THE USE OF TECHNIQUES IN THE MANAGMENT OF WATSE PLASTIC BY REUSE IT IN THE ASPHALT MIX

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ABSTRACT

The quantity and type of waste being generated is growing at enormous rate. The plastics waste produced particularly in the form of bags, plates, containers, is non-degradable and with limited recycling options it poses disposal problem. An academic research aimed at probable use of waste plastic in pavement structure so as to come up with an ultimate safe disposal together with improvement in the performance of asphalt mix of road through better mix design is undertaken.

Preliminary investigations have indicated RPWA (from 1.2 in (1.5 cm) to No. 200 sieve (0.075 cm) , used in surface mix design when utilized up to (5% to 15%) by weight substitution, gives an optimum condition, time of reaction, and weight percent of substitution replacement aggregate in asphalt mix. The variables were studied: temperatures (109-206) c^{o} , time of (20-60) min and weight at waste substitution of (5-15) % wt. The optimum conditions were: were 172 ^{o}c, 40 min, and 10% wt RPWA.

The effects of experimental variables on the properties of improved asphalt mix were studied using the Box-Wilson technique of experimental design and useful relationships could be attained. The improved optimum conditions give high stability in Marshall Test and low distortion with acceptable low constant wet density and unaffected dry density with these conditions and high resistance to chemical solutions exposure it is envisaged that use of RPWA in the conventional asphalt hot mix design is likely to improve the surface asphalt mix performance with sustainable solution for the disposal of plastic waste.

KEYWORDS: waste plastic plates, Recycled plastic waste aggregate. Marshall Flow and stability. Sustainable. Solution. Plastic waste, Non-conventional Aggregate.

الخلاصة :

ان العديد من النفايات اخذت بالنمو وبمعدلات كبيرة وعلى الاخص النفايات البلاستيكية والمنتشرة على شكل (حقائب ، طبقات ، حافظات وقناني) والتي تكون غير قابلة للتحلل وتسبب مشاكل كبيرة منها التراكم ومحددات معينة لاعادة التدوير ، والبحوث الاكاديمية الحالية تهدف الى تطوير الامكانيات لاستخدام هذه النفايات في تصميم وتحسين الخلطات الاسفلتية المستخدمة في الرصف من ناحية الاستخدام الامن مع تحسين اداء هذه الخلطات . وتجريبيا تبحث في استخدام النفايات البلاستيكية ذات التدرج الحبيبي من ٢/١ انج (١.٥ سم) الى ٠.٠٧٥ سم (تدرج حبيبي رقم ٢٠٠) (بشكل متدرج وخليط من عدة حجوم حبيبية) في تصميم الخلطات الاسفلتية للطبقة السطحية المستخدمة في التبليط للطرق وبنسبة تعويضية من ٥% نسبة وزنية الى ١٥% نسبة وزنية وذلك بتطبيق البرنامج التصميمي بوكس _ ويلسن في تصميم هذه التجارب وصولا الى الظروف المثلى للتفاعل (درجة حرارة التفاعل ، زمن التفاعل ، النسبة المئوية الوزنية للاستبدال او التعويض مع الركام الخشن والناعم وحسب التدرج الحبيبي للخلطة) .

والمتغيرات التي تمت دراستها هي درجة الحرارة من (١٠٩ – ٢٠٦)^{o}م وزمن تفاعل بين (٢٠ – ٦٠) دقيقة ، ونسبة استبدال وزنية تعويضية

تصل الى (٥ – ١٥) % نسبة وزنية على التوالي . وكانت الظروف المثلى للخلطة المثالية هي :

درجة حرارة ١٧٢ ºم ، وزمن تفاعل ٤٠ دقيقة ، ونسبة استبدال تعويضية من النفايات البلاستيكية بالركام مقدارها ١٠ % نسبة وزنية.

ان تأثير المتغيرات التجريبية على خصائص الخلطات الاسفلتية المحسنة درست باستخدام تقنية البوكس – ويلسن (البرنامج التصميمي) وقد تم تحسين ظروف الاداء للخلطات ، حيث اعطت الخلطات المحسنة والخلطة المثالية المحسنة اسقرارية عالية لاختبار مارشال ، واقل تشوه ، ونتائج مقبولة وثابتة للكثافة الرطبة ، وكثافة جافة مستقره غير قابلة للتغير ، ومقاومة كيمياوية عالية للرطوبة والمحاليل الحامضية (٥% محلول H_2SO_4) . هذا الذي يشجع استخدام النفايات البلاستيكية في تحسين اداء الخلطات الاعتيادية المستخدمة في الرصف ويشكل الحل الامثل للتخلص من هذه المشكلة البيئية الحالية .

1. INTRODUCTION

Plastics are everywhere in today's lifestyle. It's used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, communication or it technology has been virtually revolutionized by the application of plastics. Use of this non-biodegradable (according to recent studies, plastics can stay as long as 4500 years on earth) product is growing rapidly and the problem is what to do with plastic waste. Studies have linked the improper disposal of plastic to problems as distant as breast cancer and reproductive problems in humans and animals, genital abnormalities and much more [1, 2].

The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste materials world over. Attempts are still being made by various organizations and researchers to find methods for effective utilization of some of these waste materials. Of these, the efforts to find useful applications of some of the waste products in highway construction have given encouraging results. A study on the possible use of the processed plastics waste bags with the bituminous mixes was carried out at the R.V. College of Engineering Bangalore, 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 polymer, rubber latex, crumb rubber-treated with some chemicals etc., also recycled plastic, mainly polyethylene is used in the manufacture of polymer–modified asphalt cement or bitumen [3,4].

