127&128)	Coarse	Fine
1	Bulk specific gravity	2.52	2.6

2	Apparent specific gravity	2.61	2.66
3	Percent water absorption	0.6	0.7

TABLE III Gradation as required by SCRB \R9

Binder layer			
Sieve size(In)	**Sieve size(mm)**	**%(passing)**	**Average &research mix**
1	25	100	100
03-Apr	19	90-100	95
01-Feb	12.5	76-90	83
03-Aug	9.5	56-80	68
No.4	4.75	35-65	50
No.8	2.36	23-49	36
No.50	300 µm	5.19	12
No.200	75 µm	03-Sep	6

TABLE IV Aggregate Physical Properties [15] [16]

Property	ASTM Designation No.	Coarse aggregate	Fine aggregate	ASTM limits
L.A. abrasion	C 131-06	20.7	-------	40 Max.
Bulk Sp.gr.	C127-93	2.64	2.67	------

C. Mineral Filler

The asphalt mixes prepared by filler from crush building as mineral filler, which obtained from solid waste in Mosul city.

TABLE V Sieve Analysis of Mineral Filler

Sieve size(In)	Sieve size(mm)	Percentage Passing by Weight (%)	SCRB Specification
No.30	0.600	100	100
No.50	0.300	100	100

No.200	0.075	72	75-100

D. Polymer additives

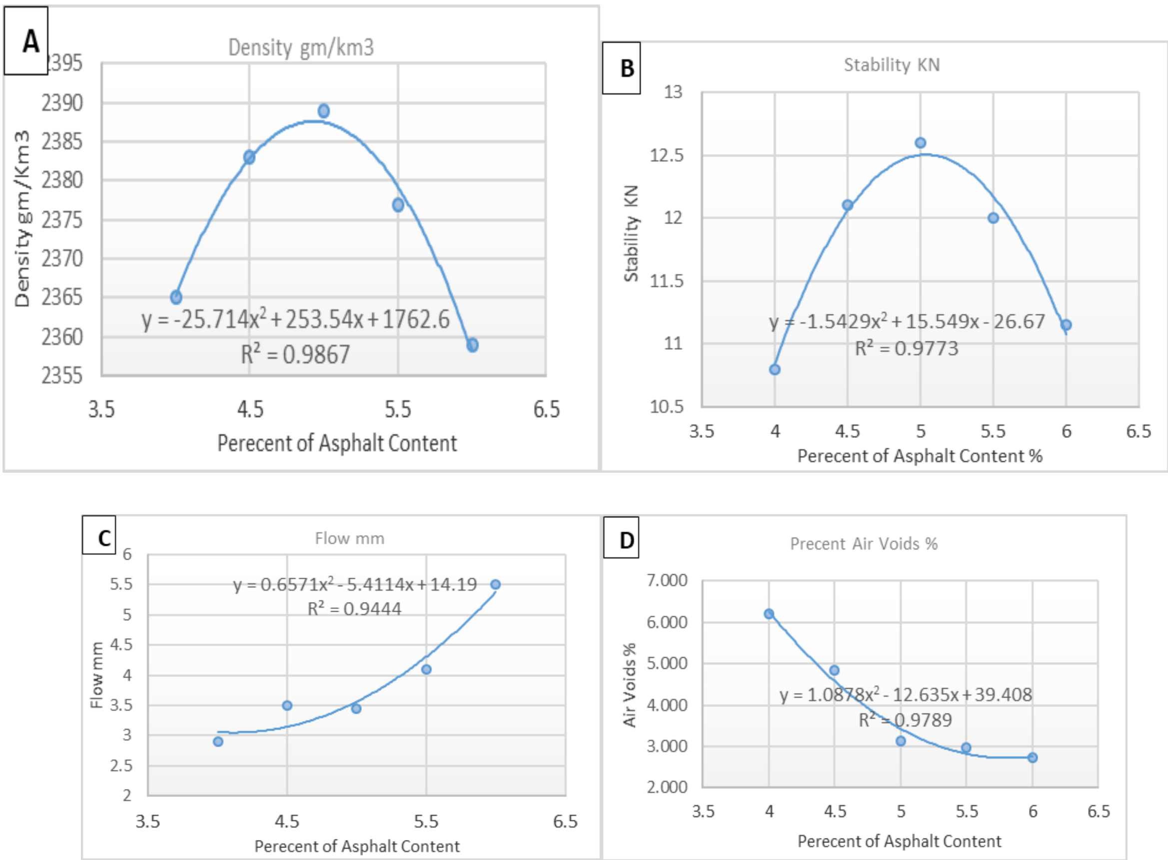
The type of polymer chosen must be affordable, robust, excellent for adhesion, and readily available. However, just one kind of polymer—polyethylene—was chosen for this study to assess in asphalt paving mixtures. By adding one percent of polymer to four percent of asphalt by weight, these polymers will be used to change asphalt cement.

