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RESEARCH ARTICLE

UTILIZING OF POLYETHYLENE AND PLASTIC WASTES FOR PAVING ASPHALT MODIFICATION IN JORDAN

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ABSTRACT

As the number of world's population continues to increase, the amount of solid waste that people produce is increased. Definitely, disposable products required high engineering technology. Solid waste varies such as plastics, soda cans, polyethylene bags plastics or bottles of water…etc., but the accumulation of these products has led to increasing amounts of plastic pollution around the world. As plastic is composed of major toxic pollutants, it has the potential to cause great harm to the environment. This research will be focused on utilization of polyethylene and plastic wastes for asphalt bitumen modification. Procedures are aimed to determine of optimum asphalt content of pure bitumen asphalt and concerned on tested the asphalt samples prepared with different percentages of polyethylene and waste plastic as an additives to pure asphalt with the following percentages of (2%, 3%, 4%, 5%, and 6%). The physical properties of the prepared specimens were tested for their stabilities, specific gravities, flows and air void ratios according to Marshal Method procedures. It was founded that the optimum asphalt content (OAC) is (7%) of the weight of specimens for pure asphalt samples. While the optimum values of additives to asphalt content were found as (4.1%) and (4.6%) for polyethylene and waste plastics, respectively. Results shown that for pure asphalt sample, the stability is (1367 kg), specific gravity is (Gmb) (2.182), the flow is 11.9 and the voids ratio is (3.89). Hot mixed asphalt with polyethylene additives gives that the following results of (1817 kg), (2.270), (10.4) and (4.3%) for the properties of stability, specific gravity, flow and voids ratio, respectively. on the other hand asphalt with waste plastic additives gives the results as follows (1745 kg), (2.257) and (10.2) and (5.1%) for the properties of stability, specific gravity, flow and voids ratio, respectively. It was concluded that a significant modifications in Marshal Properties of the tested control samples were achieved. In addition, the recycling of polyethylene waste and waste plastic for paving asphalt mixtures helps alleviate an environmental problem and saves energy and costs.

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INTRODUCTION

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. According to World Bank Solid Waste Thematic Group, about 1.3 billion tons of waste is being generated in the world annually. This waste is a cause of various diseases. Open dumping of waste also destroys valuable agricultural land. Various researchers have beneficially used plastic waste in cement concrete and asphalt concrete in the past.(Shah and Khan. 2016). Attempts are still being made by various organizations and researchers to find methods for effective utilization of some of these waste materials (Falak *et al.*, 2014). Natural asphalt deposits occur in various parts of the world, mainly as a result of mineral oil seepage from the ground.

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The best known natural deposit is Trinidad's Pitch Lake; asphalt deposits can also be found in Venezuela, the Dead Sea, Switzerland, and the Athabasca oil sands in northeastern Alberta (IPCS, 2004; Budavari, 1989; Lewis, 1993). In addition, asphalt is produced from crude petroleum, and it is these petroleum-based asphalts that are the focus of this document (WHO, 2004). Asphalt has different types and usages. The major types of asphalt products are paving asphalts and roofing asphalts. Asphalt is also used in asphalt-based paints as protective coatings to prevent corrosion of metals; in lining irrigation canals, water reservoirs, dams, and sea defence works; in adhesives in electrical laminates; and as a base for synthetic turf (Lewis, 1993). A broad spectrum of asphalt modifiers and additives spanning categories such as antioxidants, anti-stripping agents, extenders, fibers, fillers, hydrocarbons, oxidants, plastics, rubbers, waste materials, and miscellaneous products are also employed with the various asphalts (Speight, 1992; Roberts *et al.*, 1996). The highest amount of plastics waste is found in containers and packaging's (i.e. bottles, packaging, cups etc.), but they also are found in durables (e.g. tires, building materials, furniture, etc.) and disposable goods (e.g medical devices), (US EPA. 2013). Addition of plastic and polyethylene wastes to the asphalt mixture will affects the bitumen physical properties. Polyethylene (PE) is the most common type of plastic. In daily life, plastic bags, plastic bottles, and many other PE products are seen everywhere. Significant amount of plastics are not disposed properly and therefore present as waste material in the environment. Using polyethylene as an additive to asphalt binders may be considered a good way to utilize this material. However, modified asphalt binder properties should be investigated (Ghuzlan *et al*., 2014). There were different quantities and types of plastics and industrial poyethelyne wastes generated in most cities in Jordan. These wastes have to be treated and disposed in landfalls. To avoid these procedures and land filling requirements many attempts were done to utilize these wastes and used in different usages. Modification of paving asphalt mixtures one of these applications worldwide. testing's results of poly-ethylene (terephthalate - PET) added to asphalt bitumen sample showed that the aggregate replacement of 20% by volume with PET granules would result in a reduction of 2.8% in bulk compacted mix density and the value of flow in the plastic asphalt mix was lower than that of the control samples (Hassani *et al*., 2005).

