The Use of New Techniques in The Management of Waste Plastic by Reuse it in The Asphalt Mix

Dr. Falak O. Abas
Engineering College, University of Koya/ Duhok
Email:Falak_usama@yahoo.com
Raghad U. Abass
Material Engineering Department, University Of Technology/Baghdad
Enas .A .A
Environmental Research Center, University Of Technology/Baghdad

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ABSTRACT:

The quantity and type of waste being generated is growing at enormous rate. The plastic waste produced particularly in form of bags, Plates, Containers, being non-degradable and with limited recycling options 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 was under taken.

Preliminary investigations have indicate of RPWA (from 1.2 in (1.5 cm) to No. 200 sieve (0.075 cm) , in surface mix design when utilized up to (5% to 15%) by weight substitution, through the use of Box-Wilson design program in order to give an optimum condition, time of reaction, and weight percent of substitution replacement aggregate in asphalt mix. The above following variables were studied temperatures (109-206) c^{o} , time (20-60) min and weight at waste substitution (5-15) % wt. respectively. 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. Which improved these optimum conditions give high stability of Marshall Test and low distortion with acceptable low constant wet density and uneffect dry density with these condition with high resistance to chemical solutions exposure? It is envisaged that use of RPWA in the conventional asphalt hot mix design 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.

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2412-0758/University of Technology-Iraq, Baghdad, Iraq
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استخدام التقنيات الحديثة في ادارة النفايات البلاستيكية واستخدامها في الخلطات الاسفلتية

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 2/1 انج (1.5 سم) الى 0.075 سم (تدرج حبيبي رقم 200) (بشكل متدرج وخليط من عدة حجوم حبيبية) في تصميم الخلطات الاسفلتية للطبقة السطحية المستخدمة في التبليط للطرق وبنسبة تعويضية من 5% نسبة وزنية الى 15% 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 (109 – 206)°م وزمن تفاعل بين(20 – 60) دقيقة ، ونسبة استبدال وزنية تعويضية تصل الى (5 – 15) % نسبة وزنية على التوالي . وكانت الظروف المثلى للخلطة المثالية هي درجة حرارة 172 °م ، وزمن تفاعل 40 دقيقة ، ونسبة استبدال تعويضية من النفايات البلاستيكية بالركام مقدارها 10 % 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 كيميـاوية عالية للرطوبة والمحاليل الحامضية 5% محلول) H_2SO_4هذا الذي يشجع استخدام النفايات البلاستيكية في تحسين اداء الخلطات الاعتيادية المستخدمة في الرصف ويشكل الحل الامثل للتخلص من هذه المشكلة البيئية الحالية.

INTRODUCTION:

Plastics is every where in today's lifestyle. It's used for packaging, Protecting, serving, and even disposing lf all kinds of consumer good. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, communication or infortech has been virtually revolutionsed by the applications of plastic. 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 caner 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 product in highway construction have given encouraging results. A study on the possible use of the processed plastic 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 the use of recycled plastic, mainly polyethylene 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 in to conventional asphaltic (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, there by utilizing the waste plastic, to increase pavement durability decreased deformation resistance and increased hardness and ductility have been reported by adding other plastic waste in amounts, Also improved technical performance relative to primary aggregate alternatives. This could include properties such as superior abrasion resistance, enhanced flow properties, beneficial effects on other durability enhancements. Economically thought the use of less binder and Environmental enhancecement egaesthetic appearance, energy saving [5, 6, and 7].

Several attempts were carried out by the use of waste plastic in asphaltic cement mix [8,9] where Adnan Qadir, and Mansoor Imam have been use the waste plastic bags in bituminous mix for improved performance of roads to improve desired mechanical characteristics for a particular road mix by the use at (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. and et.al were used of liquid plastic additive to enhance the properties of asphalt where in the liquid plastic is 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 and et, al were used of waste 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. et, al are used of waste materials in asphalt mixture such as (rubber and plastic (5%, 10%, and 20% of the total)) of three particle size (4.75mm (No. 4), 0.85mm(No. 20), and 0.075mm (No. 200), as replacement by stone powder in asphalt mix specimen to improve the Marshall stability moisture susceptibility [13].
Also Hassani A., et al were used of waste plastic (polyethylene terephalate) in asphalt concrete mixture as aggregate replacement of 3mm diameter replace by volume apportion of the mineral coarse aggregate of an equal size (2.36- 4.75mm) and reached optimum value at 6.6% vol. , an reduction of bulk compacted mix density [14].
Recently Rajib B. Mallick. et al, have a successful use of synthetics light weight aggregates made from waste fly ash and plastic in a hot mix asphalt at different percentage of aggregate at 0%, 5%, 10%, 15%, and 20% by weight of aggregate replacement percent, then check 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 plastic carded to carry various materials including house hold articles has become a common practice all over the country, and find useful application for these wastes. Environmental enhancement, energy saving and economics 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 or 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 soft ware program analysis

Experimental

A schematic diagram of experimental reaction system is shown in figure (1). Weight in to separate pans the amount of each size fraction required to prepare a batch standard design asphalt mix (aggregate [fine & coarse], cement [filler] and asphalt cement [binder]) at the classification of each component shown in table (1) put the pan of a batch mix 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 forming an asphalt mix material containing recycled (waste) plastics. Comprising the steps of [16-18].