III. Asphalt Mixture Design

Asphalt blend made utilizing the Marshall Mix design technique as per by (SORB/R9) specification.

A. Asphalt Mixture without additives

Prior to being added to the heated aggregates and filler in the mixing tank, asphalt cement with a known weight was heated in the furnace to a temperature of 150Co. The components were appropriately combined until the asphalt covered every particle. The liquid poured into the prepared mold, 75 blows administered to the top and bottom of the specimen, before it removed. For each asphalt content, three Marshall Specimens made. At a deformation rate of 51 mm/min (2 in/min) and a temperature of 60 °C, the Marshall test was performed. During the test, the values for Marshall Stability and flow behavior were established. The greatest load that the asphalt mixture can support is referred to as stability. The yield behavior is the deformation as soon as the load begins to decrease. Stability is evaluated in (KN), and sloppiness in (KN) (mm). To determine the Marshall characteristics, several asphalt-cement compositions of Marshall Specimens were created and tested. The optimal asphalt content of the various blends calculated to be equal to (4.883). Figure (1) include (A, B, C, D, E&F) shows Marshall Properties.



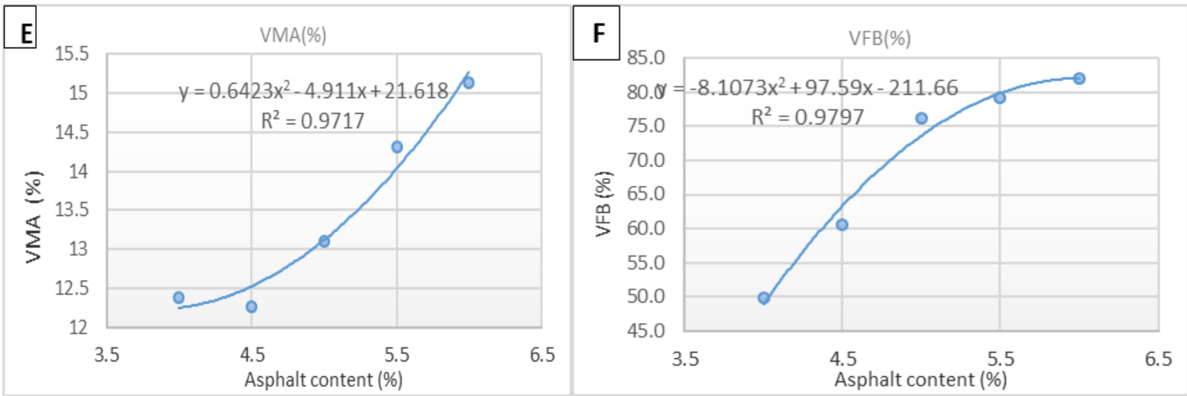


Figure 1: Marshall Properties

B. Asphalt Mixture with additives

Polymer is added at a rate of 2, 3, or 5% by weight of ideal asphalt to known quantities of asphalt cement that have been heated to a temperature of 160°C in a furnace and mixed thoroughly for one hour. Asphalt is then combined with polyethylene using a mix shear device. [17], then append to the adjusted asphalt to the aggregate. All of the components mixed properly until modified asphalt completely covered all of the particles. The fluid filled the pre-arranged mold, 75 blows managed to the top and lower part of the example, before it eliminated. For each asphalt content, three Marshall Specimens made. The Marshall test was conducted at a temperature of 60°C and a deformation rate of 51 mm/min (2 in/min).

It should mind to make polymer completely viable in the admixture to forestall polymer division during blending, which will cause an issue of conflicting fastener quality.

IV. Rheological Test for PE Modified Asphalt

A. Penetration Test

The findings of laboratory experiments showed that the polymer concentration and storage temperature had an impact on the shape of PE modified binders. When using control and significantly changed asphalt mixtures. In general, the trend of consistency declines when polymer is added. As the mix's polymer content rises, so do the penetration values for modified binders. Figure (2) shows the variation of penetration values with the various percentages of PE modified asphalt.

