International Journal of Transport, Highways & Railways Engineering – IJTHRE
Volume 3 : Issue 1 [ISSN : 2475-2746]
Publication Date: 06 April, 2017

Enhancing of Asphalt mix properties using waste polyethylene and Fly Ash

M. S. EISA[1], M. E. Basiouny [2] & A. H. Boraie [3*]

[1] Lecturer of Highways and Airports Engineering, Faculty of Engineering, Benha University, Egypt
, E-mail: mohamedeisa524@bhit.bu.edu.eg
[2] Professor/ Dept. Head, Faculty of Engineering, Benha University, Egypt
, E-mail: mbasiouny@ecu.edu.eg
[3] Department of Civil Engineering, Al-Safwa High Institute of Engineering, Egypt
, E-mail: ahmedboraie_55@yahoo.com

ABSTRACT

Increasing traffic volumes, heavier loads on Egyptian road network cause several pavement distresses. Several trials were done to eliminate pavement distresses by using some additives. One of the cheapest methods for mix enhancement is to use the solid waste material such as plastic and fly ash. This study aims to investigating the effect of using fly ash and waste plastic on the properties of asphalt concrete mixtures. To achieve the study objectives, Marshall Test was conducted on standard mix without additives as a reference and on two groups of asphalt concrete mixtures. In the first group different percentages of fly ash was used instead of fine aggregate. While in the second group, different percentages of waste plastic Resin instead of fine aggregate portion in hot mix asphalt with a combination of the best percentage of fly ash instead of fine aggregate in hot mix asphalt was used. Finally, some special tests were performed to measure the different mix characteristics. These tests included loss of stability test and wheel tracking test. Analyzing the study results it can be concluded that the use of waste plastic resin and fly ash greatly enhance the rutting depth and properties of asphalt mixtures compared with conventional asphalt mixtures. Finally the study recommended using two proposed mixes .the first mix consists of 2% fly ash instead of fine aggregate portion in hot mix asphalt (HMA). While the second mix consists of 9% waste plastic resin with a combination of a 2% fly ash instead of fine aggregate portion in hot mix asphalt.

Keywords:

Waste Plastic Resin (WPR), FLY ASH, Asphalt Mixes, Marshall Properties, Loss of stability and wheel tracking test.

**Corresponding author: Email:* ahmedboraie_55@yahoo.com

1. INTRODUCTION

As a result of the huge increase in the types of industries and population growth produces large amounts of solid waste, such as Plastics, Blast Furnace Slag, Fly ash, Steel Slag, Scrap Tires etc. In other side, the increase in road traffic during the last two decades, in addition with an insufficient degree of maintenance, has caused an accelerated deterioration of road structures in many countries. The modification of asphalt with polymers is considered one of the best options to improve asphalt properties.

Plastic materials are mainly composed of Low Density Polyethylene (LDPE). However, disposal of waste plastic materials in large quantities has been a problem as it's not a biodegradable material. This study was conducted to investigate the possible use of waste plastic Resin (WPR) as a modifier of hot-mix asphalt and to review the feasibility of incorporating waste plastic resin to improve the performance of asphalt mix.

2. LITERATURE REVIEW

The Use of plastic waste and fly ash in flexible pavements would open up a solution for the disposal issues regarding plastic wastes and fly ash. Many research works have been done in the area of use of plastic waste and fly ash in bituminous road construction. Sreedevi & Salini investigated pavement performance on roads surfaced using bituminous mixtures with coated aggregates and concluded that, the use of waste plastic for road construction can save the environment, increase the service life of roads, reduce the consumption of petroleum products and serve the society with additional income for those associated with it [5].

(Yash Menaria, Rupal Sankhla) reported the Utilization of waste plastic improves the binding property of mix , using Waste plastic in roads increases the stability value and durability to a great extent and Replacement of bitumen with plastic reduces the cost of construction significantly [9]. Apurva & Chavan, in their research, showed that polymer-bitumen blend helps to have a better binding of bitumen with plastic coated aggregate due to increased bonding and increased area of contact between polymers and bitumen. The polymer coatings also reduce voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting, raveling and pothole formation [1].

(Bhageerathy K. P, Anu P. Alex, Manju V. S, Raji A.K) investigated the use of biomedical plastic waste in bituminous road construction. They concluded that the Marshall Stability value of plastic modified mix was found to be 51 percent more than that for the normal mix which indicates an increase in load carrying capacity [2].