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

- Dry mixing and heating aggregate and sand (Fine & coarse) aggregate at the same design mixing ratio replacement by waste plastic at range (5-15)% wt. then dry mixing untreated plastic particles with the aggregate and sand while continuing heating until the mixture of plastic particles, aggregate and sand reaches temperature of reaction at range (109-206) °c and afterward adding liquid asphalt to the mixture of plastic particles, aggregate, sand, and filler with continuous mixing 950 cycle/mix for mixing time range (20-60) min due to experimental program design (Box-Wilson method) then mold these prepared (standard & improved mix) in to a clean, hot and crease molder assembly them face the compaction hammer (Germany comp 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 apply 75 blows with compaction hammer prepaideircularly to the base of mold , remove the base plate and collar then reverse and reassemble the mold with the application of same No. 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].

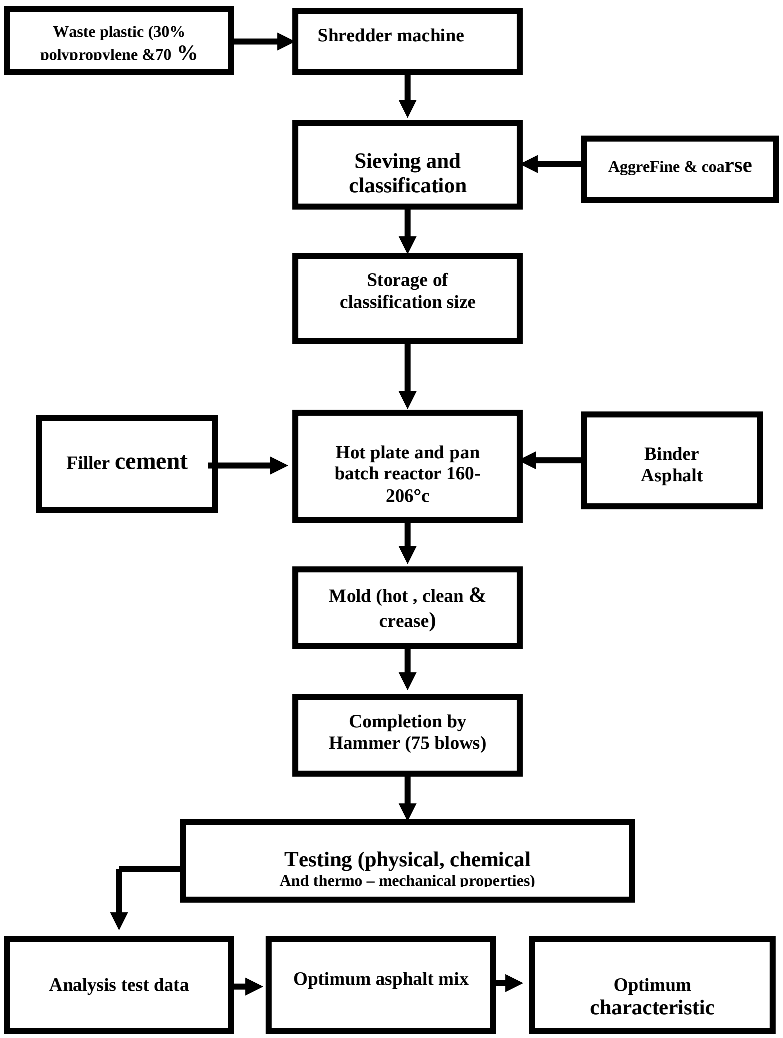

Figure (1): Schematic diagram for standard asphalt and improvement mix preparation and characterization.

The waste plastic used in this study consist of (30% polypropylene and 70% polyethylene PET) mixed in the form (3/8 inch to No. 200 sieve) [19, 20] was 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 plastic of 12.5 mm and smaller that it was collected manually from domestic waste and land fill in Baghdad.

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 type of 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 type of test is determined by the use of Marshall Machine tester in asphalt lab/ of building Eng. Depart. Due to (ASTMD 155982- Marshall apparatus)stability and dynamically measurement, where put the prepared samples 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 and this factor is called Marshall stable (KN) and record the failure of stable sample only after load stable occur and record the dynamic failure and called flow distortion modulus of elasticity in (mm).

Results and Discussion:

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 (gm/cm^3)	92.999	0.99978	0.23
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:

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

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

$$Y\ \rho_D = 2.189986 – 0.691X_1 \quad … (3)$$

$$Y\ \rho_W = 0.955 + 0.273\ X_3^2 \quad … (4)$$

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 improvement asphalt mix was performed by suing 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 find 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 the values of dry density is less decreased with continues increasing reaction temperature until reach optimum values at 172°c then afterward these values are highly decreased due to highly crosslinked between asphalt binder and waste plastic that convert it light material polymer then cause a drop in density.