Salah E. Zoorob and Zoorob and Superman have shown that recycled plastics composed predominantly of polypropylene and low density polyethylene can be incorporated into conventional asphalted (bituminous) road surfacing mixtures. It has been proposed to melt polystyrene foam with asphalt, to add sand and to mold the material as a concrete substitute, thereby utilizing the waste plastics, to increase pavement durability, decrease deformation resistance and increase in hardness and ductility has been reported by adding other plastics waste in various amounts, also technical performance is improved relative to primary aggregate alternatives. This could include properties such as superior abrasion resistance, enhanced flow properties, beneficial effects on other durability enhancements, economically the use of less binder and environmental enhancecement e.g. aesthetic appearance, energy saving [5, 6, and 7].

Several attempts were carried out on the use of waste plastics in asphaltic cement mix [8,9] Adnan Qadir, and Mansoor Imam have used the waste plastics bags in bituminous mix for improved performance of roads to improve desired mechanical characteristics of a particular road mix by the use of (1.2-3mm particle size) in the surface and base mix design up to 2.5%wt. Substitution has shown improved stability and flow (Marshall test) [10].

Forgac, John M. etal used of liquid plastics additives to enhance the properties of asphalt wherein the liquid plastics was derived from waste recycle, and scrap polymer and plastic sources (LPP) from (polypropylene, polyethylene, polystyrene , PVC, PET, Polybuytene at 7, 70, 9, 5, 2, 7) additive formulation by weight from 100°c to 170°c[11].

Sinan Hinislio etal used waste of high density polyethylene as bitumen modifier in asphalt concrete mix at (4, 6 and 8%) additive weight at temperatures (145, 155 and 165°c) and 30 min of mixing time to increase in the Marshall stability (strength) [12].

Mustafa T. etal used of waste materials in asphalt mixture such as (rubber and plastic (5%, 10%, and 20% of the total)) three particle sizes or (4.75mm (No. 4), 0.85mm(No. 20), and 0.075mm (No. 200), as replacement for stone powder in asphalt mix specimen to improve the Marshall stability moisture susceptibility [13].

Also Hassani A. etal used waste plastics (polyethylene terephalate) in asphalt concrete mixture as aggregate replacement of 3mm diameter replaced by volume apportion of the mineral coarse aggregate of an equal size (2.36- 4.75mm) and reached optimum value of 6.6% vol. , an reduction of bulk compacted mix density [14].

Recently Rajib B. Mallick. et al, have made a successful use of synthetic light weight aggregates made from waste fly ash and plastic in a hot mix asphalt at different percentages of aggregate at 0%, 5%, 10%, 15%, and 20% by weight of aggregate replacement percent, then checked bulk specific gravity, theoretical maximum density, resilient modulus, and indirect tensile strength at 25°c and 60°c [15].

AIM OF THE PRESENT WORK

1. Use of thin discarded plastics to carry various materials including house hold articles has become a common practice all over the country, and found useful applications for these wastes. Producing environmental enhancement, energy is saving and low cost using less binder.
2. Improved properties of the paving material and technical performance relative to primary aggregate alternative, such as superior abrasion resistance, enhanced flow properties, beneficial effects on reinforcement, corrosion, freeze thaw and other durability enhancement.
3. Reaching optimum conditions from mixing weight ratio, time of mixing and temperature, in order to give improved properties (physical, chemical, and thermo-mechanical) performance, by the use of modern software program analysis

2. EXPEERIMENTAL

A schematic diagram of experimental reaction system is shown in Figure (1). Separate pans were used to weigh the amount of each size fraction required to prepare a batch standard design of asphalt mix (aggregate [fine and coarse], cement [filler] and asphalt cement [binder]) at the classification of each component shown in Table (1) the pan of a batch mix was put on the hot plate (0-250°c) with continuous mechanical mixing (950 cycle/min) until the temperature of standard aggregate asphalt mixture reaching 168°c (hot wet process).

Table (1) Design of asphalt mix standard and improvement

Sieve No. mm	1	2	3	4	%wt. mixing
25	100	100	95	98	
12.5	93	95	77	66	
4.75	63	80	12	34	
2.36	54	35	5	3	
0.3	28	6	0	0	

0.075	2	0	0	0	
Pan	-	-	-	-	
(wt. of cement% filler)	6	6	6	6	6
Wt.% of binder asphalt	5.5	5.5	5.5	5.5	5.5
pin No.% wt.					
1					24
2					20
3					10
4					40

A second step for forming an asphalt mix material containing recycled (waste) plastics comprises these steps [16-18].

- Forming recycled plastics in to plastics particles then sieving these particles in same way as that of aggregate at the same sieve No. (½ inch , 3/8 inch, No.4, No.8, No. 50, and No. 200) then they were mixed at the same mixing weight percent of aggregate (pin (1,2,3,4) and mixing ratio.

- Dry mixing and heating aggregate and sand (fine and coarse) aggregate at the same design. Mixing ratio replacement waste plastics at range of (5-15)% wt. then untreated plastics particles were dry mixed with the aggregate and sand while heating continued until the mixture of plastics particles, aggregate and sand reached temperature of reaction at range of (109-206) °c and afterwards liquid asphalt was added to the mixture of plastic particles, aggregate, sand, and filler with continuous mixing at 950 cycle/mix at mixing time of (20-60) min according to experimental program design (Box-Wilson method) then these prepared (standard and improved mixes) were poured to a clean, hot and mold assembly whose inside face was covered with grease, the compaction hammer (Germany Company in asphalt lab, ring No. 11142) after place appear toweling cut to size in the bottom of mold then place the mold assembly on the compaction pedestal in to mold holder 75 blows were applied with compaction hammer prepaideircularly to the base of mold , remove the base plate and collar then reverse and the mold was reassume used with the application of same number of blows. After compaction remove the base plate and leaving specimen in atmosphere field for 24 hrs, before any test applied, then applied the final characteristic test thermo-mechanical, chemical, and physical properties in order to reach the optimum improvement mix condition (%wt. waste plastic replacement, temperature of reaction (ºc), time of reaction (min)) that give optimum properties (thermo-mechanical, chemical and physical properties) [16-18].