(Zoorob & Suparma reported the use of recycled plastics composed predominantly of low density polyethylene (LDPE) and polypropylene (PP) in conventional bituminous concrete mixtures with improved durability and fatigue life [8].

Kalantar et al investigated the possibility of using waste polyethylene terephthalate (PET) as polymer additives for binder in asphalt mix. Waste PET is powdered and mixed in proportions 2,4,6,8 and 10% (by the weight of OBC) with bitumen at temperature 150^{o}c. PET modified binder resulted in higher resistance to permanent deformation and higher resistance to rutting due to their higher softening point when compared to conventional binders. Decrease in consistency and increase in the resistance to flow and temperature changes also appears in PET modified binder [6].

The introduction of fly ash into asphalt mixtures (Asphalt) was reported to improve the performance of the asphalt binders at levels compared to those achieved through polymer modification (sobolev ET al) [4]. Sankaran and rao [3] and tapkin [7] found that additions of fly ash provided higher stability for asphalt mixtures. The use of fly ash in bitumen materials is attractive as it improves performance and reduces costs and environmental impacts.

3. STUDY OBJECTIVES

This study aims at investigating the effect of fly ash material on the properties of asphalt mixtures. It also aims at investigating the use of waste plastic resin in producing asphalt concrete mixtures and evaluating the properties of such mixtures regarding to distresses resistance.

4. STUDY METHODOLOGY

To achieve the study objective the following steps are perfprmed:

- Identifying Optimum Bitumen Content (OBC) using Marshal Mix design procedure. Four percentages of bitumen have been examined to determine the Best percentage of bitumen content, which include 3.5, 4, 4.5 and 5% by weight of the mix.

- Testing Marshall Samples containing different percentages of fly ash as it is (1, 2, and 3%) of fine aggregate portion in HMA.

- Marshall Test will use to examine the specimens of asphalt mixture with different percentages of waste plastic Resin as it is (3,6,9,and 12%) of fine aggregate portion in HMA with a combination of the best percentage of fly ash (instead of fine aggregate in hot mix asphalt (HMA).

5. EXPERIMENTAL WORK AND MATERIALS

Research materials were collected from common sources in Egypt. Qualification tests were conducted on coarse aggregate, fine aggregate, crushed sand, plastic materials, fly ash, and asphalt materials. The properties of coarse aggregate (pin 2+ pin1) are presented in table (1), The gradation of the different materials is presented in table (2), The mixes designed conditions are mentioned in table (3), The properties of asphalt binder are presented in table (4), properties for fly ash shown in table (5) and the properties for resin plastic are presented in table (6). Marshall Method for designing hot asphalt mixtures was used to determine the optimum bitumen content to be added to specific aggregate blend and evaluate the specimens of fly ash and waste plastic Resin to determine the best content of fly ash and waste plastic. Some special tests were conducted to evaluate the different properties of the investigated mixes. These tests include loss of stability and wheel tracking test.

Table (1): properties of coarse aggregate

TEST NO.	TEST	AASHTOO DESIGNATION NO.	RESULTS for pin 2	RESULTS for pin 1	Specification limits
1	Abrasion value after 500 revolution	T-96	26.2%	26.5%	≤ 40%
2	Water absorption values	T-85	1.2%	1.3%	≤ 5%
3	Specific gravity - Bulk -saturated -apparent	T-85	 2.659 2.711 2.755	 2.680 2.722 2.788	- - - -
5	Stripping value	T-182	> 95%	> 95%	> 95%

Table (2): Gradation of Different Materials (%passing).

Material \ Sieve size, inch	1	3/4	1/2	3/8	No. 4	No. 8	No. 30	No. 50	No. 100	No. 200
Coarse aggregate(pin2)	100	86	37	10	0.2					
Coarse aggregate(pin1)	100	100	99	85	20	1.5				
sand					100	99	78	40	6	3.5
Crushed sand					100	76	42	33	27	24
Plastic resin					100	100	0	0	0	0
Fly ash					100	96	90	87	85	76