Figure (3) shows the effect of set temperatures of reaction on the wet density of asphalt mix at different replacement mixing of waste plastic and optimum time of reaction of (40 min) that give constant effect of wet density at increasing temperature with increasing amount of waste plastic replacement at high values 15% replacement wp% of (1.42) than standard of 0.45 g/cm^3 due to the high effect of temperature on the properties of polymer waste plastic and crosslinked between these waste and asphalt cement binder in asphalt 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 temperatures of preparation asphalt mix. These curves show increasing in weight change with continuous increasing of soaking time with high chemical stability i.e. less change in weight for optimum one run 6 at 189 °c less change in weight for sample soaking in moisture and high change in weight for sample soaking in H_2SO_4 solution at increasing time with high chemical stability for run (10) at high temperature 206 °c, because of high crosslinked of atoms between binder asphalt cement and waste plastic at high temperature and gave high chemical resistances for chemical solution (5% H_2SO_4) than of moisture at 189 °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 this improved mix (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 at 172 °c and 15% wp of 50 KN than standard one of 23 KN.

And figure (7) show the decreasing of flow modulus of elasticity at increasing temperature of reaction until reach optimum one at 172 °c then increased with less distortion for optimum one of 10% wp of 1.1 mm than standard one of 3.5 mm distortion due to the high crosslinked between asphalt binder and polymer additive waste at high temperature then give a stable improved asphalt mix chemical, physical and thermo-mechanical resistance [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 the values of dry density is decreased with increasing time of preparation with less change at optimum time of (40 min) with dependent on 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 replacement mixing of waste plastic and optimum reaction temperature of waste plastic and optimum reaction temperature of (172 °c).

It appear that constant effect of time on the wet density with high wet density at replacement 15% wp, of 1.4g/cm^3 than standard one of 0.44 g/cm^3 due to the 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 soaking time with high chemical stability for run (2) at moisture and 5% H_2O_4 exposure than standard one dependent on high reaction temperature of 189 °c that give high crosslinked and high chemical stability [1, 6].

Thermo-Mechanical properties:

Figures (12, 13) show the effect of set time of reaction of asphalt mix preparation on the mechanical properties of these improved mixes (stability & flow modulus of elasticity). It appears that all stability values of improved mix are decreased with increasing time of preparation until reach optimum time at 40 min then increased with high mechanical stability for 15% wp (waste plastic replacement) of 50 KN then standard of 23 KN at this conditions.

And figure (13) show decreasing of flow modulus of elasticity at increasing time of reaction until less distortion for optimum one of 10%wp (waste plastic replacement), at this conditions have 1.1 mm than standard one of 3.5mm due to the high crosslinked between asphalt binder and polymer additive waste at optimum conditions 10%wp, 172°c, and 40min) then give a stable improved asphalt mix, chemical, physical, and thermo-mechanical properties [1, 4].
Effect of waste plastic replacement percent (%wt.) on the final improved asphalt mix.

Physical properties:

Figure (14) shows the effect of set replacement waste plastic percent on the physical properties of improved asphalt mix (dry density ρ_D) under optimum additive waste plastic (13% wt.). It appear that the values of dry density is decreased with increasing additive wp replacement with less change get at optimum percent at (13% wt) with dependent on figure (2) result [1, 2].

And (figure 15) shows the effect of set additive weight percent at wp on the wet density of asphalt mix at different reaction temperatures and optimum time of preparation at (40 min). It appear that constant effect of wp additive replacement on the wet density with high wet density at high temperature 206ºc due to the high crosslinked between asphalt binder and wp additive at this temperature [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 replacement additive wp. These curves show increasing in weight change with continuous increasing soaking time with high chemical stability for run (11) than standard one due to high crosslinked between asphalt binder and additive replacement wp at these optimum conditions 172°c and 15%wt. wp replacement additive. [1, 2].

Thermo-Mechanical properties:

Figures (18, 19) show the effect of set additive replacement waste plastic (WP) on the thermo-mechanical properties of these improved asphalt mix (stability and flow modulus of elasticity). It appears that all stability values of improved asphalt mix are decreased with increasing waste plastic additive replacement until reach optimum percent of wp additive 10% wt. then increased with high mechanical stability for sample of high temperature reaction at 206°c 50KN than standard one of 23KN due to the high crosslinked between asphalt mix and wp additive at high temperature that give high mechanical stability [1, 4].

And figure (19) show decreasing of flow modulus of elasticity at increasing wp additive replacement until reach optimum one at 10%wt, wp, then increased, with less distortion for optimum one of 10%wt. wp and 172°c temperature reaction and 40 min time of reaction of 1.1mm than standard one of 3.5mm [1, 5].

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

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

Conclusions:

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 plastic additive replacement:

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 plastic replacement.
2.Quantitative relationships could be obtained between the experimental variables and the final excellent performance of optimum improved asphalt mix.
3.The same values of dry density 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 density of samples of large waste plastic replacement because it depends on the characteristic of both binder and waste plastic 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 soaking in (5% H_2SO_4) with less change for optimum one No. (11) at 172°c, 40 min, 10% wt.wp).
6.The final optimum mix (No.11) have high performance in thermo-mechanical properties under sever condition (60°c) for elasticity then it improved the final strength performance properties, where optimum improved asphalt mix give increasing 54% of Marshall stability compared to standard mix and decrease of 69% of distortion compared to standard one.
7.Then waste plastic (HDPE, PET, and polypropylene) modified bituminous binders provide better resistance against permanent deformations due to their high stability and high Marshall Quotient and it contributes to recirculation of plastic waste as well as to protection of the environment.
8.Waste plastic will increase the melting point of the bitumen. The 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.