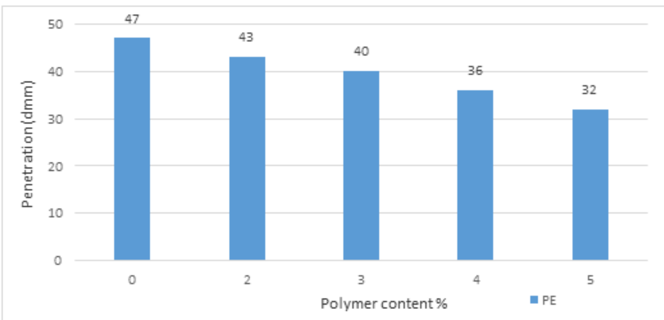


Figure 2: Relationship between Polymer Content and Penetration

B. Ductility Test

When a material sample is ripped apart into briquettes at a specific temperature, the asphalt binder's lengthening before cutting is measured in centimeters. Figure (3) shows that SBS is maintaining the (+100) ductility value.

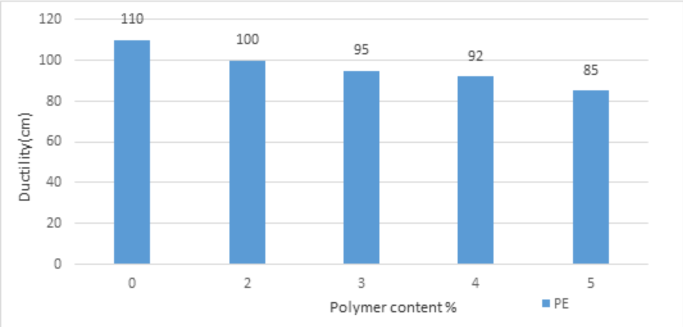


Figure 4: Relationship between Polymer Content and Ductility

C. Softening Point Test

A measurement of the temperature at which asphalt starts to exhibit fluidity is the softening point. The results unambiguously demonstrate that adding SBS to asphalt raises its softening point value, and that as polymer content rises, so does the softening point, as seen in figure (4).

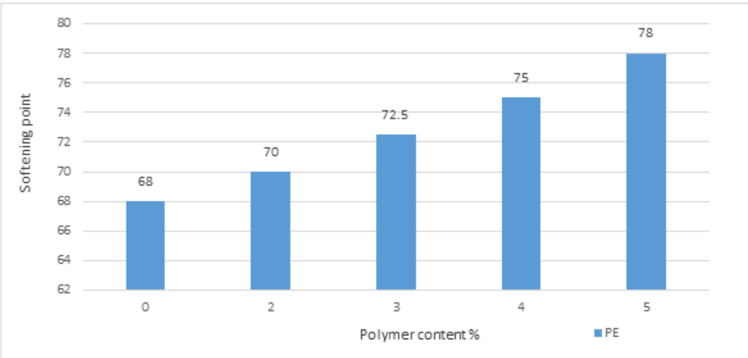


Figure 5: Relationship between Polymer Content and Softening Point

D. Penetration Index (PI)

As a function of temperature, it is described as the variation in the consistency parameter [18]. Equation (1) below can be used to determine PI.

$$(20-PI)/(10+PI)=(\log 800-\log(pen))/(Trb-T) \qquad .(1)$$

T=Testing temperature for penetration (25C°)

Trb=Ring and Ball softening point.

It can be said that the asphalt which has suitable properties for pavement should have PI occurs between (-2and2) [19].

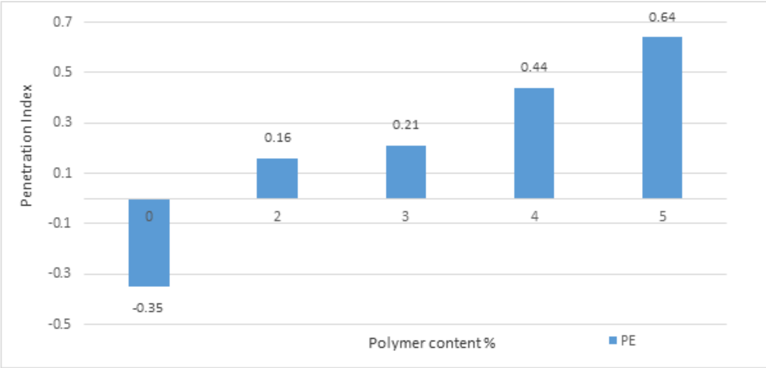


Figure 6: Relationship between Polymer Content and PI

E. Storage Stability Test

Modified asphalt's storage stability has been highlighted as a crucial factor in the creation and application of modified asphalt. According to typical storage tank designs in this industry, most modified asphalt is kept at a constant temperature and stirred to ensure homogeneity in the substance [20]. The softening temperature difference between the top and bottom of tubes is displayed in (Table VI). Modified asphalt exhibits good storage stability at high temperatures.