Table (3): Conditions of the Designed Mixes Used In the study

Mix. no	description
Mix 1	(Mix contains the Optimum Bitumen Content (OBC) without any additives) it will be a reference mix.
Mix 2	Mixes contains different percentages of fly ash (1%, 2%, 3% measured from natural sand fine portion of the reference mix).
Mix 3	
Mix 4	
Mix 5	mixes contains different percentages of waste plastic Resin (3, 6, 9, 12)% as a percentage of fine portion and a combination of the best percentage of fly ash measured from natural sand fine portion of the reference mix.
Mix 6	
Mix 7	
Mix 8	

Table (4): properties of asphalt binder

Test No.	Test	AASHTO Designation No.	Results	Specification limits
1	Penetration ,0.1mm	T-49	64	60-70
2	Softening point , °c	T-53	52	45-55
3	Flash point , ° c	T-48	+270	+250
4	Kinamatic viscosity , cst	T-201	+345	+320
5	Ductility,cm	T-51	130	≥ 95

Table (5): properties for fly ash

Material	Physical property	Chemical property
Fly ash	Powdery particles - fine particles , spherical in shape , either solid or hollow and mostly glassy in nature	Calcium hydroxide – calcium sulfate and glassy components in combination with alumina and silica

Table (6): properties for waste plastic resin polyethylene

Property	Typical value	Test based on
Density	0.926 gm. /cm3	ExxonMobil method
Melt index (190°c/2.1kg)	50 g /10 min	AST MD1238
Peak melting temperature	121°c	ExxonMobil method
Vicat softening temperature	91°c	ISO 306
Tensile stress at yield	11 MPs	Iso527-2/1A/50
Tensile strain at yield	20%	Iso527-2/1A/50
Tensile strain at break	>100%	Iso527-2/1A/50
Flexural modulus	290Mpa	ISO 178
Environmental stress –crack resistance 10 % Igepal	7 hr.	ASTMD 1693

According to (LLDPE LL6201 series) Exxon mobile.

6. RESULTS AND DISCUSSION

Marshall Test results of mixture with different binder content, different percentages of fly ash and different percentages of waste plastic Resin are summarized in table (7).

Table (7): Results of all tests for all investigated mixes

Property \ Mix No.	M1	M2	M3	M4	M5	M6	M7	M8
Density (gm./cm3)	2.35	2.38	2.40	2.42	2.22	2.19	2.10	2.07
Stability (kg)	785.5	1136.2	1208.1	1455	1364	1586	2229	1734
Flow(mm)	2.77	2.93	2.27	1.93	3.17	2.7	2.47	2.2
AV%	5.24	4.19	3.71	2.95	6.28	3.21	3.04	1.8
VMA%	15.55	14.65	14.22	13.55	16.02	12.8	12.23	9.10

6.1 conventional mix results:

Figure (1) shows the relationship between stability and bitumen content. Stability of asphalt mix increases as the bitumen content increase till it reaches the peak (785.5 kg) at bitumen content 4.5% then it started to decline gradually at higher bitumen content. Bulk density of asphalt mix increases as the bitumen content increase till it reaches the peak (2.35 gm. /cm3) at bitumen content 4.5% then it started to decline gradually at higher bitumen content shown in figure (2). Figure (3) air voids (AV %) results for different bitumen contents are represented. Maximum air voids content value is at the lowest bitumen percentage (3.5%), AV% decrease gradually as bitumen content increase due to the increase of voids percentage filled with bitumen in the asphalt mix. Figure (4) present the flow results for different bitumen contents. Maximum flow value is at the highest bitumen percentage (5%), flow increase gradually as bitumen content increase. Figure (5) explain the Voids of mineral aggregates (VMA) results for different bitumen contents. Maximum VMA value is at the highest bitumen percentage (5%), VMA increase gradually as bitumen content increase.

6.1.1Determination of optimum bitumen content (OBC):

The optimum bitumen content was found equal to 4.5% by weight of the total mix which is investigating the Egyptian specifications as shown in table (8).

Table no (8): Properties of the asphalt mix using optimum bitumen content

Test	Test Result	Specifications for Egypt ECP – 2008 (binder course)
Stability (Kg)	785.5 kg	700 kg
Flow (mm)	2.77	(2 - 4) mm
A.V (%)	5.24	(3- 8)%
V.M.A (%)	15.55	>15