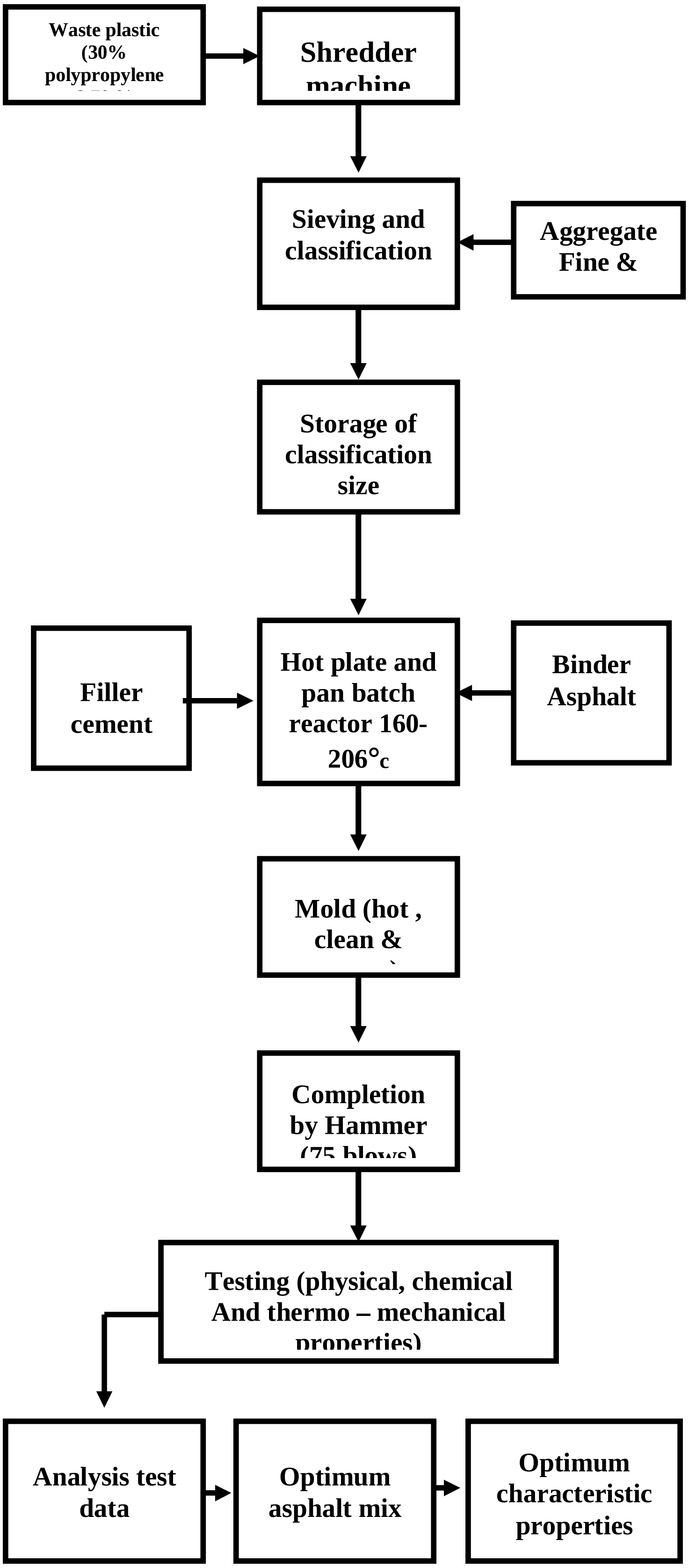

Figure (1): Schematic diagram for standard asphalt and improvement mix preparation and characterization.

The waste plastics used in this study consisted of (30% polypropylene and 70% polyethylene PET) mixed in the form of (3/8 inch to No. 200 sieve) [19, 20] were collected manually from domestic waste and land fills (bottles, plate, etc) of Baghdad.

And the designed of experiments were carried out according to the CCRD [19] for three variables in fifteen experiments for preparing improved asphalt mix as follows.

X_1= temperature of reaction for prepared batch asphalt mix (109-206) °c.

X_2 = time of reaction (min) from (20-60) min.

X_2 = weight percent replacement waste plastic (% wt) from (5-15) % wt.

The response of experiments conducted according to Box-Wilson method was fitted to a second order poly- nominal model from which the optimum response was calculated as shown in Table (2).

Table (2) results of experiments planned according to (CCRD) real variables.

Exp. No.	X1 (temp.) °C	X2 (time) min	X3 (%wt) of wp.
1	160	28	7
2	189	28	7
3	160	28	7
4	189	51	7
5	160	28	13
6	189	28	13
7	160	51	13
8	189	51	13
9	109	40	10
10	206	40	10
11	172	20	10
12	172	60	10
13	172	40	5
14	172	40	15
15	172	40	10

MATERIAL IN EXPERIMENTAL PROGRAM:

Different and mixed particle size of waste plastics of 12.5 mm and smaller that were collected manually from domestic wastes and land fills in Baghdad city.

The asphalt binder is brought from the middle spot of Iraq in Al-Durra refinery factory. The characteristic properties of this binder are given in Table (3).

