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The Effect of Additives in Hot Asphalt Mixtures

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Abstract

The increase in road traffic during the last two decades in combination with an insufficient degree of maintenance due to shortage in funds have caused an accelerated and continuous deterioration of the road network in Iraq. To alleviate this process, several types of measures may be effective, e.g., securing funds for maintenance, improved roadway design, use of better quality of materials and the use of more effective construction methods. In this research, waste plastic bags as one sort of polymers and polypropylene fiber are used to investigate the potential prospects to enhance asphalt mixture properties. The objectives also include determining which one of the two additives is better than the other to be used and its proportion.

The two additives were introduced to the mixture in state of small pieces (2-4 mm). Marshall mix design was used, first to determine the optimum bitumen binder content and then further to test the modified mixture properties. In total, (51) samples were prepared (15 samples were used to determine the optimum binder content and the remaining samples were used to investigate the effect of modifying the asphalt mixtures).

The optimum asphalt content was (5 %). Six proportions of each additive type and stated by weight of the optimum binder content were selected to be tested (2, 4, 6, 8, 10, and 12%). The tests include the determination of bulk density, stability and flow. Marshall Mix design requires the determination of the percentages of air voids and air voids of mineral aggregate. The results indicated that polypropylene fiber (PPF) modifier provides slightly better engineering properties.

The recommended proportion of the polypropylene fiber (PPF) modifier is not more than (6%) by the weight of bitumen content, while it is not more than (8%) for recycled plastic bags (polyethylene). It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate, but no clear effect on the flow for both additives.

Key words: hot mix asphalt, asphalt additives, recycled plastic bags, polypropylene fiber.

الخلاصة

إن الزيادة في الحجم المروري أثناء العقدين السابقين مع الصيانة الغير كافية بسبب نقص الموارد قد تسببت في التدهور المتسارع والمستمر في شبكات الطرق في العراق. للحد من هذه العملية، هناك عدة حلول مؤثرة، كمثال، رصد المبالغ لغرض الصيانة، تحيسن تصميم الطرق، استخدام مواد بجودة أعلى، واستخدام طرق إنشاء أكثر نجاعة. في هذا البحث، تم استخدام أكياس البلاستك المستعملة كأحد مصادر البوليمرات، بالإضافة إلى ألياف البوليبروبيلين للتحري عن الدلائل المحتملة لتحسين خصائص الخلطة الإسفلتية.الاهداف أيضاتتضمن تحديد الأفضل بين هذين النوعين من المضافات لاستخدامها و نسبة إضافتها. المضافان الاثنان ادخلا الى الخليط بحالة قطع صغيرة (2-4 ملم).

وقد استخدمت طريقة مارشال لتصميم الخلطة الاسفلتية , اولا لتحديد النسبة المثلى للمادة الاسفلتية الرابطة ثم الاستمرار الى فحص خواص الخلطات المعدلة. كمجموع تم اعداد (51) نموذج، (15 نموذجا منها استخدمت لتحديد المحتوى الاسفلتي الامثل و النماذج المتبقية استخدمت للتحري عن تأثير تعديل الخلطات الاسفلتية). محتوا القير الامثل كان (5%). ستة نسب من كل نوع من المضافات محسوبة من وزن المحتوى الاسفلتي الامثل اختيرت لتكون (12,10,8,6,4,2%). الفحوصات تضمنت تحديد كل من الكثافة العظمى و الثبات و الزحف.

لقد اشارت النتائج بأن مضاف الياف البوليبروبيلين (PPF) تعطي تحسين طفيف للخواص الهندسية. النسبة المقترحة لأضافة الياف البوليبروبيلين (PPF) لا تزيد عن (6%) من وزن المحتوى الاسفلتي، في حين هذه النسبة لا تزيد عن (8%) من وزن المحتوى الاسفاتي بالنسبة للاكياس البلاستيكية المعادة (PE). لكلا المضافين، وجد بأنهما يزيدان الثباتية و يخفضان الكثافة و يزيدان الفراغات الهوائية بعض الشيء وكذلك نسبة الفراغات مابين حبيبات الركام المعدنية, ولكن لا تأثير واضح على التدفق لكلا المضافين.

1. INTRODUCTION

The use of many types of additives like polymers and fibers in asphalt mixture as a modifier started in the 80s of the last century and has been tested in a number of countries around the World.

There is 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 additives.

It has possible to improve the performance of bituminous mixes of the surfacing course of road pavements, with the help of various types of additives to bitumen such as polymers, rubber latex, crumb rubber - treated with some chemicals, etc. some limited studies have been reported on the use of recycled plastic, mainly polyetheline, in the manufacture of polymer-modified asphalt cement or bitumen. Recycled polyethelene from grocery bags may be useful in asphaltic (bituminous) pavements, resulting in reduced pavement deformation in the form of rutting and reduced low – temperature cracking of the pavement surfacing, greater durability and fatigue life have been reported in these modified mixes as compared to the conventional mixes (Behbahani, 2008).

The addition of polymers 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.

The polymers used in modifying bitumen are classified as plastomers, or elastomers. Plastomers include ethylene vinyl acetate, polyethylene (unstabilized and stabilized) and various compounds based on polypropylene. These products may require high shear mixing, which depends on the modification process. They increase the viscosity and stiffness of bitumen at normal service temperatures (Mohammed, 2007).

Elastomers (rubbers) include natural rubber, polybutadiene, polyisoprene, isobutene-isoprene copolymer, polychloroprene, etc. These products are normally milted into the asphalt binder at temperatures above 160°C by a high shear mixer. These types of polymers are elastomeric, which describes the ability of a material to return to its original shape when a load is removed (Mohammed, 2007).