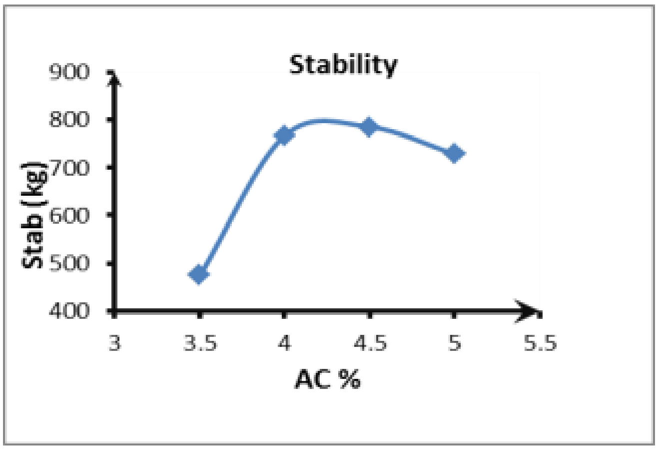

Figure (1): stability & asphalt content

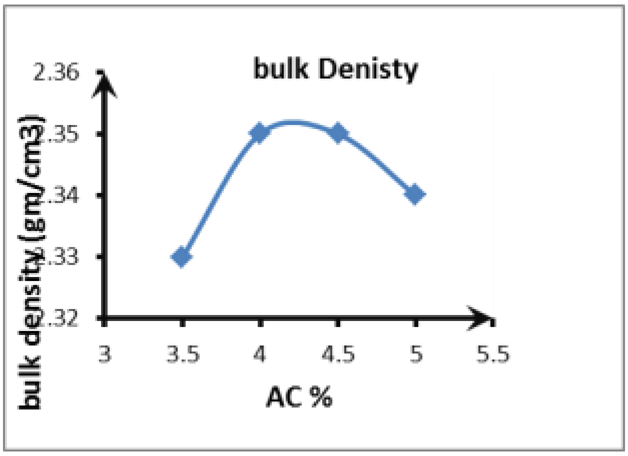

Figure (2): bulk density & asphalt content.

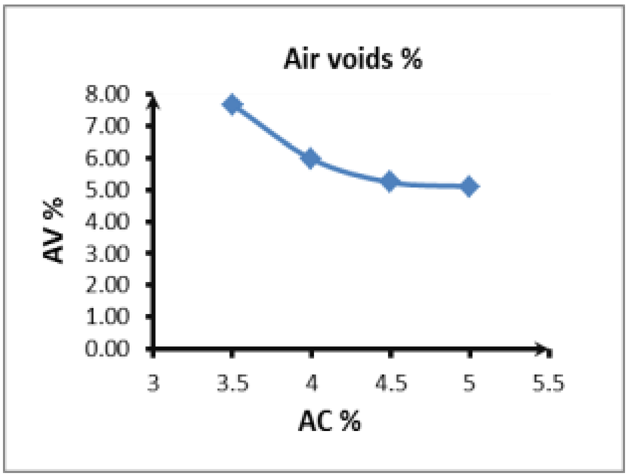

Figure (3): Air voids & asphalt content.

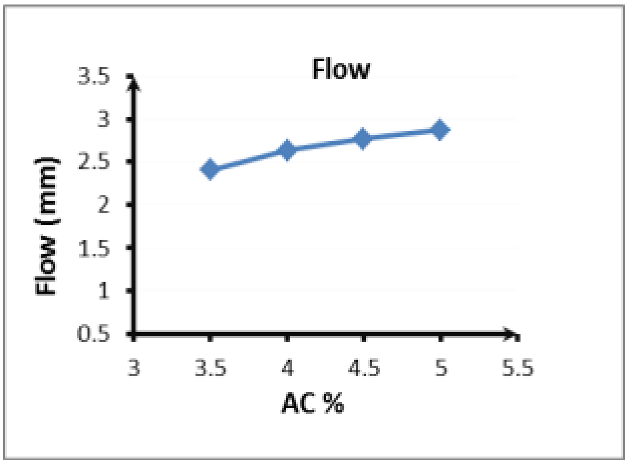

Figure (4): Flow & asphalt content.