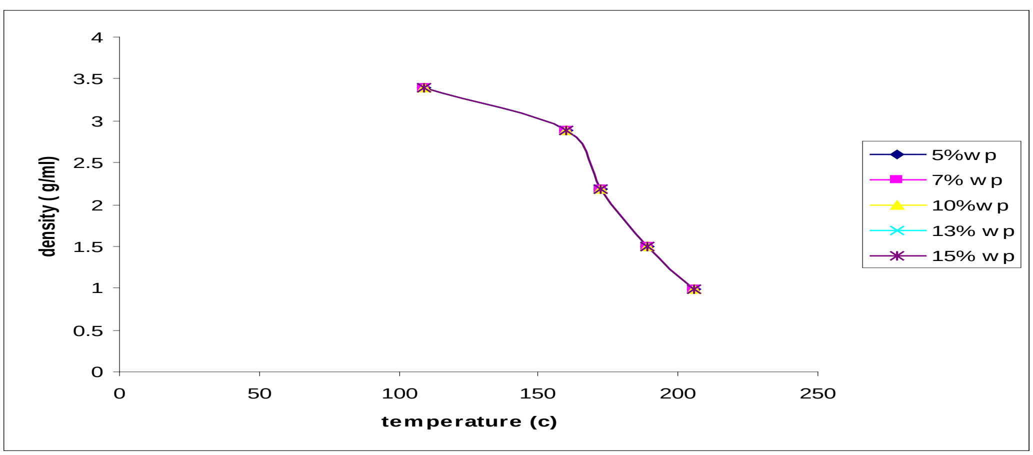

Figure (2) the effect of temperature on dry density of improved and standard mixes.

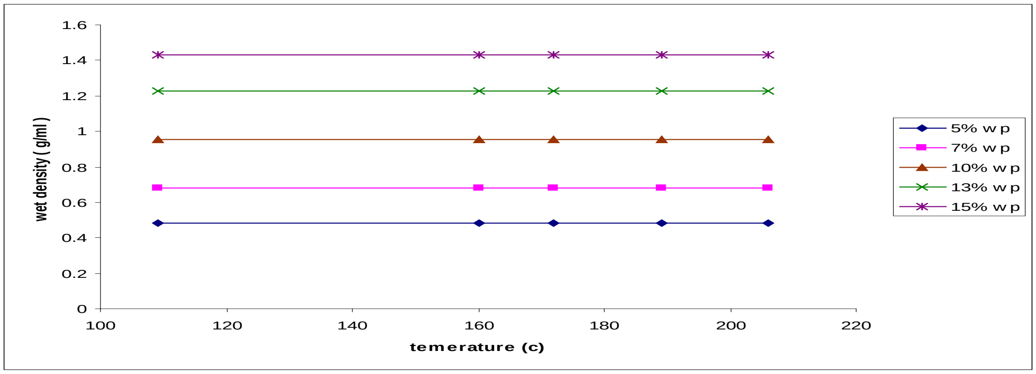

Figure (3) the effect of temperature on wet density of improved and standard mixes.

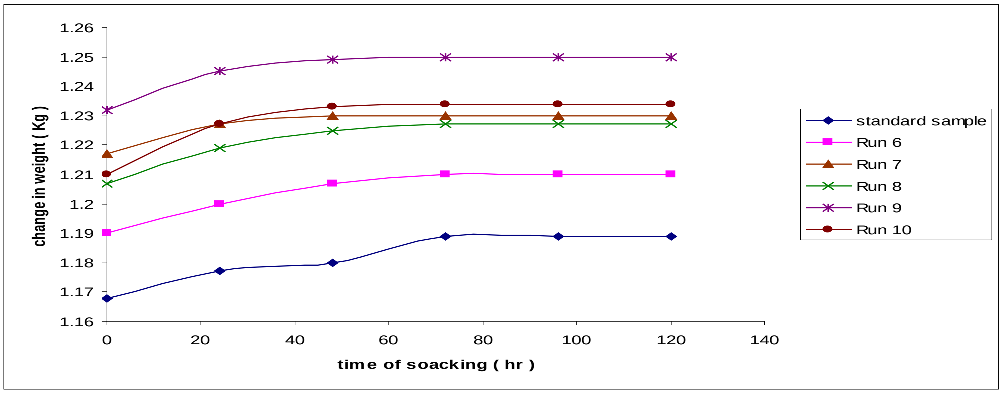

Figure (4) effect of moisture on chemical activity of improved and standard mixes.

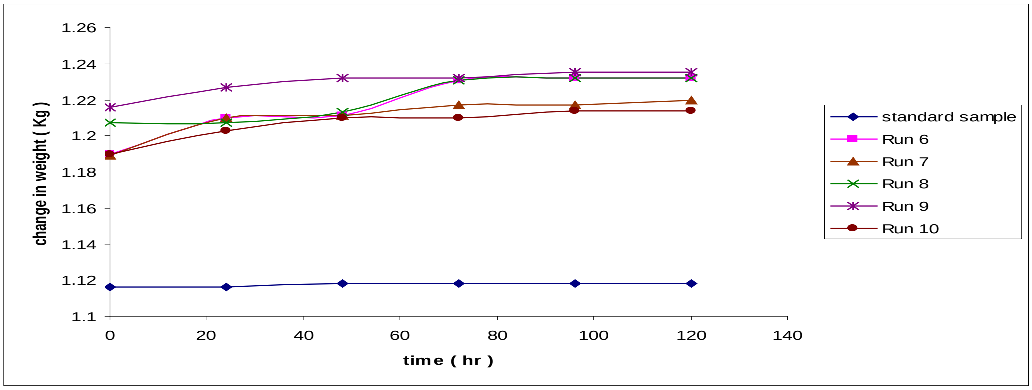

Figure (5) effect of acidic solution (5% H_2SO_4) on chemical activity of improved and standard asphalt mixes.