Table (3): The characteristic properties of asphalt used in present work.

Type of property	Temperature	Values
Grade	25 °c	40 – 50
Specific gravity	15.6°c	1.04
Flash point (C.O.C)	°c (min)	240
Penetration (100gm/ 5 sec., 0.1mm)	25 °c	40 – 50
Softing point (R &B)	°c	49 – 58
Ductility (cm) (min)	25 °c	100
Solubility inCCl_4% wt. (min)	25 °c	99.0
Loss on heat in % wt. max (5 hrs)	163°c	0.5
Penetration of residue after loss of original value (min)	25 °c	75

TESTING OF STANDARD AND IMPROVEMENT ASPHALT MIX:

- Physical properties:

Wet and dry density is determined by the exposure of prepared sample to air (dry) and water (wet) then applied the general density equation.

- Chemical properties:

This test is determined by the preparation of different concentration of chemical solutions (100% H_2O, 5% H_2SO_4) then all prepared standard and improvement samples as in Table (1) is soaked for 5 days at 50 °c afterward recorded the change in weight every 24 hrs to check which of samples is more chemically stable than others (optimum one).

- Thermo-mechanical properties:

This test is determined by the use of Marshall Machine tester in asphalt lab/ of building Eng. Depart. according to (ASTMD 155982- Marshall Apparatus) stability and dynamically measurement. where the prepared samples were put in a water bath at 60 °c for 2 hrs to give sever condition results, afterward put this sample horizontally in the center of this tester then exposure it to sever load until failure occurs this factor is called Marshall stable (KN), then record the failure of stable sample only after stable of load occur and record the dynamic failure called flow distortion modulus of elasticity in (mm).

3. RESULTS AND DISCISSION:

The statistical analysis system (SAS) software was used for estimating mathematical model representing the second order response surface fitted to the design point and response (Table4).

Table (4): the results of statistical analysis for preparing improved asphalt mix.

Property	Correlation coefficient (%)	Estimate Standard of dev.	Average abs. error.
Stability (KN)	93.457	0.9994	0.2
Flow (mm)	95.578	0.9997	0.4
ρ_W	92.999	0.99978	0.23

(gm/cm^3)			
ρ_D (gm/cm^3)	90.777	0.9998	0.25

The non-linear estimation order is made for a defined function model. The coefficients of this model are estimated and the second order response mathematical model can be written as follows:

Y stability = 43.94 – 0.7232 X_1 + 1.57378 X_2 + 1.95516 X_3 + 1.768 X_1^2 + 2.218 X_2^2 + 0.644 X_3^2 +0.63 X_1X_2 – 1.6695 X_2X_3 + 0.4157 X_1X_3 - -(1)

Y flow = 1.20888 + 0.21786 X_3 + 1.115649 X_1^2 + 0.59895 X_2^2 + 0.79673 X_3^2 + 0.79673 X_3^2 + 0.343276 X_1 X_2 - 0.27422 X_2 X_3 - 0.2689 X_1 X_2 -- (2)

Y ρ_D = 2.189986 – 0.691X_1 -- (3)

Y ρ_W = 0.955 + 0.273 X_3^2 -- (4)

From this model the optimum operating variables and optimum properties were determined and graphical correlations of these characteristics properties (stability, flow, ρ_D. And ρ_W) with each variable are constructed over the range used in forming the model.

The evaluation of the optimum operating conditions for improved asphalt mix was performed by ruing a computer program namely (Optimization Techniques). The results of optimization are:

X1 = temperature of reaction (°c) = 172 °c

X_2 = time of reaction (min) = 40 min.

X_3 = wt. % of replacement waste plastic (wp): 10% wt.

3.1. The effect of operating conditions on the characteristic properties of final improved asphalt mix:

3.1.1. Effect of reaction temperature on the final characteristic properties of improved asphalt mix.

*** Physical properties.**

Figure (2) shows the effect of set temperatures of reaction on the physical properties of improved asphalt mix (dry density ρ_D) under optimum time of reaction (40 min). It appear that values of dry density is less decreased with continues increasing reaction temperatures until reach optimum values at 172°c afterward these values give drops effect according to crosslinking between asphalt binder and waste plastics that convert improved mix to a light polymer with a drop in density.

Figure (3) shows the effect of set temperatures of reaction on the wet density of asphalt mix at different percent of waste plastics for optimum reaction time (40 min) that give constant effect of wet density at increasing temperatures with increasing amount of waste plastic displacement at high values 15% of (1.42) than standard of (0.45) g/cm^3 according to high effect temperature on properties of waste plastics and crosslinked between these wastes and asphalt binder in prepared mix [1, 2].

*** Chemical properties:**

Figures (4, 5) show the effect of different chemical solutions (100% H_2O, and 5% H_2O_4) on final improved asphalt mixtures, at different reaction temperatures. These curves show increasing in weight change with continuous increasing of resident time. High chemical stability and less change in weight for optimum sample run 6 prepared at 189 °c exposure to moisture. High change in weight for samples exposure to H_2SO_4 solution at increasing resident time with high chemical stability for run (10), because of high crosslinked of atoms between asphalt binder and waste plastics prepared at high temperature 206 °c [1 , 2].

*Thermo- mechanical properties**.

Figures (6, 7) show the effect of set temperatures of preparations of asphalt improved mixture on the mechanical properties of these mixes (stability (KN), Flow modulus of elasticity (mm)). It appears that all stability values of improved mix are decreased with increasing temperature of preparation until reach optimum temperature at 172 °c then increased with high mechanical stability of 50 KN than standard sample of 23 KN.