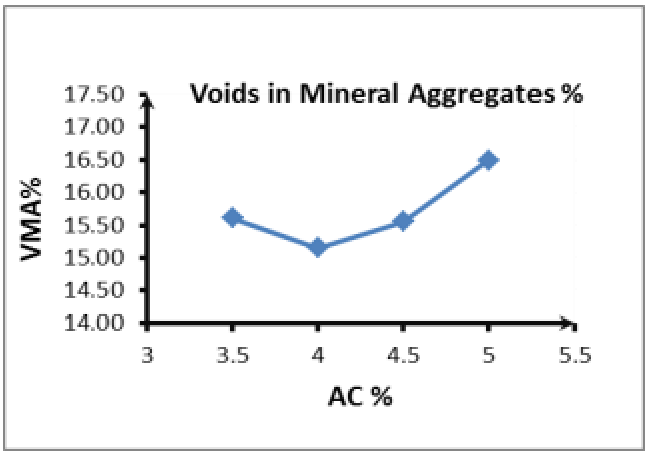

Figure (5): voids in mineral aggregates& asphalt content.

6.2 Results for Asphalt mixes modified by different percentages of fly ash:

Figure (6) show all the values of stability for different modifier percentages are higher than stability of conventional mix. All the values of bulk density for different modifier percentages are higher than bulk density of conventional mix which explains in figure (7).Figure (8) present the results of flow of modified asphalt mixes are lower than the conventional asphalt mix (2.77) except (M5) is higher than the conventional mix (2.93).Figure (9) illustrate the results of air voids of modified asphalt mixes are lower than the conventional asphalt mix (5.24). From Figures (6) to (9), we can observe the best percentage of fly ash content is 2% which is investigating the Egyptian specifications. The Comparison between asphalt mixes modified by 2% fly ash content, conventional mix properties illustrate in table (9).

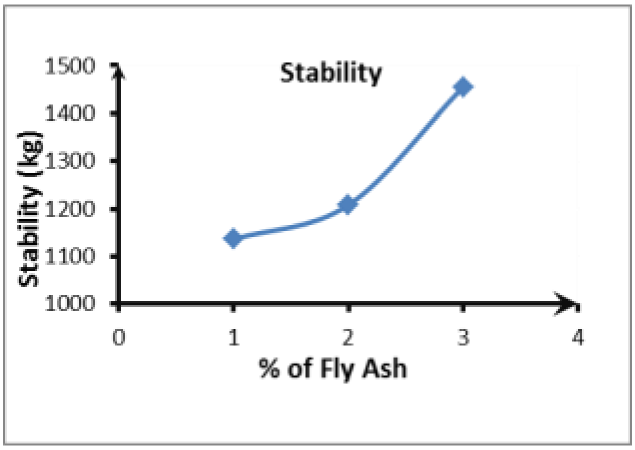

Figure (6): stability& fly ash content.

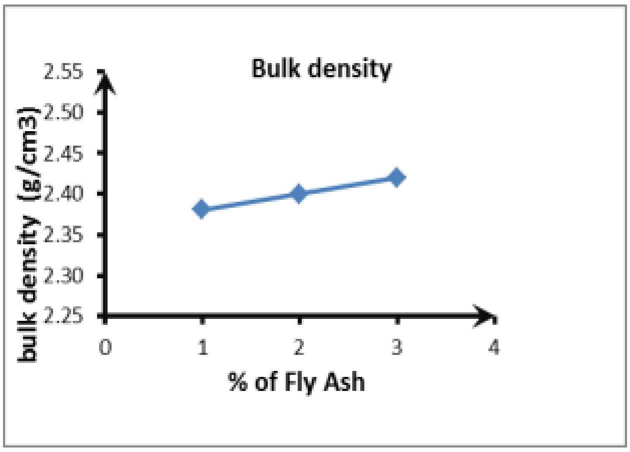

Figure (7): bulk density& fly ash content.

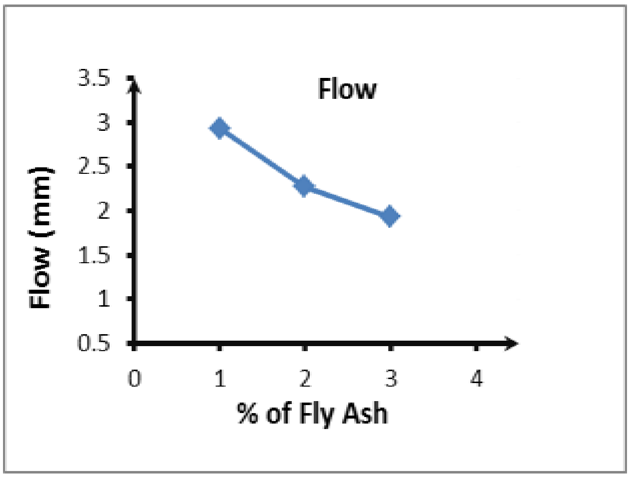

Figure (8): flow& fly ash content.