TABLE VI Marshall Properties at OAC

Polymer content %	PE		
	Top(R&B)	Bottom(R&B)	Difference(C°)
0	55.5	55.5	0.0
2	57.5	58.0	0.5
3	58.5	59.5	1.0
4	61.3	63.2	2.2
5	63.0	65.0	2.0

Asphalt samples from the bottom area get firmer and those from the top section become softer at 4% PE, according to a comparison between stored and regular asphalt.

F. Marshall Properties Results

Including base asphalt, polymer-modified asphalt, and MQ, the mechanical characteristics of the HMA are displayed in Figures (7) to (9).

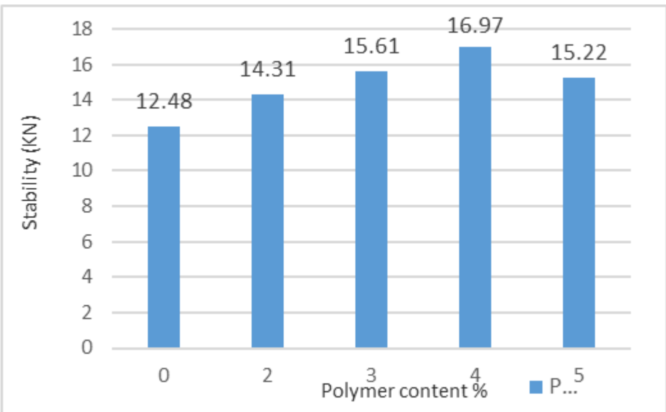


Figure 7: Relationship between Polymer Content and Stability

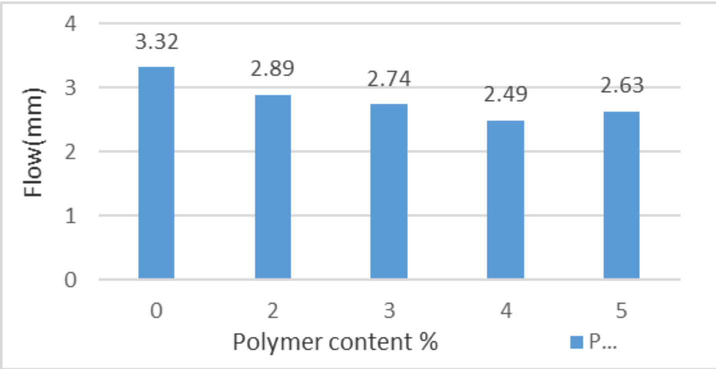


Figure 8: Relationship between Polymer Content and Flow

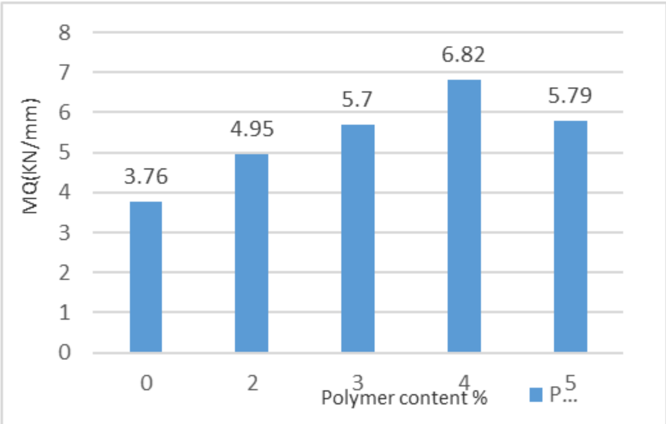


Figure 9: Relationship between Polymer Content and MQ

G. Modified Asphalt Concrete Performance Tests

The performance qualities of a polymer altered with asphalt admixtures must be determined. A conserved Marshall Stability test and an indirect tensile test were used to forecast the tensile force and determine how long the asphalt polymer

1. Indirect Tensile Strength: One of the most significant tests by shooting vertical loaded to the diameter of specimen at 60 C° and 25 C°. The test provides details on the tensile force and lassitude properties. According to the image (10).