And Figure (7) shows the decreasing of flow modulus of elasticity for increasing temperature of reaction until reach optimum value at 172 °c with less distortion for optimum sample at (1.1 mm) than standard sample of (3.5 mm) according to high crosslinked between asphalt binder and waste plastics at high temperature that give a stable improved asphalt mix chemical, physical and thermo-mechanical resistance [1, 2].

3.1.2. Effect of reaction time of preparation on the final improved asphalt mix properties.

***Physical properties:**

Figure (8) shows the effect of set time of reaction on the physical properties of improved asphalt mix (dry density ρ_D) under optimum temperature 172 °c. It appear that values of dry density is decreased with increasing time of preparation with less change at optimum time of (40 min) according to Figure (2) results [1, 2].

And Figure (9) shows the effect of set time of reaction of preparation on the wet density of asphalt mix at different displacement of waste plastics percent and optimum reaction temperature of (172 °c).

It appear that constant effect of time on the wet density with high value at 15% displacement waste plastic of (1.4g/cm^3)than standard sample of (0.44 g/cm^3) according to highly crosslinked between asphalt binder and waste plastic additive [1, 2].

***Chemical properties:**

Figures (10, 11) show the effect of different chemical solutions (100% H_2O, and 5% H_2SO_4) on final improved asphalt mixtures, at different time of reaction these curves show increasing in weight change with continuous increasing resident time with high chemical stability for run (2) exposure to moisture and 5% H_2O_4 than standard sample according to high reaction temperature of 189 °c that give high crosslinked and high chemical stability [1, 6].

***Thermo-Mechanical properties:**

Figure (12) shows the effect of set time of reaction of asphalt mix preparation on mechanical properties of these improved mixes (stability and flow modulus of elasticity). It appears that all stability values of improved mix are decreased with increasing time of preparation until reach optimum values of 50 KN and 23 KN for standard sample prepared at 40 min and 15% displacement percent of high mechanical stability

And Figure (13) shows decreasing of flow modulus of elasticity at increasing time of reaction until reach less distortion of (1.1 mm) than standard sample of (3.5mm) according to the high crosslinked between asphalt binder and displacement waste plastics at optimum conditions (10%wp, 172°c, and 40min) that give a stable improved asphalt mix, chemical, physical, and thermo-mechanical properties [1, 4].

3.1.3. Effect of waste plastic displacement percent (%wt.) on the final improved asphalt mix.

***Physical properties:**

Figure (14) shows the effect of set displacement waste plastics percent on the physical properties of improved asphalt mix (dry density ρ_D) under optimum additive waste plastics (13% wt.). It appears that the dry density values are decreased with increasing a displacement waste plastics percent according to Figure (2) results [1, 2].

And Figure 15 shows the effect of set additives weight percent waste plastics on wet density of prepared asphalt mix at different reaction temperatures and optimum preparation time of (40 min). A constant effect of wet density is showed at optimum displacement ratio and time at high temperature 206ºc according to high crosslinked between asphalt binder and waste plastics additive at optimum conditions [1, 3].

Chemical properties:

Figures (16, 17) show the effect of different chemical solutions (100% H_2O, and 5% H_2O_4) of final improved asphalt mixture at different displacement waste plastics percent. These curves show an increasing in weight change with continuous increasing of resident time. A high chemical stability for run (11) produced compared to standard sample according to high crosslinked between asphalt binder and additive displacement waste plastics at these optimum conditions 172°c and 15%wt. wp displacement additive. [1, 2].

Thermo-Mechanical properties:

Figure (18) shows the effect of set displacement waste plastics (wp) on thermo-mechanical properties of improved asphalt mixes (stability and flow modulus of elasticity). It appears that all stability values of improved asphalt mixes are decreased with increasing waste plastics displacement until reach optimum percent of wp additive 10% wt. then increased with high mechanical stability for sample prepared at high temperature 206°c (50KN) than standard sample of (23KN) according to high crosslinked between asphalt mix and wp additives at high temperatures then give high mechanical stability [1, 4].

And Figure (19) shows a decreasing of flow modulus of elasticity at increasing wp displacement until reach optimum sample at 10%wt. wp, then increased, with less distortion for optimum sample of 10%wt. wp and 172°c and 40 min of (1.1mm) than standard sample of (3.5mm) [1, 5].

And Tables (5, 6) show the comparison of these properties between optimum and standard asphalt mixes.

Table (5) shows a comparison of characteristic properties between S.A.M and I.A.M. characteristic properties of asphalt mix.

Asphalt mix type	ρ_{dry} g/cm^3	ρ_{wet} g/cm^3	Stability KN	Flow Mm	% improvement
S.A.M	2.00	0.90	23	3.5	+ 8% for dry density + 15% for wet density + 54% for stability - 69% for distortion
I.A.M	2.18	0.995	50	1.1	+ 8% $\rho_{.D}$ + 10% ρ_W + 54% M.S - 69% F.D

Table (6): Show a comparison of chemical proportion between S.A.M. and I.A.M.

Asphalt mix Type	H_2O solution	5% H_2SO_4 sol.	% improvement In resistance
S.A.M.	1.19	1.13	+ 0.5 for H_2SO_4 + 3% for H_2SO_4
I.A.M.	1.2	1.16	+ 0.8% H_2O + 3% for H_2SO_4

4. CONCLUSONS:

Based on the present work the following conclusion can be drawn regarding the improvement of asphalt mixture that will be used in the local street paving by the use of waste plastics additive displacement:

1. The optimum conditions which give excellent characteristics and performance properties in (physical, chemical, and thermo-mechanical properties) are: 172°c temperature 40 min time and 10% wt of waste plastics displacement.

2. Quantitative relationships could be obtained between the experimental variables and the final excellent performance of optimum improved asphalt mix.