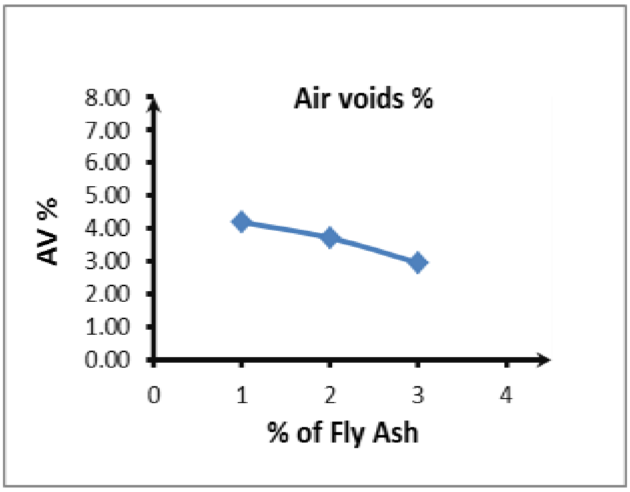

Figure (9): Air voids& fly ash content.

6.3 Results for Asphalt mixes modified by different percentages of waste plastic Resin with a combination of a 2% of fly ash:

Figure (11) show all the results of bulk density for modified mixes by waste plastic resin + 2% fly ash are lower than the bulk density of conventional mix (2.35).Figure (12) illustrate The flow for modified asphalt mixes is lower than the conventional asphalt mix (2.77) except at 3% plastic content the flow value is (3.17) higher than the conventional asphalt mix. Figure (13) explain The percentage of air voids for modified asphalt mixes is lower than the conventional asphalt mix (5.24) except at 3% plastic content the percentage of air voids value is (6.28) higher than the conventional asphalt mix . From Figures (10) to (13), we can observe the best percentage of waste plastic resin content is 9% which is investigating the Egyptian specifications. Table (10) explains the comparison between asphalt mixes modified by 9% waste plastic with a combination of a 2% of fly ash, conventional mix properties.

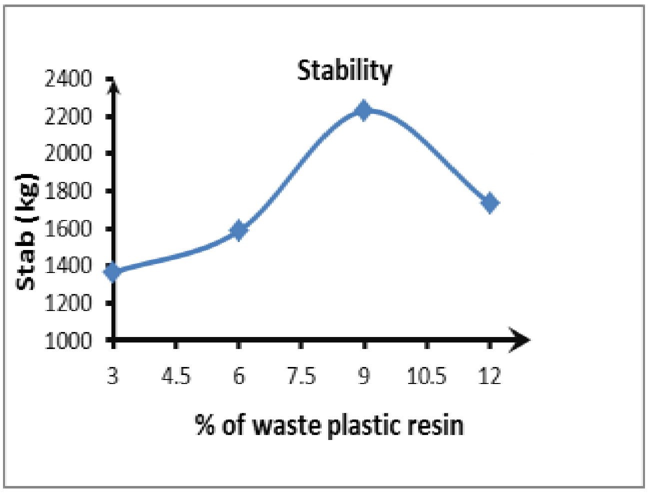

Figure (10): stability& %of waste plastic resin

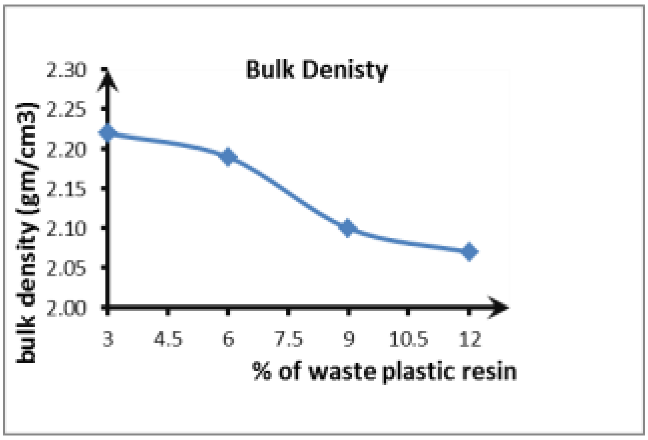

Figure (11): bulk density& % of waste plastic resin.