Awwad and Shbeeb (2007) found that the recommended proportion of the modifier is 12% by the weight of bitumen content and it is found that the addition of polyethylene to asphalt samples is increasing the stability, reducing the density and slightly increasing the air voids and the voids of mineral aggregate. On the other hand, and on the basis of experimental results, it was concluded that the asphalt mixtures with waste polyethylene modifier up to 10% and waste PVC modifier up to 7.5% can be used for flexible pavement construction in a warmer region from the standpoint of stability, stiffness and voids characteristics (Ahmed *et al.,* 2013) . Again, it was founded that PET may be modified bituminous binders and provide better resistance against permanent deformations due to their higher G*/sin d and their higher softening point when compared to conventional binders (AZIZ *et al.,* 2011). High density polyethylene (HDPE) can also be used as a modifier of asphalt concrete and this modified binder become more resistant to permanent deformation and it contributes to recirculation of plastic wastes as well as the solid waste disposal problem is relatively solved (Hinislioglu and Agar 2004). Researchers have been found that, with the addition of some waste materials and certain polymers to asphalt binders can improve the performance of asphalt concrete (Little, DN, 1993 and Jew, P, and Woodhams, RT, 1982). In general, using plastics and polyethylene (PET) as modified binders will enhance the asphalt's properties and also contribute to the recirculation of plastic waste, as well as to the protection of the environment.

MATERIALS AND METHODS

A local Jordanian bitumen asphalt produced in Jordan refinery with 60/70 penetration value at 25°C, 100 g, 5 sec, ASTM D 5-97, flash point of 312 °C ASTM D-92, fire point of 331°C ASTM D-92, softening point of 52°C ASTM D-36 and ductility of 103 cm @ 25°C ASTM D-92 was used in this research. This asphalt binder has an equivalent performance grade of PG 64-10 and specific gravity of the asphalt binder is 1.05. The asphalt binder was prepared with the following percentage (5, 5.5, 6, 6.5, 7 and 7.5) of total weight of mixtures. Polyethylene and plastic material wastes were prepared with different percentages ratios of asphalt bitumen as follows:- (2%, 3%, 4%, 5%, and 6%). Plastics waste were collected from domestic waste and then cleaned properly and shredded to form the size of the particle sizes of 2-3 mm for the preparation of the recycled plastics waste. Specific gravity and melting temperature of the polyethylene and plastic waste used in this investigation were 0.97 and 1.26 at 119°C, respectively. Samples contents were agitated together at gentle mixing speeds at temperature between (124 – 150)°C. Asphalt mixtures were prepared and tested according to Marshal Method procedures. Testing's results of pure sample and modified asphalts mixtures are figure out and determined the optimum percentages of bitumen and wastes additives for critical properties of stability, specific gravity, flow and air voids. The aggregate used in this investigation is described as coarse and fine sand, the aggregate's particle sizes retained on sieve 3/8" is 33%, on sieve 8" is 73 % , on sieve 8" is 94 % and on sieve 200" is 94.3 %. The specific gravities of the coarse aggregate, fine aggregate and filler are 2.61, 2.62 and 2.73, respectively.

DISCUSSION OF RESULTS

Testing and analysis of results aim to determination of optimum asphalt contents for the conventional asphalt mixtures and polyethylene and plastics wastes additions effects.