3. Constant values of dry density produced for all sample because it related to the characteristic properties of aggregate only. And constant effect of wet density with different preparation conditions with high values for samples of high waste plastics displacement percent according to characteristic of both binder and waste plastics additive that give highly crosslinked properties.

4. All chemical resistance measured are higher than standard mix of asphalt against moisture (100% H_2O) with excellent chemical resistance for optimum prepared improved asphalt mix No. (11) of less change in weight (1.16).

5. Large change in weight for samples exposure to (5% H_2SO_4) with less change for optimum one no. (11) at 172°c, 40 min, 10% wt.wp).

6. Optimum mix (No.11) have high performance in thermo-mechanical properties under sever condition (60°c) for elasticity therefore, it improved the final strength performance properties asphalt mix of increasing 54% of Marshall stability compared to standard mix and decrease of 69% of distortion compared to standard sample.

7. Waste plastics (HDPE, PET, and polypropylene) modified bituminous binders provide better resistance against permanent deformations according to their high stability and high Marshall Quotient and it contributes to recirculation of plastic wastes as well as to protection of the environment.

8. Waste plastics will increase the melting point of the bitumen. Then use of the 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.

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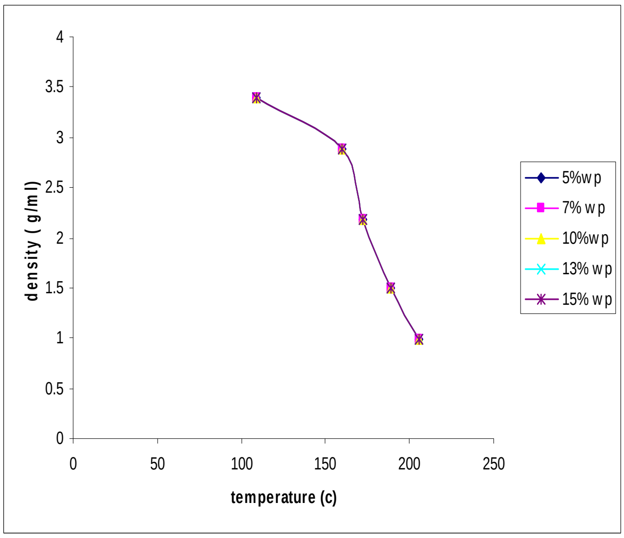

Figure (2) the effect of temperature on dry density of improved and standard mixes.

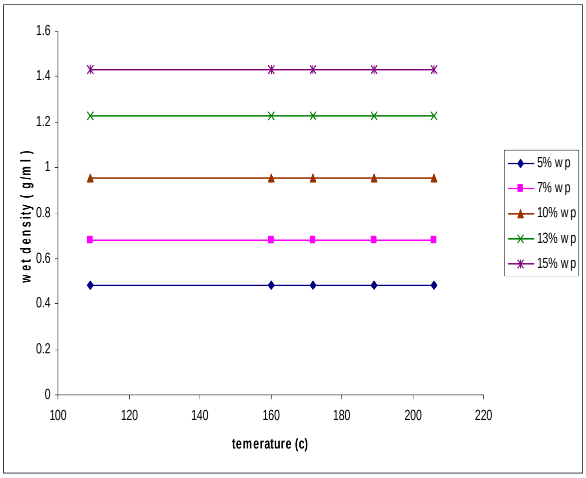

Figure (3) the effect of temperature on wet density of improved and standard mixes.

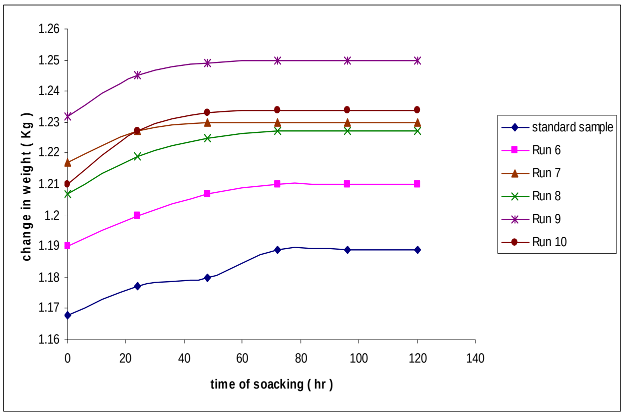

Figure (4) effect of moisture on chemical activity of improved and standard mixes.

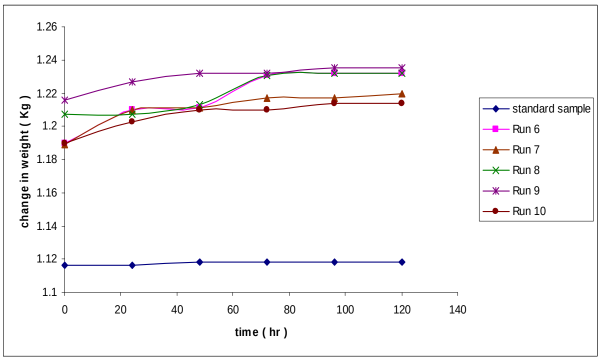

Figure (5) effect of acidic solution (5% H_2SO_4) on chemical activity of improved and standard asphalt mixes.

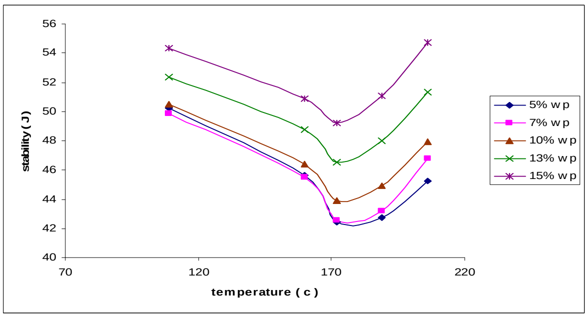

Figure (6) the effect of temperature on Marshall Stability of improved and standard mixes.