These polymers increase the bitumen viscosity rather than elastomeric strengthening. In this research the use of the waste trash or grocery bags (polyethelene), which is one type of plastomers, to modify asphalt mix properties was investigated. It is used as aggregate coating rather than modifying bituminous properties. The principle objectives of this research were to:

- Study the effect of adding polyethylene and fibers on the hot mix asphalt.
- To identify which type of them yields the highest material performance.
- To identify the best mechanism of adding the two modifiers to the asphalt mixture to achieve better mixture properties.
- To determine the optimum percent of asphalt and additives in the hot mix asphalt.

2. BACKGROUND

During the last two decades, the amount of vehicle miles traveled per year and the amount of equivalent single axle loads, ESAL, have increased by 75 and 60 percent respectively. As a result, hot mix asphalt HMA, pavements have struggled to perform the intended design life, presenting rutting, fatigue and thermal cracking problems. This has created a need to develop an enhanced hot mix asphalt concrete design procedure (Amirkhanian, 2001). For approximately the past 50 years, engineers have designed asphalt mixtures using the Marshall or Hveem mix design methods, and over this period, different highway agencies have modified these design procedures to better fit their particular needs. Both methods have proven to be satisfactorily effective in aiding the design of highways and interstates, but some problems exist. The primary problem is that both the Marshal and Hveem design methods are empirical- they do not produce samples that share the properties or performance of the finished product. This makes it difficult to accurately predict how a particular mix will perform in the field. (khalid and Jason, 1998). Hot mix asphalt (HMA) is the most common material used for paving applications in the world. It primarily consists of asphalt cement binder and mineral aggregates. The binder acts as an adhesive agent that binds aggregate particles into a cohesive mass. When bound by asphalt cement binder, mineral aggregate acts as a stone framework that provides strength and toughness to the system. The behavior of HMA depends on the properties of the individual components and how they react with each other in the system.

2-1 Use of Re-cycled Plastics as Additives in Bituminous Mixes:

It has been possible to improve the performance of bituminous mixes used in the surfacing course of road pavements, with the help of various types of additives to bitumen such as polymers, rubber latex, crumb rubber- treated with some chemicals, etc. Some limited studies have been reported on the use of re-cycled plastic, mainly polyethylene, in the manufacture of polymer - modified asphalt cement or bitumen. According to Larry Flynn (1993), re-cycled polyethylene from grocery bags may be useful in asphaltic (bituminous) pavements, resulting in reduced permanent deformation in the form of rutting and reduced low - temperature cracking of the pavement surfacing. Salah E. Zoorob (2000) and Zoorob and Suparma (2000) have shown that re-cycled plastics composed predominantly of polypropylene and Low Density Polyethylene can be incorporated into conventional asphaltic (bituminous) road surfacing mixtures. Greater durability and fatigue life have been reported in these modified mixes as compared to conventional mixes.

2-2 Marshall Mix Design Method:

Bruce Marshall, formerly the bituminous engineer with the Mississippi state highway department, developed the original concept of the Marshall method of designing asphalt pavements. The present form of Marshall mix design method originated from an investigation started by the US army corps of engineers in 1943 to develop a simple apparatus for airfield pavements with increased wheel loads during World War II. These engineers also evaluated various compaction efforts, such as impact compaction, and produced densities in the laboratory that were similar to those achieved in the field. In addition, they simulated aircraft loadings in order to select the proper, optimal asphalt content. The number of blows and the foot design for the compactor were determined as a standard. Initial criteria were established and upgraded for increased tire pressures and loads. The purpose of Marshal method is to determine the optimum asphalt content for a particular blend of aggregates and traffic level. The optimum asphalt content is determined by the ability of a mix to satisfy stability, flow, and volumetric properties, (Vasavi K. , 2002).

3. MATERIALS AND METHODS

3-1 Bituminous material

Asphalt binder 40/50 penetration grade from Al-Dorah refinery was used in this research. The laboratory tests performed to evaluate the bitumen properties were: Specific Gravity, Ductility, Flash Point, Penetration, and Softening point. The properties of asphalt binder, which are presented in Table (1), are within the specification of penetrated asphalt grade 40/50.

Table (1) Properties of Used Asphalt Binder

Test *	Test results	Specification	
		Min.	Max.
Specific gravity (g/cm³)	**1.013**	**1.01**	**1.06**
Ductility (cm)	**>130**	**100**	
Flash point (c°)	**309**	**250**	
Penetration (0.1 mm)	**42-45**	**40**	**50**
Ring and ball softening point (c°)	**51**	**46**	**56**

* These tests had been made in asphalt technology laboratory of Al-Mostansiriyah University – College of Engineering.

3-2 Aggregate properties

Aggregates are the second principal material in HMA. They play an important role in the performance of asphalt mixtures. For HMA, they make up about 90 to 95 percent by weight and comprise 75 to 85 percent of the volume (Roberts et al., 1996 Asphalt Institute MS No. 22, 2003). Therefore, knowledge of aggregate properties is crucial to designing high quality HMA mixtures.

The coarse and fine aggregates used were imported from Al-Nibaee district at the northern of Baghdad. The coarse aggregate was crushed gravel and the filler used was Portland cement to supplement the fine materials size in hot mix asphalt (HMA) mixture design. The physical properties of al-Nibaee aggregate With the tests that used to obtain them are listed in table (2).

Table (2) Physical Properties of Al-Nibaee Aggregates

Properties	Coarse aggregate	Fine aggregate
Bulk Sp.G. (ASTM c127 and c128)	2.610	2.631
Apparent Sp.G. (ASTM c127 and c128)	2.641	2.680
Percent water absorption (ASTM c127 and c128)	0.423	0.542
Percent wear (loss Angeles Abrasion) (ASTM c131)	20.10	

3-3 Filler:

Asphalt mixture has an optimum cohesion where maximum compaction will occur. This cohesion can be effected by the amount of filler used in a mix. Santucci and Shcmidt, 1962, showed that if the binder volume (asphalt + filler) is held constant, there is an optimum filler percentage where maximum compaction can occur. A study by Heukelom, 1965 also showed that the amount of filler used in a mix could influence how well a mix is compacted. For a given filler type, the ease of compaction increases with the percentage of filler in the overall binder content.