2. Retained Marshall Stability: Two groups of three Marshall cylindrical specimens, each set of which was prepared for the test, were used. The Marshall exam was not administered to the first group before testing. The Marshall test was applied after the second group had specimens soaked in water that was 60 °C warmer than bathroom temperature for 24 hours, equation (2) below.

$$Retained\ Marshall\ Stability = \frac{Stability\ of\ treated\ specimens}{Stability\ of\ untreated\ specimens} \quad . (2)$$

A retained Marshall Stability value is not less than 70% is acceptable by (SORB/R9) specification.

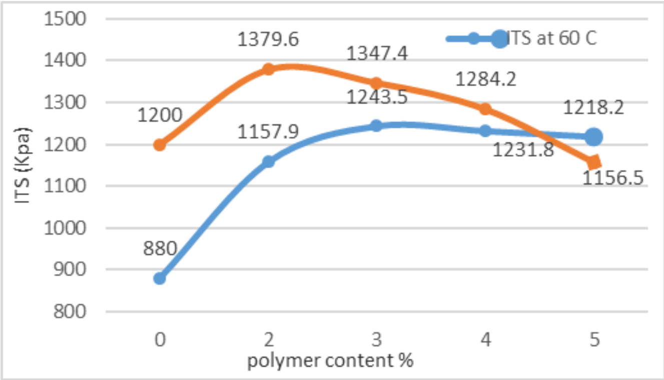


Figure10: Connection between ITS and Polymer Composition

H. Cantabro Loss Result

The resistance of the sample to particle loss was assessed using the Contabro test. The sample is weighed both before and after the test, and the amount of original sample weight lost as a percentage is used to compute the Contabro abrasion [21]. Cantabro Loss was calculated using the equation (3) and figures shown below (11)

$$CL=(A–B/A) *100 \qquad .(3)$$

CL= CANTABRO LOSS %

A=INITIAL WEIGHT OF TEST SAMPLE (GM)

B= FINAL WEIGHT OF TEST SAMPLE (GM)

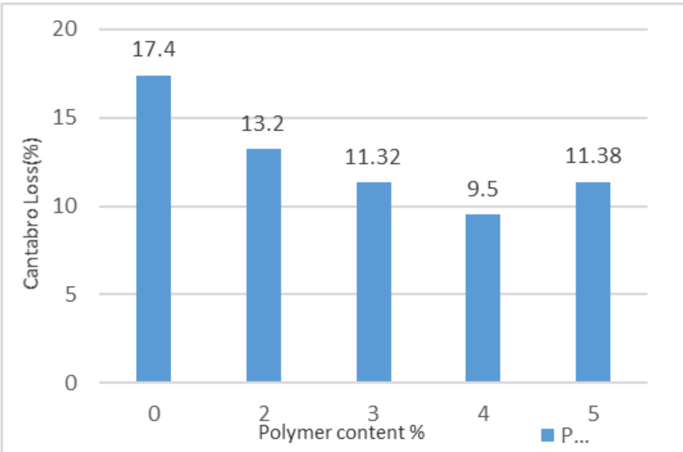


Figure 11: Relationship between Polymer Content and Cantabo Loss

IV. Conclusions

In light of the consequences of this study, conclusion come to show that adjusted asphalt mixture and using solid waste with polystyrene, As shown below :

1- Reducing the solid waste in the city of Mosul from the effects of war, recycling it and using it as a substitute for gravel, sand and filler.

2- Reducing the cost resulting from purchasing aggregate and using the alternative material, which is solid waste.
3- Develop pavement properties in further by using solid waste and modified bitumen, due to increases the tensile strength and improves the durability of highway pavement in the binder layer.
4- When added polyethylene to bitumen, percentage of penetration decrease 46.9% and decrease softening point 14.7%. But PI increases with increasing PE, and vice versa with elongation.
5- So we′ll get the best results at 4% polyethylene by the weight of optimal asphalt, percentage of stability and MQ increase to 35.98% &81.4%, but flow reduce to 25%. When increase stability and decrease flow, due to resistance of rutting when high and low in temperature. Using polymer additives combined with asphalt binder is the most popular method of reducing moisture damage.
6- We give best Cantabo loss decrease in sample when added 4%of polyethylene to bitumen.

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