Conventional asphalt mixtures studies

Stability effect - conventional asphalt mixture: Figure (1) shows stability results for different asphalt contents. It is obvious that stability of asphalt mixture increases as the asphalt content increases till it reaches a peak value of (1367 kg) at asphalt content of (7%), after that it started to decline gradually at higher bitumen content.

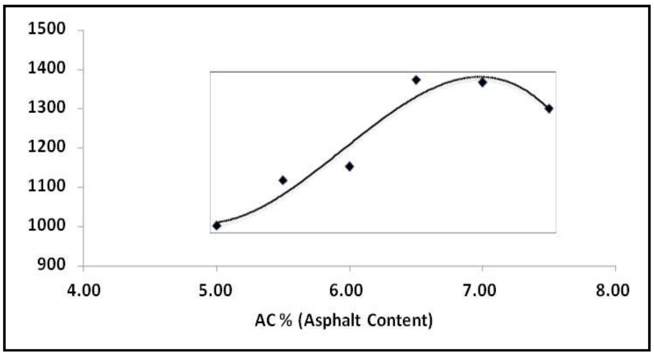

Fig. 1. Stability versus Asphalt content (%)

Specific gravity effect- conventional asphalt mixture. Figure (2) represents the specific gravity results for different asphalt contents. As a results, it is clear that specific gravity of asphalt mixture increases as the asphalt content increases till it reaches a specified peak value of (2.185) at the same optimal asphalt content of 7%, then it starts to decline gradually at higher asphalt contents. It is clear that as the percentage of asphalt increases in samples lead to easy the sliding of aggregate with each other which produce to the better inter-locking of aggregate and result in higher stability. After 7% of optimum asphalt content the effect of asphalt is inversely. This behavior is obvious for the properties of stability and specific gravity which is illustrated in Figs. 1 and 2.

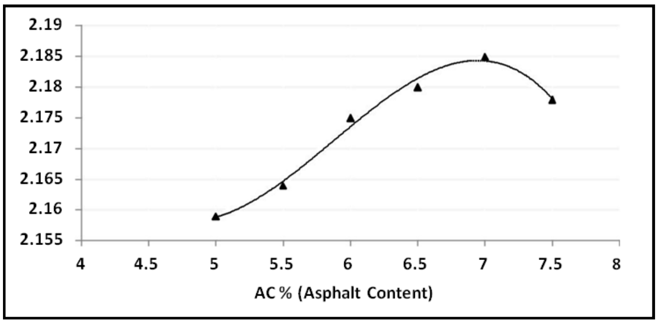

Fig. 2. Specific gravity versus Asphalt content (%)

Flow effect - conventional asphalt mixture. Figure (3) shows that as the asphalt content increases the flow of asphalt mix increases for different asphalt contents of specimen. These results are in compliance with many researches results such as (Shah and Khan, in 2016; Yadav *et al.,* (2013) and Awwad and Shabeeb (2007)).

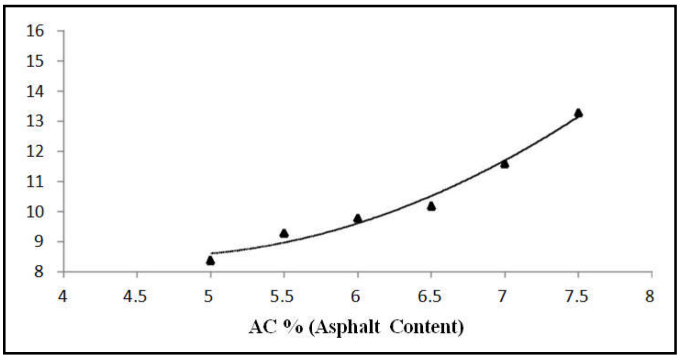

Fig. 3. Flow versus Asphalt content (%)

Air voids (Va) effect - conventional asphalt mixture: Figure (4) shows an air voids (Va%) results for different asphalt contents . it is clear that the maximum air voids content value is at the lowest asphalt percentage of (5%), the air voids (Va%) decreases gradually as asphalt content increases due to the increase of voids percentage filled with asphalt in the asphalt mixture.