All fillers must be fed to the asphalt mixture consistently and in correct proportions; otherwise, the mix properties are adversely affected. Excessive amounts of filler usually reduce the voids in mineral aggregate (VMA) to a point where sufficient asphalt content for a durable mix cannot be added. High filler content also increases the aggregate surface area and, thus, greatly reduces the asphalt film thickness. Further, mineral filler characteristics vary with the gradation of the filler. If the size of the mineral filler particles is smaller than about 10 microns, the filler acts as an extender of the asphalt cement because the thickness of most asphalt films in dense-graded HMA is less than 10 microns.

If the mineral filler size is larger than 10 microns, it acts more like an aggregate. If an excessive amount of this larger sized mineral filler is present, the asphalt content may increase because of increased VMA. Therefore, care must be taken to consider not only the amount of mineral filler, but also its size when evaluating whether an excessive amount of fine material is present in a mix that is being designed or controlled in the field (Roberts et al. 1996).

Ordinary Portland cement produced by Iraqi State Company at Kubaisa cement plant was used throughout this work. It was stored in large air- tight plastic containers to avoid exposure to atmospheric conditions like humidity. The physical properties of such cement are presented in Tables (3). Test results indicate that the adopted cement conformed to the Iraqi Specification No.5/ 1985. These tests were conducted by the National Center for Construction Laboratories and Research (NCCLR).

Table (3) Physical Properties of Cement Used in this Work †.

Physical property	Test result	Limit of Iraqi specification
Specific surface area (Blaine method), m^2 / kg	309	230 **
Setting time (Vicat apparatus):		
-Initial setting, min.	135	45**
-Final setting, min.	225	600*
Compressive strength(70.7mm cube), MPa		
- 3- days	19.26	15.0 **
- 7- days	27.04	23.0 **
Autoclave expansion %	0.25	0.8 *

***Max. value.**
**** Min. value.**
† Physical tests were carried by NCCLR.

3-4 Additives

3-4-1 Recycled plastic bags (Polyethylene) (PE)

Polyethylene (PE) 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 (Mohammed, 2007).

Waste plastic (polyethylene carry bags, etc.) (LDPE) on heating soften at around 130°C and there is no gas evolution in the temperature range of 130-180°C. moreover the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen use for road construction. Table (4) shows the mechanical and physical test results of polyethylene.

Table (4) Mechanical and physical test results of polyethylene. (Mohammed, 2007)

ASTM test	Property	LDPE	HDPE
D792	Density (g/cm³)	0.92	0.95
D570	Water Absorption, 24 hrs (%)	< 0.01	0
D638	Tensile strength (psi)	1,800-2,200	4,600
D638	Tensile Elongation at Yield (%)	600	900
D790	Flexural Modulus (psi)	-	200,000
D785	Hardness, Shore D	D41-D50	D69
D256	IZOD Notched Impact (ft-Ib/in)	No Break	3

3-4-2 Polypropylene Fibers (PPF)

Polymers have been used for a number of years for the modification of asphalt concrete mixtures because most of them have implications for performance and economy. Certain polymers may help to a certain extent to minimize asphalt pavement problems, such as permanent deformation, flushing, thermal cracking, etc. Polypropylene Fibers has been used as an additive to improve the performance of asphalt concrete mixtures. This type of polymer satisfactorily improves the Marshall properties and the results of the indirect tensile strength test (Al-Hadidy, 2006).

Fiber's main material is polypropylene modified high-molecular polymer. It looks rough but the outline is clear. The diameter varies, length differs and is shaped wavy. It has the advantage of high tenacity, high modulus and strong acid and alkali proofing ability. It looks like steel fiber in appearance and function the same, it also has the advantage of synthetically soft fiber(Al-Hadidy, 2006).

CHARACTERISTICS: Polypropylene fibers have a number of advantages over polyethylene fibers in the field of textile applications. The degree of crystallinity, 72 to 75%, results in a fiber that is strong and resilient, and does not fibrillate like high-density polyethylene.

The melting point of polypropylene is 165°C, which is low by comparison with nylon or polyester, but is high enough to make it suitable for most textile applications. So light that it actually floats, polypropylene fiber provides greater coverage per pound than any other fiber. It is highly resistant to mechanical abuse and chemical attack(Okan 2006).

USES: Polypropylene fibers are widely used in industrial, carpet, and geotextile applications. They have found important uses in fishing gear, in ropes, and for filter cloths, laundry bags and dye bags. The excellent chemical resistance of polypropylene fiber is of advantage in the filtration and protective clothing fields. Fibrillated polypropylene yarns are widely used in indoor-outdoor carpets. Staple fiber finds application in blankets, pile fabrics, underwear, and industrial fabrics; it is being developed for carpets, candlewicks, knitted outerwear, hand-knitting yarns, and upholstery. And the table (4) shows physical properties of Polypropylene fibers (Okan 2006).

Table (4) Physical Properties of Polypropylene Fbers. (Okan 2006)

Physical Nature:			
Density(g/cm^3)	**0.95**	**Elongation(%)**	**15±2**
Length(mm)	**25;30;40;50**	**Water absorption(%)**	**<0.1%**
Denier(D)	**2000-5000**	**Melting point (°c)**	**175±1**
Tenacity(MPa)	**>530**	**Burning point (°c)**	**560±50**
Modulus(MPa)	**>7000**	**Acid and alkali resistance**	**High**
Fiber section	**Diamond shape**	**Heat conductivity(W/mk)**	**0.2**

HPP fiber is in accordance with C-1116 (Standard declaration of fiber modified concrete and sprayed concrete) of A.S.T.M

4. 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 or weight. To determine the optimum bituminous content that would produce a asphalt concrete mixtures with strength and durability properties, 15 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. Five binder contents were considered (4, 4.5, 5, 5.5, and 6%).