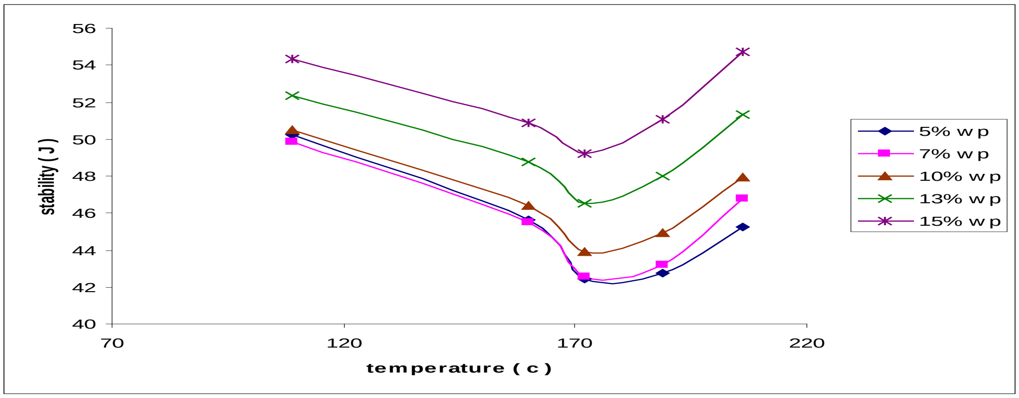

Figure (6) the effect of temperature on Marshall Stability of improved and standard mixes.

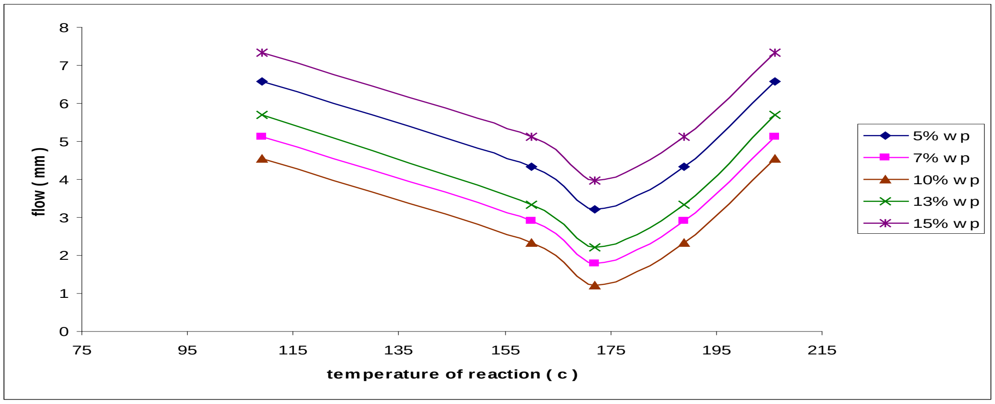

Figure (7) the effect of temperature on the flow modulus of elasticity of improved and standard mixes.

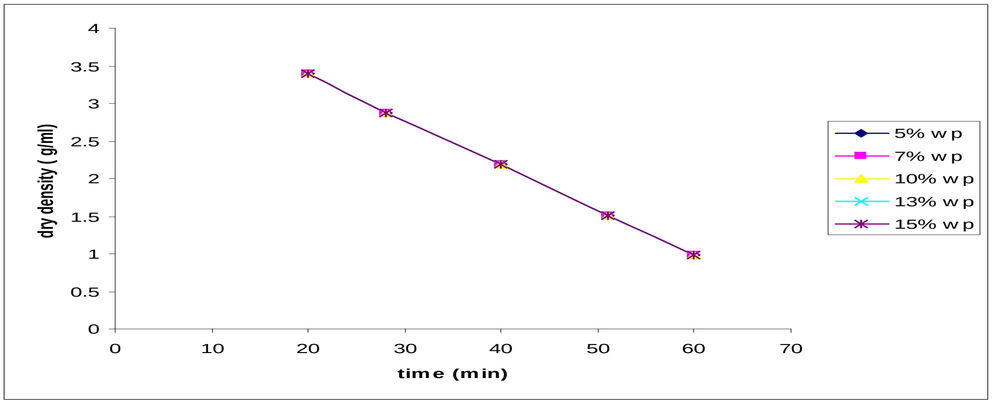

Figure (8) the effect of reaction time on dry density of improved and standard mixes.