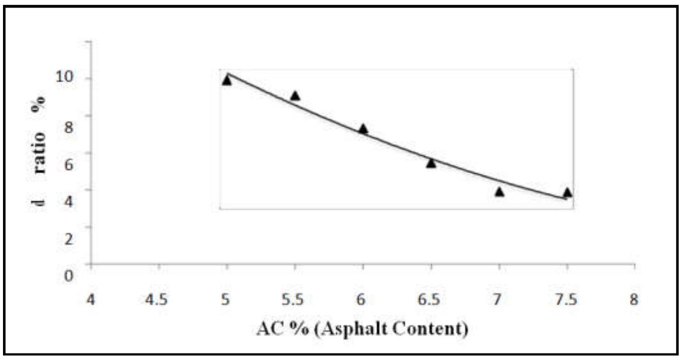

Fig. 4. Void ratio versus Asphalt content (%)

In order to determine the optimum asphalt content corresponding to the optimal asphalt properties the percentages corresponded maximum values for stability, specific gravity, and air voids are tested and then taken the best results as 7.2, 7, 6.8 respectively, then the optimum asphalt content is defined as the average value for a three resulted values for tested asphalt mixtures. As a result, the optimum asphalt content (OBC) is adapted as 7% and calculated as the average of the best corresponding percentages of resulted properties as follows = (7.2+7+6.8)/3 = 7%.

Table (1) below represents the optimal values for Marshal's properties of the tested asphalt mixtures contain optimum asphalt content of 7%. It is clearly that there are three samples were prepared with optimum asphalt content OAC % without additives. The mechanical properties of asphalt mix prepared with OAC of (7 %) are shown in Table (1). It is obvious that all resulted properties of asphalt mixture with OAC are compatible with American Asphalt Institute specifications requirements.

Table 1. Marshal's properties for control samples at optimum asphalt content (OAC) (7 %)

No.	Property	value	Unit
1	Stability	1352	Kg
2	Gmb	2.182	-
3	Flow	11.9	mm
4	Voids ratio	3.89	%

At the end of this part of research the results achieved for determinations of different physical properties represented by Stability, Flow, Air voids and Density at the optimum asphalt content (OAC) are similar to what has been mentioned in the handbook of highway engineering (page 7- edited by T. F. Fwa, in 2006, which described as follows: "The density plot typically shows a trend of increasing density until the peak is reached. After this peak, the density begins to decrease. The Marshall stability has a similar trend but its peak is typically at a lower asphalt content than density. Some recycled mixes may show a decreasing stability with increasing asphalt content with no peak. Flow typically increases with increasing asphalt content. The percent air voids should decrease and the VFA increase with increasing asphalt content. VMA is another property that increases with asphalt content until it reaches its peak and then decreases with additional increase in asphalt content".

Polyethylene addition effects studies: A fifteen samples were prepared at optimum asphalt-polyethylene content (OAPC) of 7% totally. A five weight percentages of polyethylene of (2, 3, 4, 5, and 6%) were mixed with (98, 97, 96, 95 and 94 %) of asphalt. Samples were tested to evaluate the effect of adding polyethylene to asphalt mixture on asphalt characteristics.

Stability versus polyethylene content: Results indicated that the stabilities of modified asphalt mixtures are higher than the conventional asphalts aggregate mixtures. As shown in figure 5 the maximum stability value was found nearly (1800 kg) at polyethylene content around (3.5%). The results indicated that as the polyethylene content increases the stability of modified asphalt - polyethylene mixtures increases. This behavior is continued till it reaches a peak value of stability of 1800 kg at (3.5 %) of polyethylene content additive, then it started to decline steeply at higher polyethylene content. The improvement of stability in polyethylene modified asphalt sample can be explained as a result of the better adhesion developed between asphalt film of polyethylene mixture and the coated the aggregates due to intermolecular bonding, these intermolecular attractions enhanced strength of asphalt mixture, which in turn help to enhance stability of the asphalt mixture.