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 1559-2003) using automatic compaction.

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus according to ASTM (D1559) [ASTM, 2003]. This method includes preparation of cylindrical specimen which are 4 inch (101.6mm) in diameter and 2.5inch (63.5mm) in height.

The Marshal mold spatula, and compaction hummer are heated on a hot plate to a temperature between (120-150C°). The asphalt cement is heated to the same temperature as aggregate (150-180 C°) and mixed together then the asphalt mixture is placed in the preheated mold and it is then spaded vigorously with the heated spatula 15 times around the perimeter and 10 times in the interior.

The optimum bituminous content was (5%). 18 samples of asphalt concrete mixtures were prepared at this binder content for each type of additives (polypropylene fiber (PPF), and recycled plastic bags PE) to test the effect of adding these additives to the mixture.

The additives were added to the samples by considering six proportions, (2, 4, 6, 8, 10, and 12%) of optimum asphalt content. Three samples were tested for each proportion for determining the unit weight, stability and flow.

The procedure of adding the additives is completed by heating the aggregate of each specimen until it reaches a (180-190 C°). This temperature is hot enough to melt the two additives with a particular size of (2-4 mm) such that it would stick to the aggregate surfaces and leave a textured surface with adhesion between the coated aggregates.

5. RESULTS

A comparison between asphalt mixture performance due to type of the additive is presented below. The comparison also includes the conventional asphalt mixture (No additive), which acts as the control group.

5-1 Bulk density- additive content relationships

The bulk density of the modified asphalt concrete mixtures and regardless of the modified type is lower than the conventional asphalt concrete mixture (2.38 gm/cm^3). This dropping in bulk density is due to the low density of the tow additives.

For both types of modifier, we found steadily decrease of bulk density with the increase of modifier content by weight of bitumen. But in general we found that the bulk densities of fiber modified asphalt concrete mixture is greater than those of recycled plastic modified, this happened because the density of the fiber is higher than the density of the recycled plastic, see figure (1).

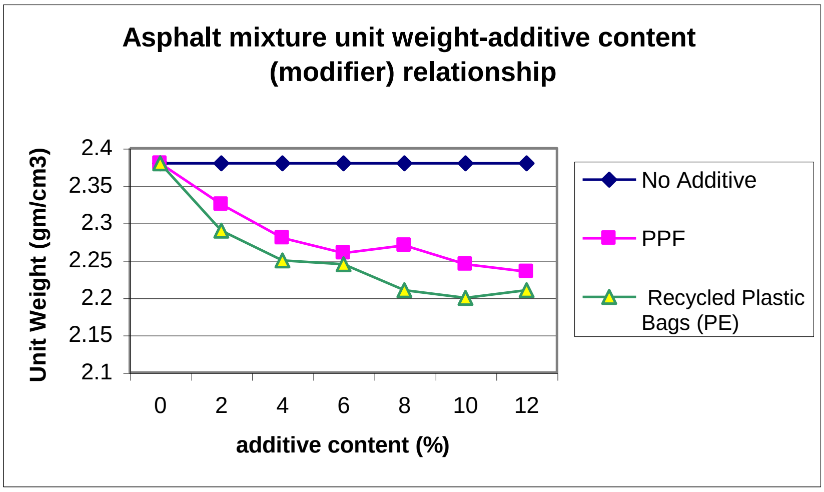

Figure (1) Asphalt Mixture Unit Weight – Additive Content (Modifier) Relationship.

5-2 Mixture Stability- Additive Content Relationships

Generally, the stability of the modified asphalt concrete mixtures and regardless of the modified type is higher than the conventional asphalt concrete mixture - no modifier (13.5 kN). The stability –modifier content relationship varies according to the type of modifier. The highest stability was reported for asphalt mixture that is treated with fiber modifier (18.5 kN). Figure (2) shows that the stability of modified asphalt concrete mixture increases till it reaches the maximum value at (6%) modifier content then declines again steeply for both modifiers.

The figure shows that the stability of asphalt concrete mixtures modified with polypropylene fiber is higher than those for modified by recycled plastic bags (polyethelene) and the tow mixture types still above the stability values of the conventional mixture due to the improvement of the modified binders to adhesion and cohesion of the asphalt mixture.

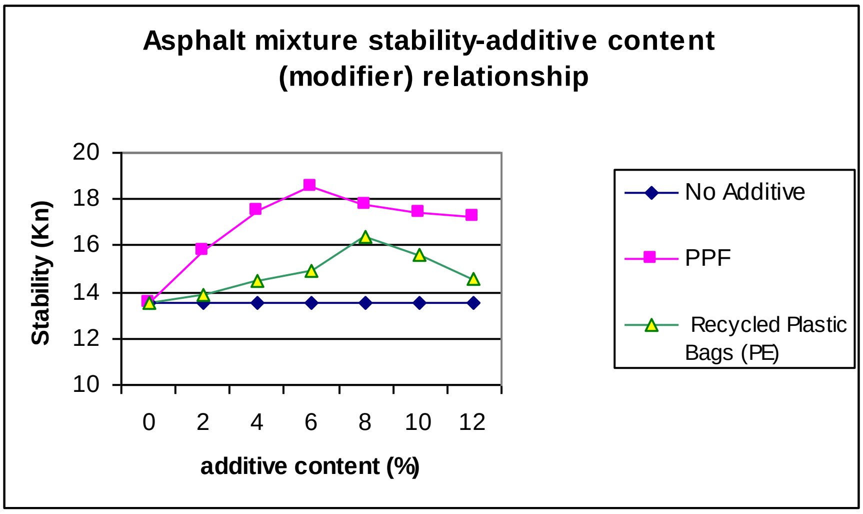

Figure (2) Asphalt Mixture Stability – Additive Content (Modifier) Relationship.