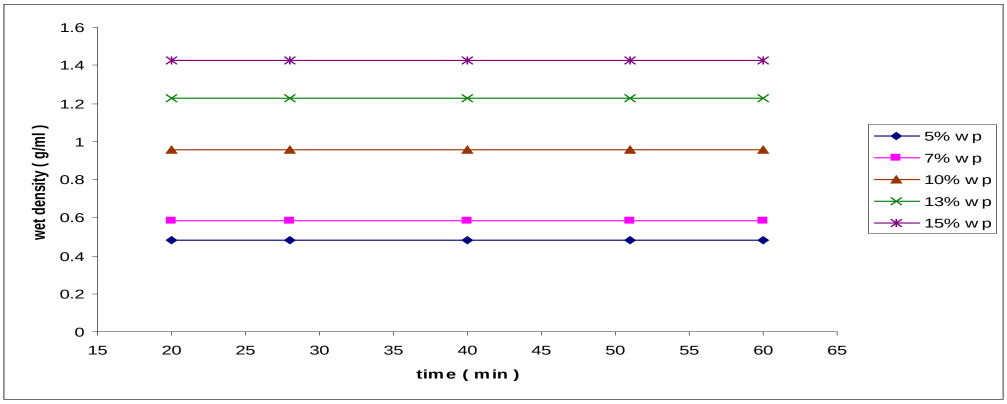

Figure (9) the effect of time on wet density of improved and standard mixes.

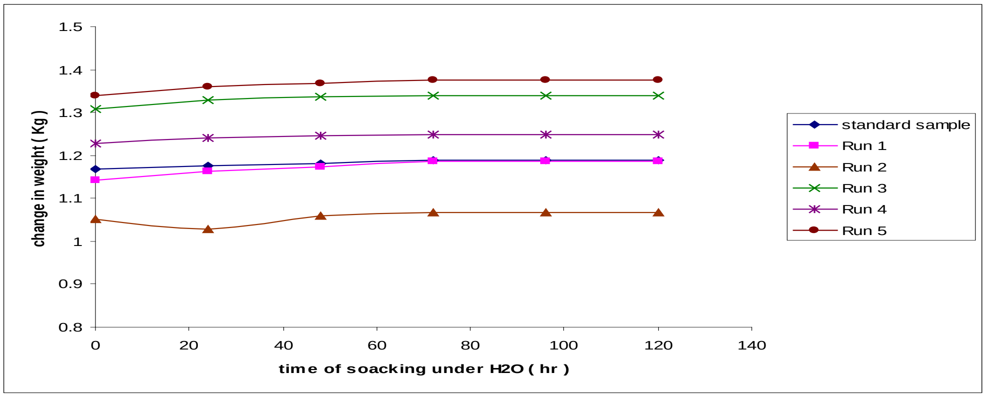

Figure (10) the effect of moisture on the chemical activity of improved and standard mixes.

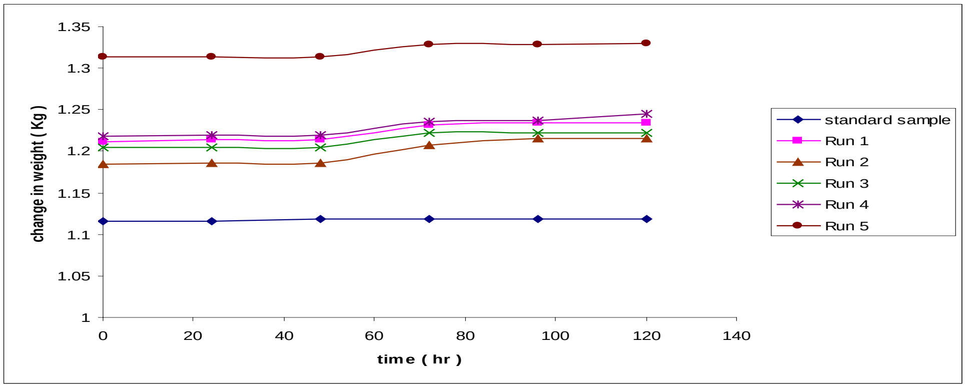

Figure (11) the effect of acidic solution on the chemical activity of standard and improved mixes.

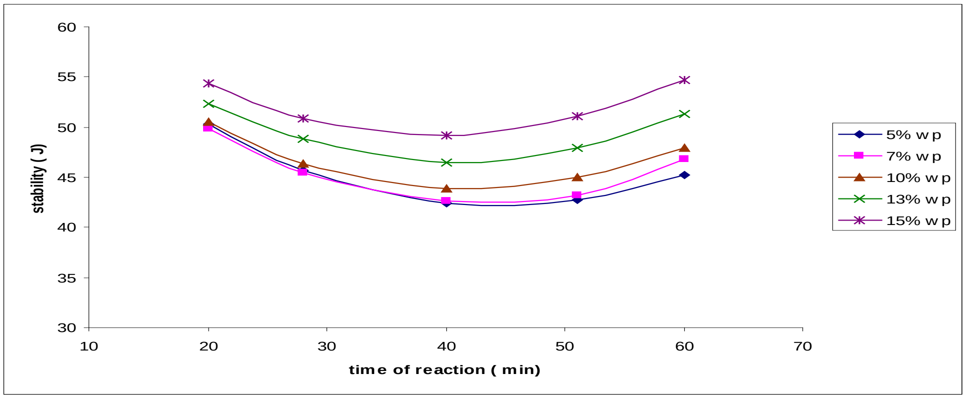

Figure (12) effect of reaction time on Marshall Stability of standard and improved mixes.