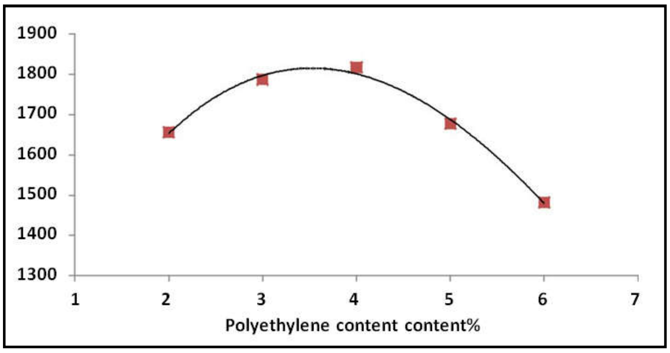

Fig. 5. Stability (Kg) versus Polyethylene (%) content

Specific gravity versus polyethylene content: The specific gravities of polyethylene modified asphalt samples are higher than the conventional specified in previous section which was equaled to 2.182 at (7%) of pure asphalt only with aggregate. Figure 6 shows that the specific gravity increases as the polyethylene content increases till it reaches a peak value of 2.275 at (4%) of polyethylene content, while it equals to 2.267 at (3.5 %) of polyethylene content, then it started to decline steeply at higher polyethylene content. The maximum bulk density is (2.273) at polyethylene content of (4%) and the minimum bulk density is (2.198) at polyethylene content of (2%) after that three is an increasing in stability up to a maximum value after that there is decreasing occurred. This is because increasing of the polyethylene lead to increase of asphalt stiffness and thus becoming the density lower because of the sliding of aggregate is decreased which lead to the less inter-locking between aggregate and.

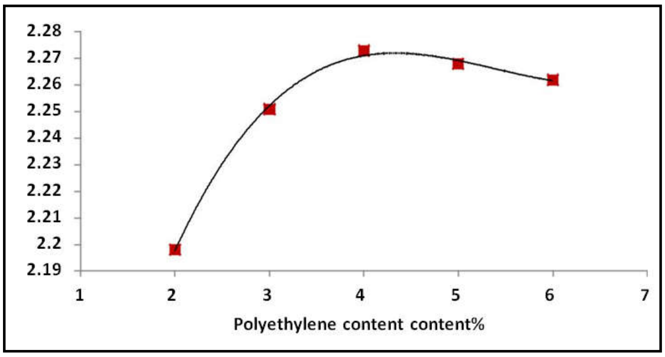

Fig. 6. Specific gravity versus Polyethylene content (%)

Flow versus polyethylene content: Generally, the flows of modified asphalt polyethylene asphalt mixture samples are lower than the flows of conventional asphalt samples. Figure 6 shows that as the polyethylene content increase in the samples then the flow decreases continuously, this result may be contributed to the formation of a tough mixture. However, a high percentage of polyethylene causes the flow to decreases while the stability increases. The flow value extend from (11.3mm) till it reach (9.1 mm) at polyethylene content (6%). It is obvious that at (3.5%) polyethylene content it was found that the flow is equaled to 10.4 mm.

Air voids (Va) versus polyethylene content. Figure 8 shows the curve which represents asphalt polyethylene mixture content versus void ratios relationship. It is clear that the void ratio inversely proportional with polyethylene mixture content of modified asphalt mixtures. It was found that the void ratio of polyethylene asphalt mixture sample (3.6 %) is lower than conventional asphalt sample which was (3.9 %) at (7 %) of asphalt content. It was estimated that the void ratio is equaled to 5.85 % at polyethylene content of 3.5%. It is clear that the void ratio (Va %) of modified asphalt mixture decreases gradually as the polyethylene content increase till it reaches the lowest Va% value at 6% polyethylene. Generally modified asphalt mixtures have (Va %) content within specifications range. These results are similar to those achieved by many researchers. Justo and Veeraraghavan (2002) compared the properties of the waste plastic modified asphalt with ordinary asphalt. It was observed that the penetration and ductility values of the modified asphalt decreased with the increase in proportion of the plastic additive, up to 12 % by weight.