5-3 Flow- Additive Content Relationships

Generally, the flow of the modified asphalt concrete mixtures and regardless of the modified type is less than the conventional asphalt concrete mixture - no modifier (3.3 mm). In fact we didn't note any real effect of the increase of the modifier content till we exceed (6%) for fiber modified mixture and (8%) for recycled plastic bags modifier mixture, after that the curve begin to raise up steeply, see figure (3).

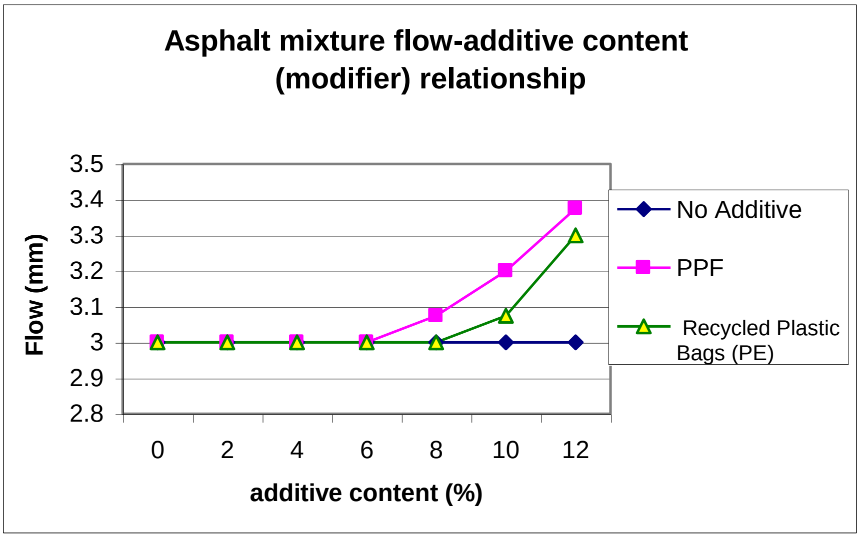

Figure (3) Asphalt Mixture Flow – Additive Content (Modifier) Relationship.

5-4 Air Voids (AV) percentage- Additive content relationships

Generally, the AV proportion of the modified asphalt concrete mixtures and regardless of the modified type is lower than the conventional asphalt concrete mixture - no modifier (4.8%). Generally modified asphalt concrete mixtures have AV content within the standards (specification), till we exceed (8%) modifier content in case of polypropylene fiber (PPF) modifier and (12%) modifier content in case of recycled plastic bags (polyethelene PE), that have air voids exceeds the specification (5%).

As shown in Figure (4), the proportion of air voids in modified asphalt concrete mixtures decreases as the modifier content increases until it reaches the lowest value at air voids content (4%) in case of fiber, and (6%) in case of polyethene, and then start to increase as the modifier increases.

The modifiers here work as a microscopic frame within the voids which allow the absorption of more asphalt cement to be in the mixture. This will be more clear in figures (5 ,and 6).

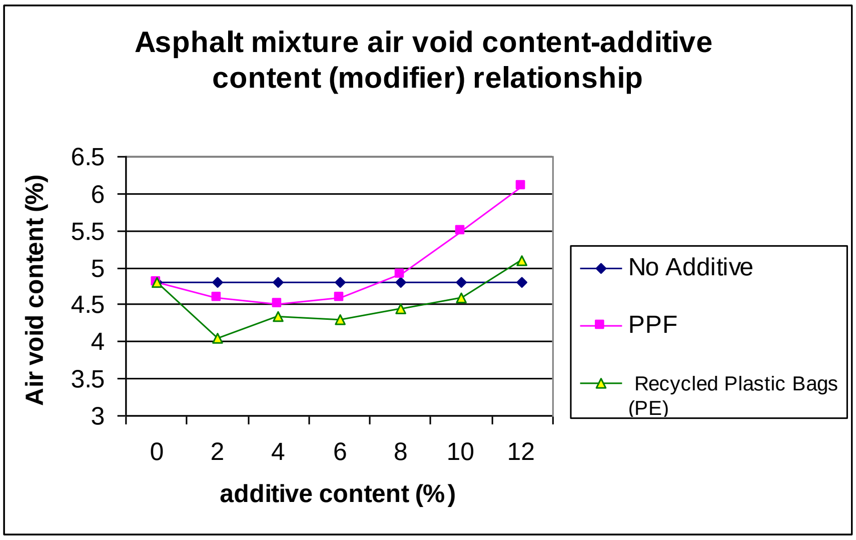

Figure (4) Asphalt Mixture Air Void Content – Additive Content (Modifier) Relationship.

5-5 Voids in Mineral Aggregate (VMA) Percentage- Additive Content Relationships

In general, the VMA percentage of the modified asphalt concrete mixtures and regardless of the modified type is higher than the conventional asphalt concrete mixture - no modifier (13.5%), because the modifier works with the filler to increase the voids. As shown in figure (5), generally the (VMA) percentage for recycled plastic modifier is higher than for PPF modifier, and we found that when the curve reaches to the specific point (6%) modifier content with (19.2%) VMA for recycled plastic bags modifier and (8%) modifier content with (18.3%) VMA for fiber modifier, the (VMA) begin to decrease steeply.