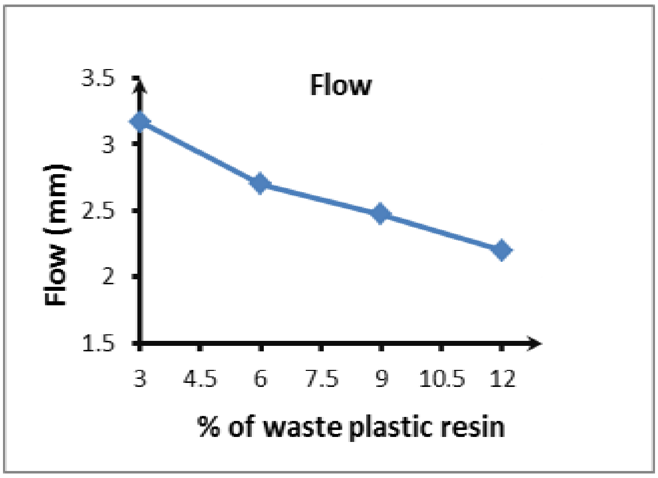

Figure (12): flow& % of waste plastic resin.

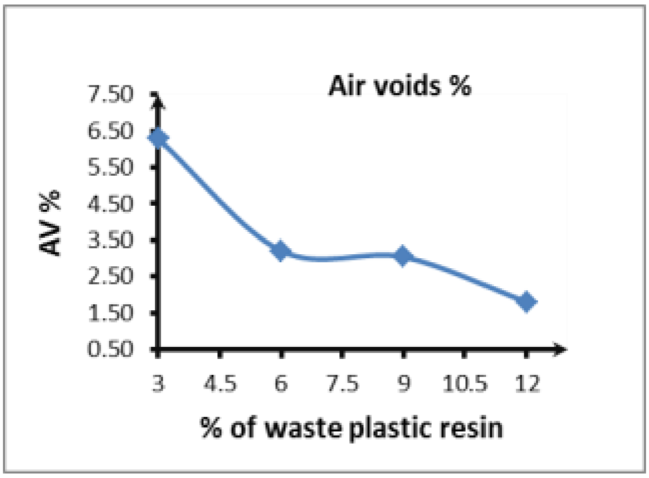

Figure (13): Air voids& % of waste plastic resin

Table (9): properties of modified asphalt mix by 2%fly ash content, specifications limits for Egypt and the comparison with the conventional mix properties.

Property	Conventional asphalt mix (M1)	2 % fly ash measured from sand fine(M3)	Specifications for Egypt ECP – 2008 (binder course)	Change amount
Optimum Bitumen content (%)	4.5	4.5	-	-
Stability (kg)	785.5	1208.1	700 kg	+ 53.8%
Flow (mm)	2.77	2.27	(2-4) mm	- 18.05%
Bulk density (gm./cm3)	2.35	2.40	-	+ 2.127%
Air voids (A.V)%	5.24	3.71	(3 – 8) %	- 29.19%
Void in Mineral aggregate (VMA)%	15.55	14.22	> 15	- 8.55%

Table (10): properties of asphalt mixes modified by 9% waste plastic resin with a combination of a 2% of fly ash, specifications limits for Egypt and the comparison with the conventional mix properties.

Property	Conventional asphalt mix (M1)	asphalt mixes modified by 9% waste plastic with a combination of a 2% of fly ash(M7)	Specifications for Egypt ECP – 2008 (binder course)	Change amount
Optimum Bitumen content (%)	4.5	4.5	-	-
Stability (kg)	785.5	2229	700 kg	+ 183.7%
Flow (mm)	2.77	2.47	(2-4) mm	- 10.8%
Bulk density (gm./cm3)	2.35	2.10	-	-10.6%
Air voids (A.V) %	5.24	3.04	(3 – 8) %	-41.9%
Void in Mineral aggregate (VMA) %	15.55	12.23	> 15	-21.35%

6.4 Analysis of loss of stability test results

Loss of stability test was performed to measure the ability of asphalt mix to serve with time. The percent loss of stability was used as an indicator to mix durability under different conditions. Table (11) shows that the loss of stability percent increases as immersion time increase for M1, M3 and M7. All mixes which conducted are in the acceptable range (<20%).Based on the results we can observe that the loss of stability percentages decreases with using fly ash and waste plastic resin.