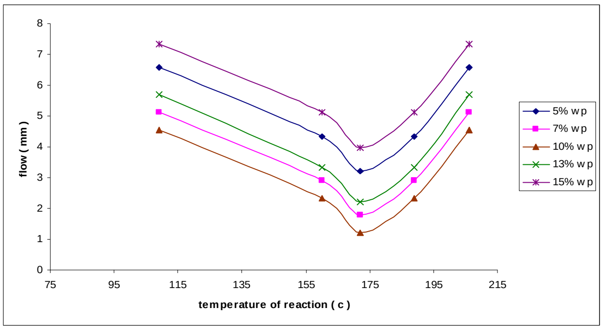

Figure (7) the effect of temperature on the flow modulus of elasticity of improved and standard mixes.

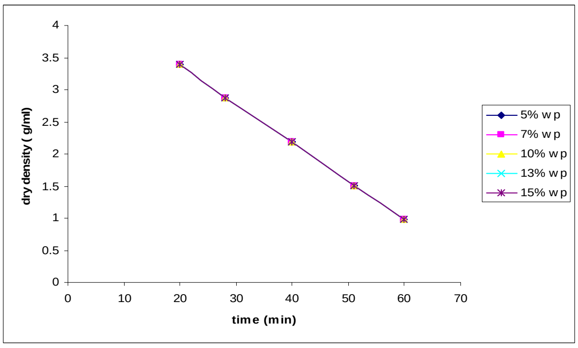

Figure (8) the effect of reaction time on dry density of improved and standard mixes.

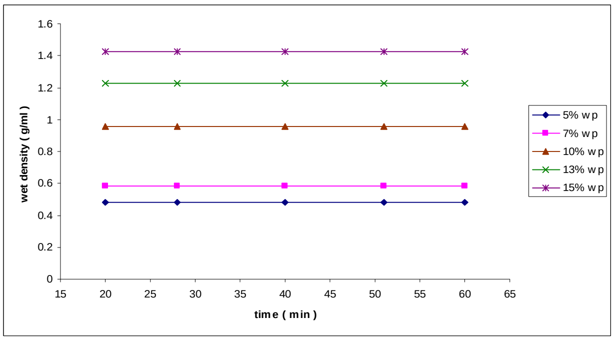

Figure (9) the effect of time on wet density of improved and standard mixes.

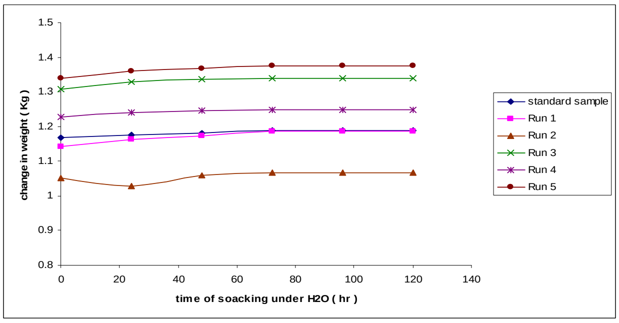

Figure (10) the effect of moisture on the chemical activity of improved and standard mixes.

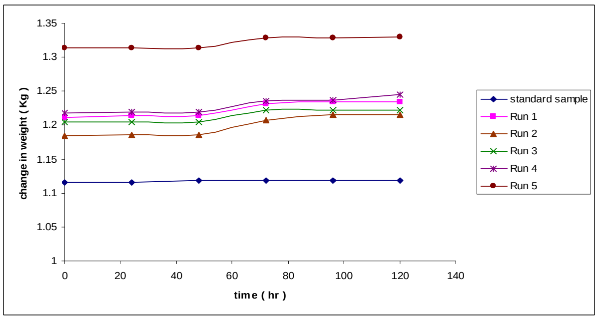

Figure (11) the effect of acidic solution on the chemical activity of standard and improved mixes.

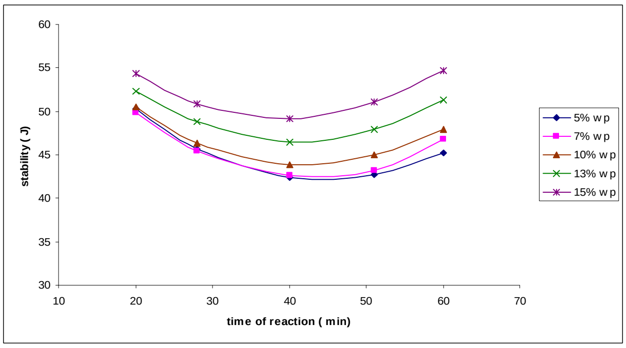

Figure (12) effect of reaction time on Marshall Stability of standard and improved mixes.

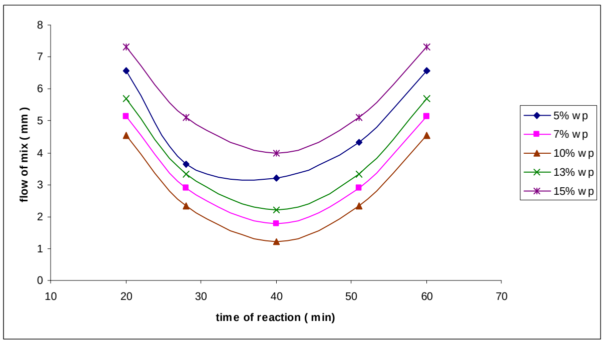

Figure (13) the effect of reaction time of the flow modulus of elasticity of improved and standard mixes.