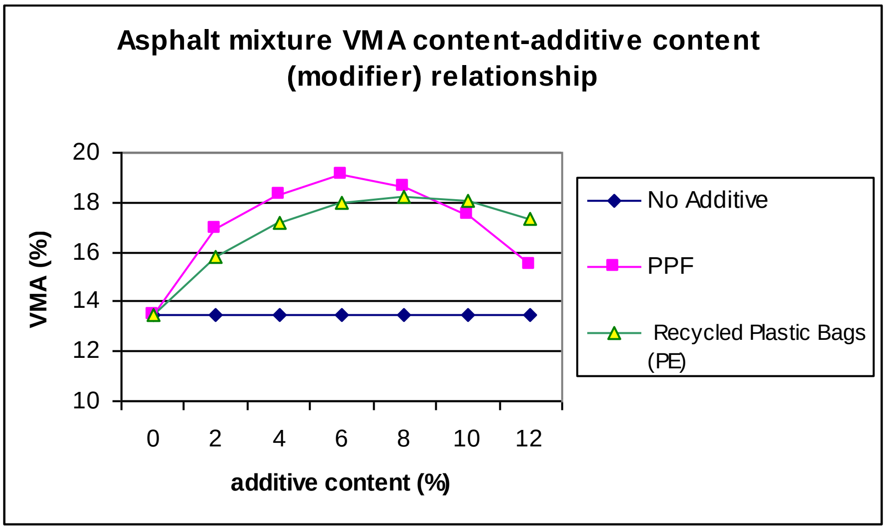

Figure (5) Asphalt Mixture VMA Percentage – Additive Content (Modifier) Relationship

5-6 Voids Filled with Asphalt (VFA) Percentage- Additive Content Relationships

In general, the VFA percentage of the modified asphalt concrete mixtures and regardless of the modified type is higher than the conventional asphalt concrete mixture - no modifier (65%). As shown in figure (6), generally the (VFA) percentage for recycled plastic modifier is higher than for PPF modifier, but no significant difference between them. It noticed that when the curve reaches to the specified point (6%) modifier content with (76.11%) VFA for recycled plastic bags modifier and (5.75%) modifier content with (76.04%) VMA for fiber modifier, the (VFA) begin to decrease slightly. As mentioned before, the modifiers here work as a microscopic frame within the voids which allow the absorption of more asphalt cement to be in the mixture

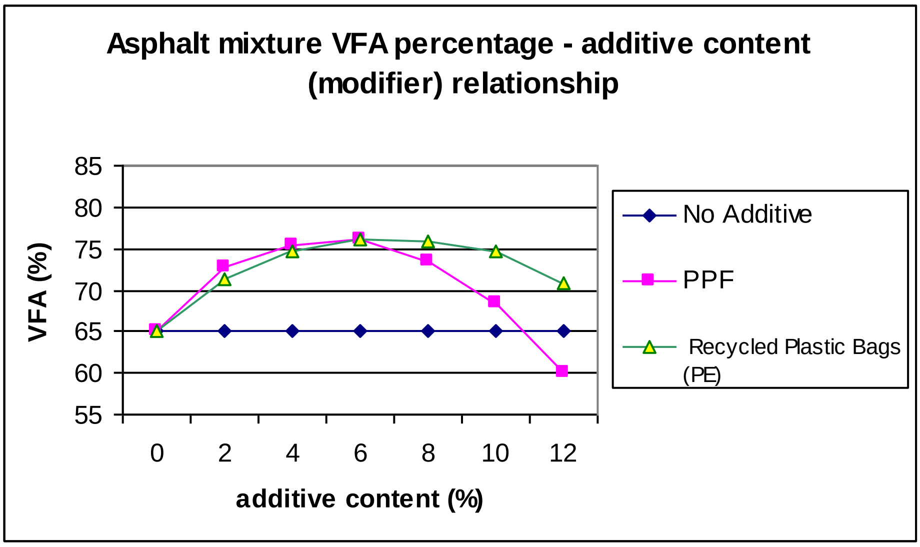

Figure (6) Asphalt Mixture VFA Percentage – Additive Content (Modifier) Relationship.

5-7 Optimum modifier content

The optimum modifier content is selected as the content that satisfies the following:

* Maximum Bulk Density

* Maximum Marshall Stability

* Minimum Flow

* The minimum AV or the closest percentage to AV content of 4%

* Maximum VMA content

* Maximum VFA content

The maximum bulk density was undefined for asphalt mixture modified with both modifiers because of the increasing of the bulk density with the increasing of the modifier content. In general, mixtures modified with PPF have a higher bulk density than those modified with recycled plastic bags (PE).

The maximum stability (18.5 KN) was reported for asphalt mixture modified with PPF at a proportion of 6% by weight of bitumen content, while it was (16.4 KN) for asphalt mixture modified with recycled plastic bags (PE) at a proportion of (8%). Figure (7) shows that mixtures modified with PPE have a higher stability than those modified with recycled plastic bags (PE).

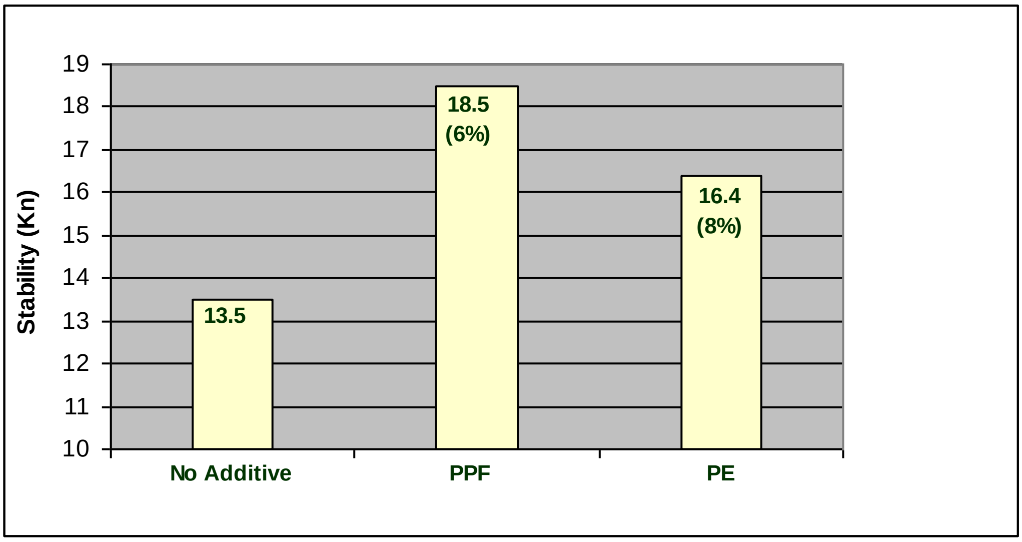

Figure (7) Maximum Asphalt Mixture Stability by Type of Modifier.