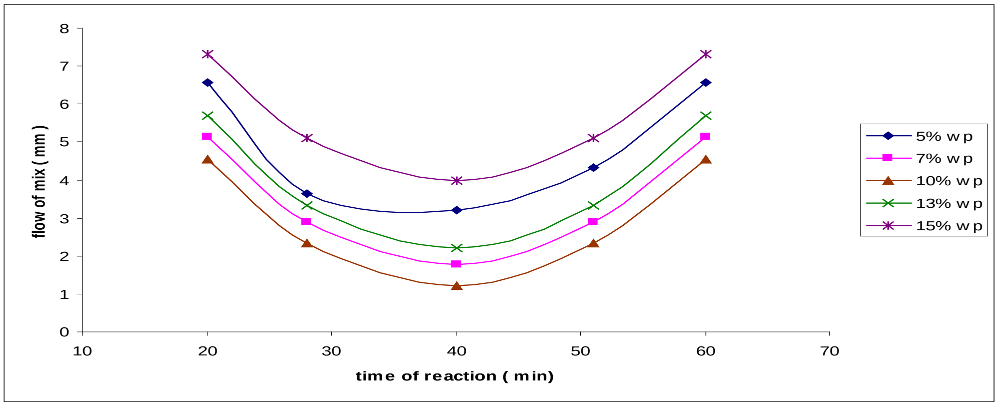

Figure (13) the effect of reaction time of the flow modulus of elasticity of improved and standard mixes.

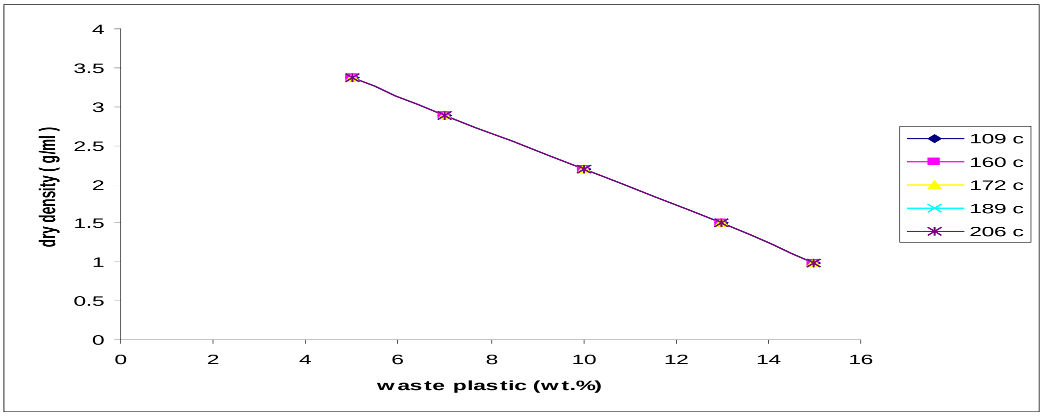

Figure (14) the effect of waste plastic replacement (wp) on dry density of improved and standard mixes.

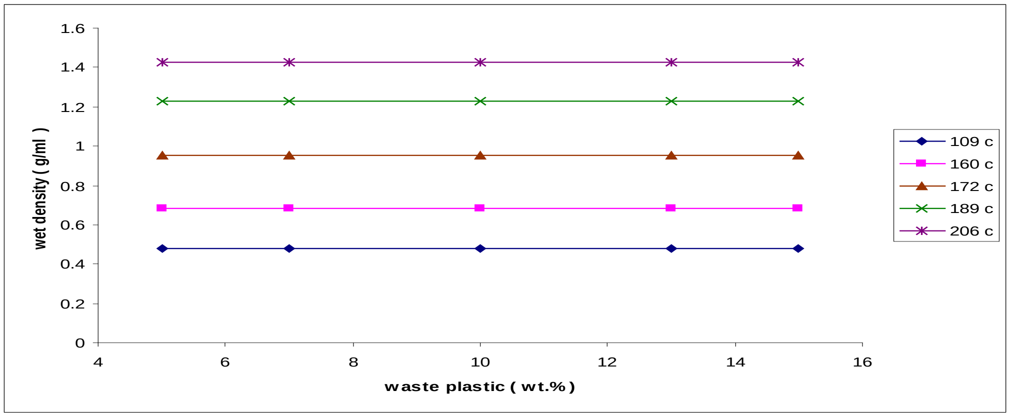

Figure (15) the effect of wp % replacement on wet density of improved and standard mixes.

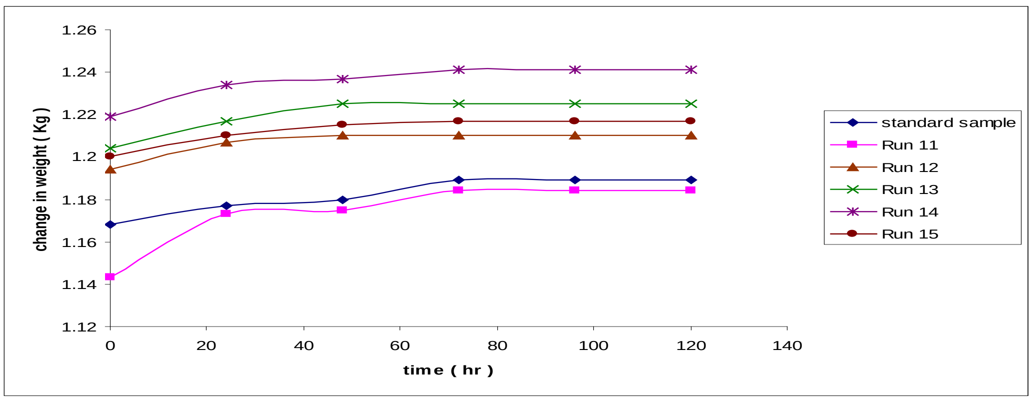

Figure (16) the effect of moisture on the chemical activity of improved and standard mixes.