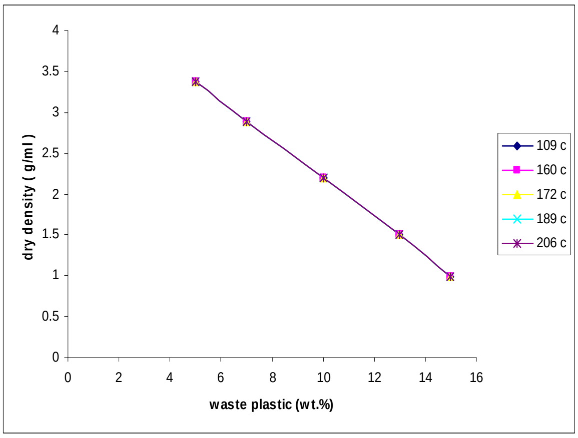

Figure (14) the effect of waste plastic replacement (wp) on dry density of improved and standard mixes.

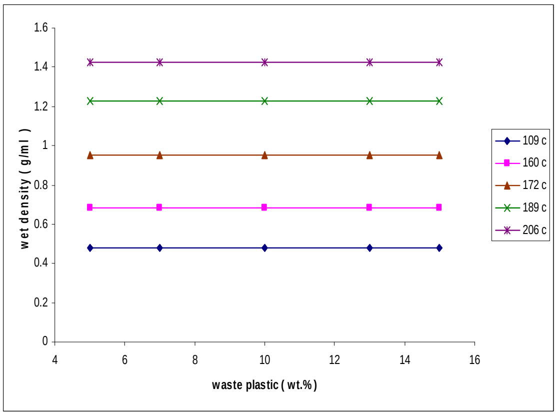

Figure (15) the effect of wp % replacement on wet density of improved and standard mixes.

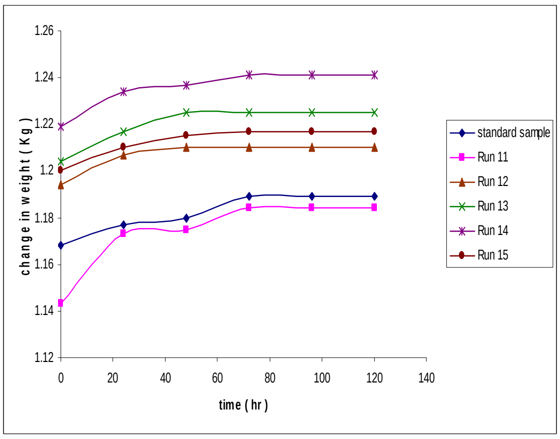

Figure (16) the effect of moisture on the chemical activity of improved and standard mixes.

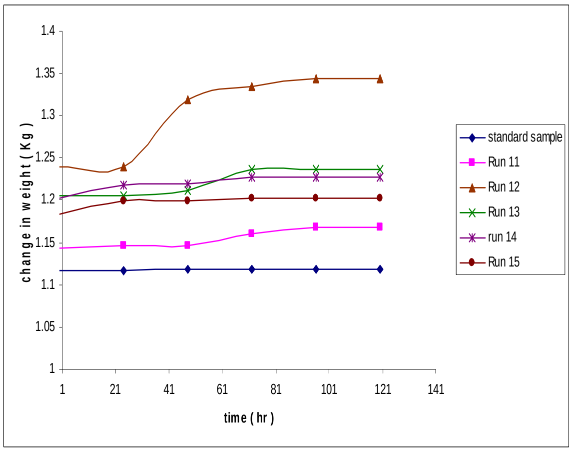

Figure (17) the effect of acidic solution on the chemical activity of improved and standard mixes.

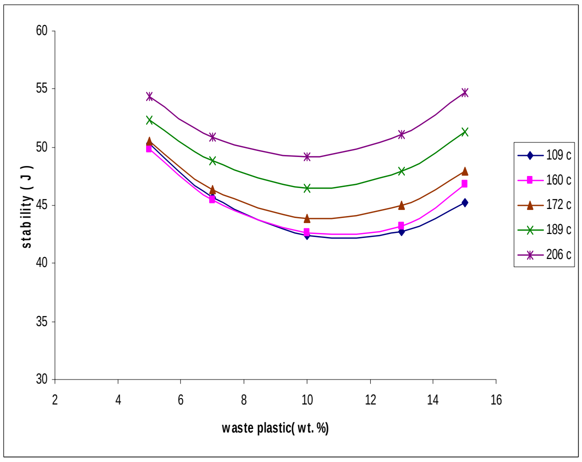

Figure (18) the effect of wp% replacement on Marshall Stability of improved and standard mixes.

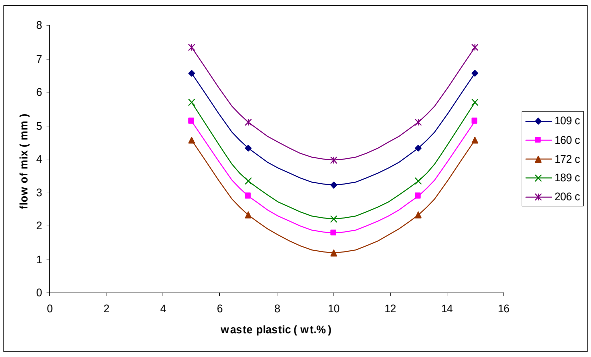

Figure (19) the effect of wp% replacement on flow modulus of elasticity of improved and standard mixes.