The minimum flow (3.3 mm) was reported for asphalt mixture modified with both modifiers that is the same as the non modifier value, but we note an increase in flow values after (6%) proportion of modifier content in case of PPF modifier and (8%) in case of recycled plastic bags (PE), while it still fixed on (3.3 mm) from no additive proportion to the point of declination. That means in these proportions there is no effect of the modifier on the flow of mixture.

The minimum percentage air void of modified asphalt mixture (4.3%) was reported for recycled plastic bags (PE) modifier at a proportion of 6% by weight of bitumen content, while it was (4.5%) AV for PPF modifier at a proportion of 4% by weight of bitumen content, which almost below AV of control group (No additive mixtures). Figure (8) shows that mixtures modified with recycled plastic bags (PE) have a lower AV% than those modified with PPF.

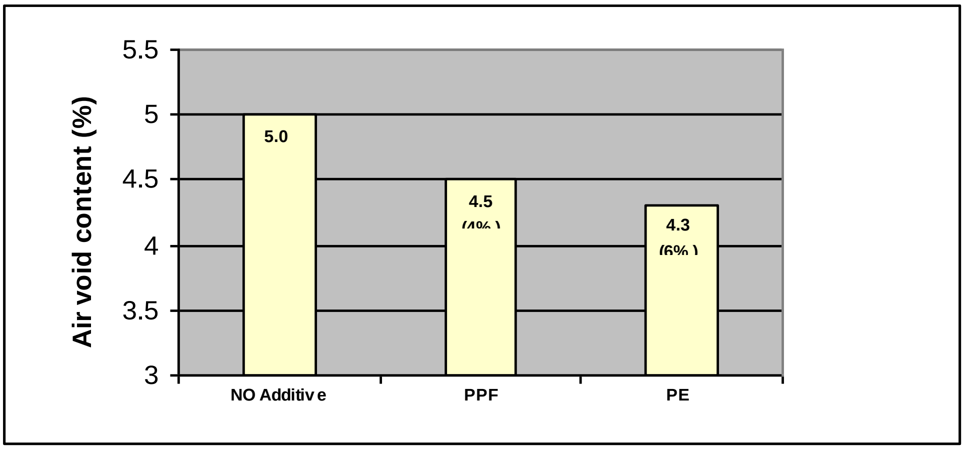

Figure (8) Minimum Asphalt Mixture Air Void Percentage by Type of Modifier.

The maximum percentage VMA of modified asphalt mixture (19.2%) was reported for recycled plastic bags (PE) modifier at a proportion of 6% by weight of bitumen content, while it was (18.3%) for PPF modifier at a proportion of 8% by weight of bitumen content. See figure (9).

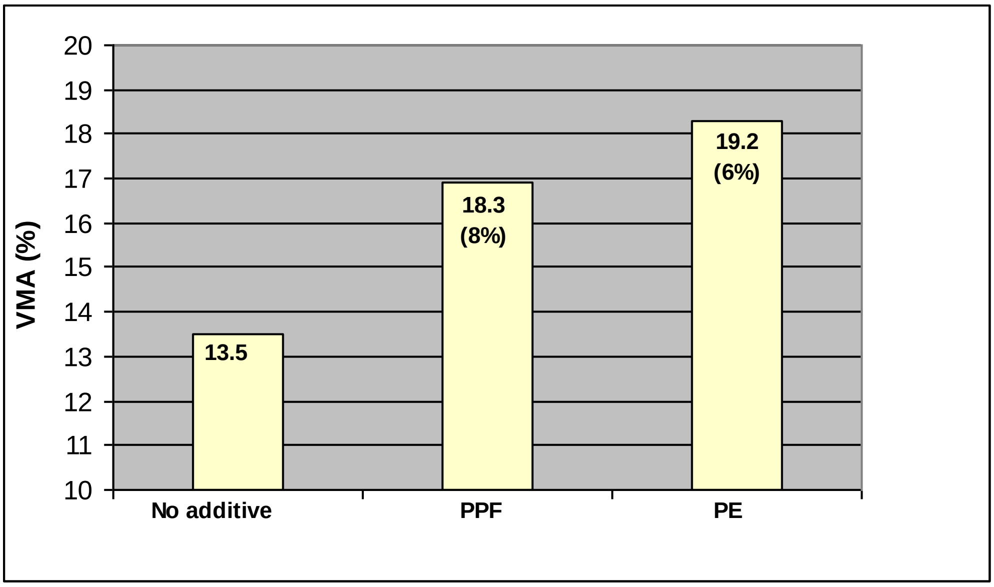

Figure (9) Maximum Asphalt Mixture Void in Mineral Aggregate (VMA %) by Type of Modifier.

The maximum percentage VFA of modified asphalt mixture (76.11%) was reported for recycled plastic bags (PE) modifier at a proportion of (6%) by weight of bitumen content, while it was (76.04%) for PPF modifier at a proportion of (5.75%) by weight of bitumen content. See figure (10).