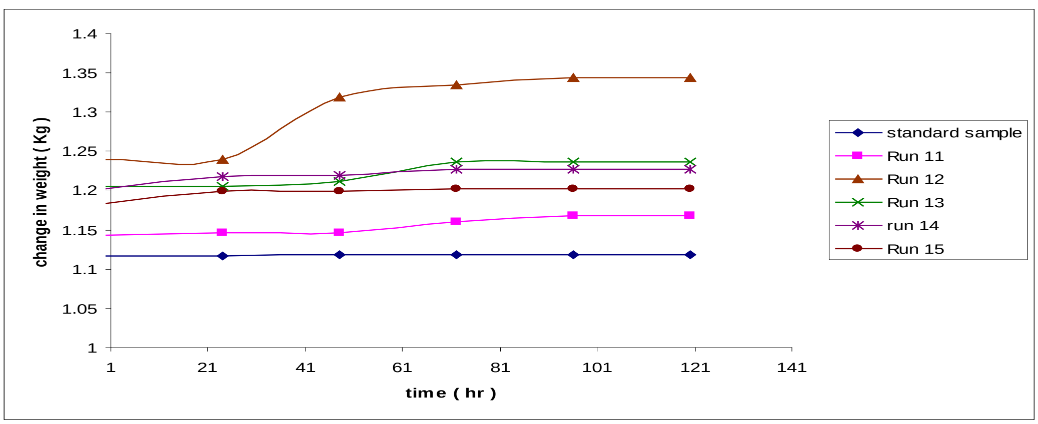

Figure (17) the effect of acidic solution on the chemical activity of improved and standard mixes.

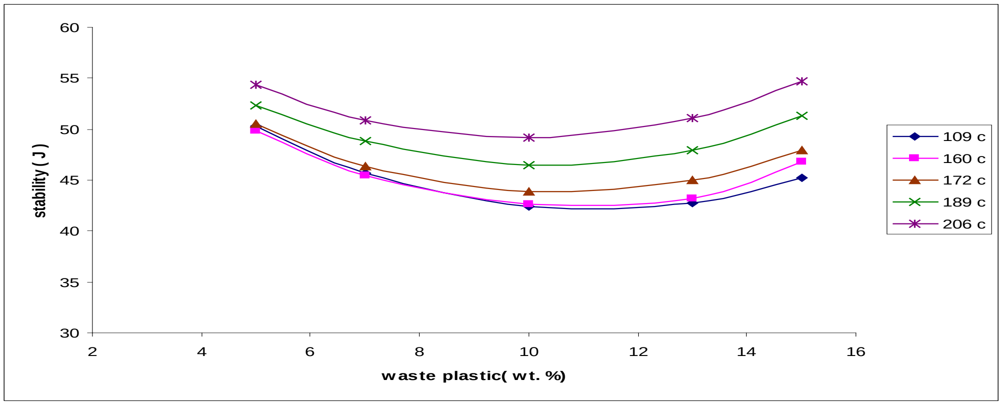

Figure (18) the effect of wp% replacement on Marshall Stability of improved and standard mixes.

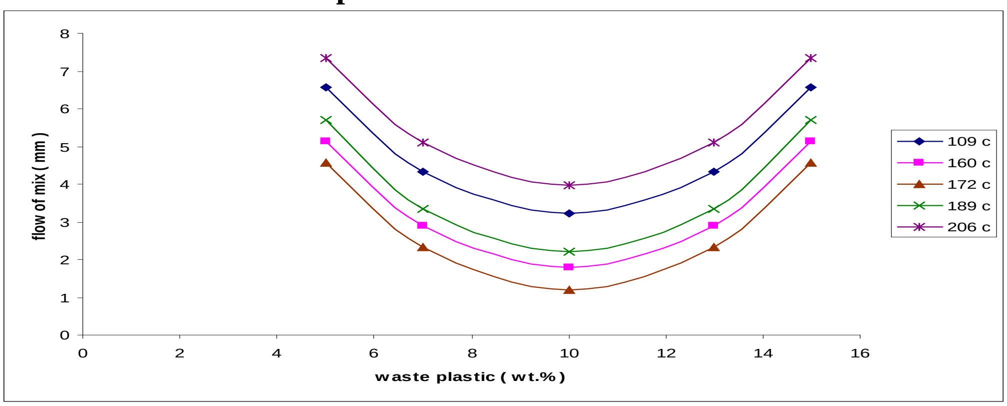

Figure (19) the effect of wp% replacement on flow modulus of elasticity of improved and standard mixes.

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