Table (11): Loss of Stability Test Results

Mix NO. / Time, days	M1	M3	M7
0	0%	0%	0%
1	9%	6%	1.5%
2	13%	9%	2.7%
3	16.5%	%12.6	3.8%

6.5 Analysis of wheel tracking test results

To study the effect of waste plastic resin and fly ash on the pavement capability to withstand rutting phenomena, several specimens were prepared and tested. Table (12) shows that the results of rutting depth for M1, M3 and M7.from the results we can observed that the rutting depth decreased when using fly ash and waste plastic resin.

Table (12): wheel tracking Test Results

No. of mix	Depth after 45 minutes (mm)	Test temperature
M1	7.6	60 °c
M3	3	60 °c
M7	1.3	60 °c

7. CONCLUSIONS

Based on experimental work results for asphalt mixtures modified by waste plastic resin (WPR) and fly ash compared with conventional asphalt mixtures, the following conclusions can be said:

1. The optimum value of fly ash to be added as a modifier of asphalt mix was Found to be (2%) by weight of fine aggregate portion in HMA.
2. The best percentage of WPR to be added as a modifier of asphalt mix was Found to be (9%) by weight of fine aggregate portion in HMA.
3. Using asphalt mixes containing fly ash with percent 2% gives stability value (1208.1) more than the reference mix stability (785.5).
4. Asphalt mixes modified with (9.0 % WPB with a combination 2 % fly ash by weight of fine aggregate portion in HMA) achieved stability value (2229 kg) more than allowable value (700 kg).
5. Using WPR in Asphalt mixes gives lower bulk density as the WPR percentage increased. This decrease in bulk density can explained to be as a result of the low density of added plastic material.
6. Stability for mixes modified by different percentage of fly ash increased as the percentage of fly ash increased.
7. The loss of stability value decrease when using fly ash and WPR compared with conventional asphalt mixtures.
8. Using WPR and fly ash in the asphalt mixes reduce the rutting depth compared with conventional asphalt mixtures.

8. RECOMMENTATION

Based on the study results and the drawn conclusions, the following recommendations are suggested:

1. Using of waste plastic resin and fly ash material in asphalt concrete mixtures is recommended to improve performance of Asphalt mix.
2. Other materials should be investigated in production of asphalt mix to overcome some dangerous pavement distresses such as plastics formed from High Density Polyethylene (HDPE).
3. Government and researchers should integrate efforts toward preparing and implementing a sustainable solid waste management plan

taking into Consideration getting the maximum benefit from the high quantities of solid Waste.

9. REFERENCES

1. Apurva J. Chavan (2013), "Use of plastic waste in flexible pavements", International journal of application or innovation in engineering and management", 2(4), 540-552.
2. Bhageerathy K. P, Anu P. Alex, Manju V. S, Raji A.K (2014) "Use of Biomedical Plastic Waste in Bituminous Road Construction" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3 Issue-6.
3. Sankaran, K.s., and Rao, D.r.1973. Theinfluence of the quality of filler in asphaltic paving maixtures.Indian Roads congress, 35:141-151.
4. Sobolev K., Flores I. Wasiuddin (wasi) N.M.The effect of fly Ash on the Rheological Properties of Bitumen Materials .Submitted to fule, 2012.
5. Sreedevi B.G. & Salini P.N. (2013), "Pavement performance on roads surfaced using bituminous mixtures with coated aggregates", International journal of Engineering research & technology, 2(9), 149-156.
6. Kalantar, Z N, Mahrez, A & Karim, M R2010, 'Properties of bituminous binder modified with waste Polyethylene Terephthalate', MUTRFC 2010: proceedings of Malaysian Universities Transportation Research Forum & Conferences, 21 December2010, University Tenaga Nasional, Malaysia.
7. Tapkin, S.2008 .improved asphalt aggregate mix properties by Portland cement modification .can. J.civ.eng.35:27-40.
8. Zoorob S.E & suparma L.B. (2000), "Laboratory design and investigation of the properties of continuously graded asphalt concrete containing recycled plastics aggregates replacement (plastiphalt)", Cement concrete composites; 22:233-42.
9. Yash Menaria, Rupal Sankhla (2015), (Use of Waste Plastic in Flexible Pavements-Green Roads), Open Journal of Civil Engineering, 2015, 5, 299-311.

About Author (s):

Demonstrator of Highways and Airports Engineering, Al-Safwa High Institute of Engineering, Egypt