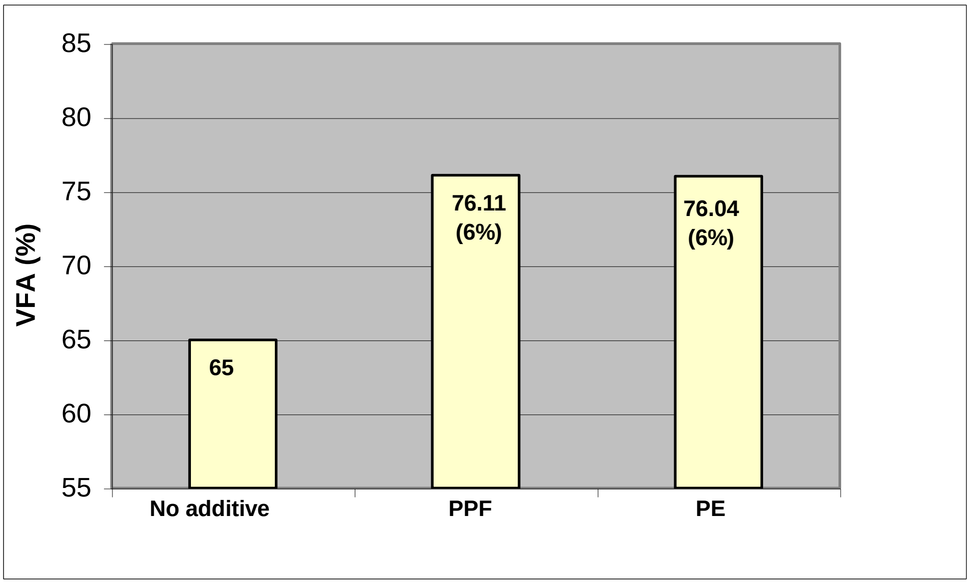

Figure (10) Maximum Asphalt Mixture Void Filled with Asphalt (VFA %) by Type of Modifier.

6. DISCUSSION

By experimentation, the appropriate amount of the additives was determined to be (2-12%) by weight of the optimum asphalt percent (5.0%), which equates to (0.1 – 0.6 %) by weight of total aggregate. However, the optimum modifier content was found to be 6% for fiber modified asphalt mixture, and 8% for recycled plastic bags (polyethelene) modified asphalt mixture. These amounts did not coat all individual aggregate particles. However, they did provide a rougher surface texture that would enhance the asphalt mixtures engineering properties.

The results of the study indicated that the modified mixtures have a higher stability, VMA, and VFA percentage compared to the non-modified mixtures. The air void contents of the modified mixture are not far from that of the non-modified mixture. Air void proportion around 4.4% is enough to provide room for the expansion of asphalt binder to prevent bleeding or flushing.

7. CONCLUSION AND RECOMMENDATIONS

The generation of waste plastics is increasing day by day. The polymers namely polyethylene, and polypropylene fibers show adhesion property in their molten state. Both will increase the melting point of the bitumen and form better material for pavement construction as the mix shows higher Marshall Stability value. Hence the use of waste plastics for pavement is one of the best methods foe easy disposal of waste plastics.

The use of innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income. Plastic roads would be a boon for Iraqi's hot climate in summer, where temperatures frequently cross 50°C. It is hoped that in near future we will have strong, durable and eco-friendly roads which will relieve the earth from all types of plastic-waste.

8. Need for Further Work:

It is necessary to work out a project proposal to carry out further studies on various aspects such as collection, processing and effective utilization of this waste material. To start with, such a study could be initiated in Bangalore, with the following components:

- **i)** Estimation of the types, quantity and useful components present in the waste plastic materials in the city and surrounding areas.
- **ii)** Methodology for collection and sorting out the useful components of the plastic waste.
- **iii)** Methodology for processing the plastic bags as required for use in the preparation of modified bitumen, including cleaning, shredding and further processing of the plastic waste materials.
- **iv)** Identification of two or three construction companies / entrepreneurs who could incorporate appropriate mixing units in their bitumen boiler / hot mix plant to add and mix the required proportion of the processed plastic additive.
- **v)** Carrying out further laboratory investigations, construction of some test tracks and field studies on the performance of pavements using the modified bitumen.
- **vi)** Working out relative economics of using the modified bituminous mixes in road construction works, considering the improved performance and increased service life of the pavement.
- **vii)** Preparation of specifications and standards for the construction industry.

It is hoped that on completion of the above project, the plastic waste materials will be put to effective use in road construction industry, resulting in improved road pavements and also relief from the waste plastic materials being littered all around urban areas.

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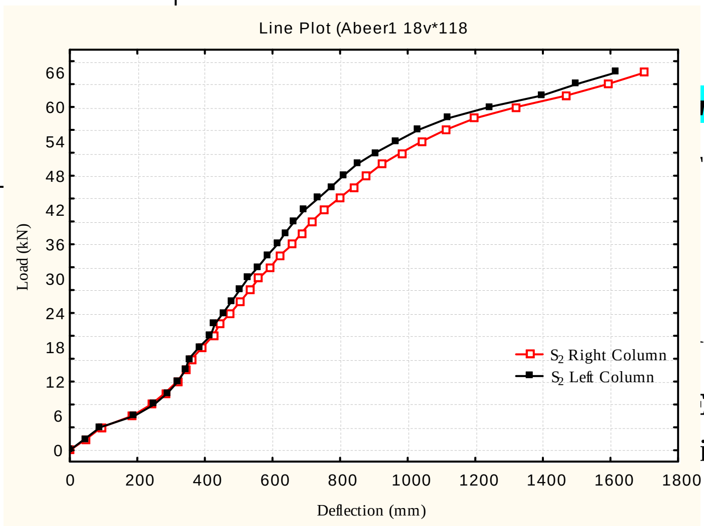

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