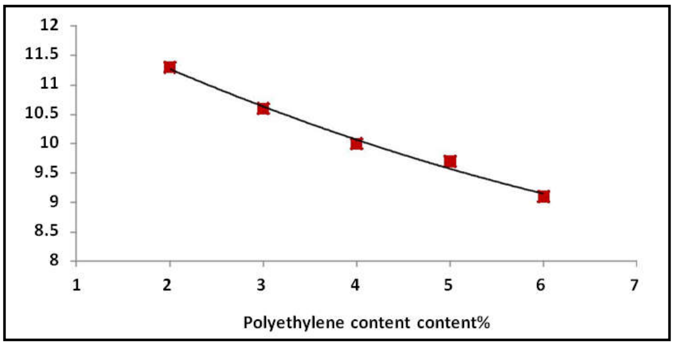

Fig. 7. Flow versus Polyethylene content (%)

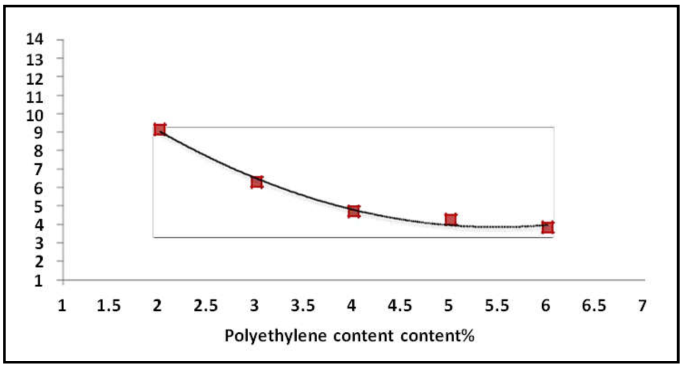

Fig. 8. Void ratio % versus Polyethylene content (%)

As mentioned in previous paragraph to determine OAC% in the same matter can be found optimum asphalt plastic content OAPC %. Three specimens were prepared with OAPC %, the mechanical properties of modified asphalt are shown in Table (2).

Table 2. Marshal results for control samples after finding OAPC (4.1 %)

No.	Property	value	Unit
1	Stability	1805	Kg
2	Specific gravity (Gmb)	2.270	-
3	Flow	10.4	mm
4	Voids ratio	4.3	%

Wastes plastic addition effects studies: Again, tested samples were prepared at optimum asphalt-plastic waste contents OA*WP*C of 7 % totally. The objective of this part of research is to investigate the effect of adding plastics waste (WP) to asphalt content by considering five proportions of plastics waste as follows (2, 3, 4, 5 and 6% w/w) out of (7%) of asphalt content in the specimens. Mechanical properties of asphalt mixture using different percentages of plastics' waste were identified and described according to the tests' results achieved in the following sections.

Stability versus wastes plastic content: Figure (9) shows that the stability of modified asphalt mixture increases as the WP content increases till it reaches the peak value of stability of 1795 kg at WP content (4 %), then it started to decreases steeply at higher WP contents. it is estimated that the maximum value of the stability is equaled to 1795 kg at 4.1 % of waste plastic content of the asphalt content of 7%. The improvement of stability in WP modified asphalt mixtures can be explained as a result of the better adhesion developed between asphalt and WP coated the aggregates due to intermolecular bonding, these intermolecular attractions enhanced strength of asphalt mix, which in turn help to enhance durability and stability of the asphalt mix.

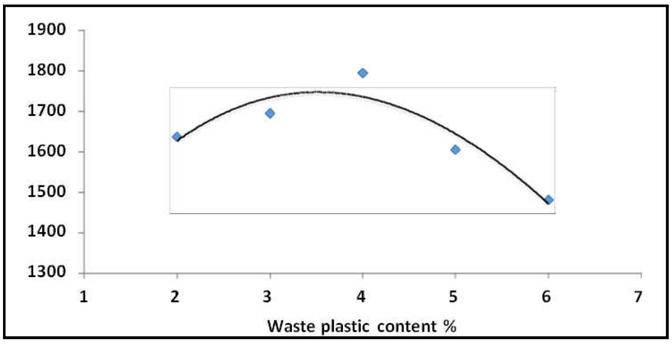

Fig. 9. Stability (Kg) versus Waste plastic content (%)

Specific gravity versus wastes plastic content: The Specific gravity of WP modified asphalt mixture is lower than the conventional asphalt mixture specific gravity. It is clear that as the WP content the specific gravity increases till it reaches a peak value of 2.269 at (5 %) of WP content, then it started to decline steeply at higher WP content. The trends is illustrated in Figure 10 below.

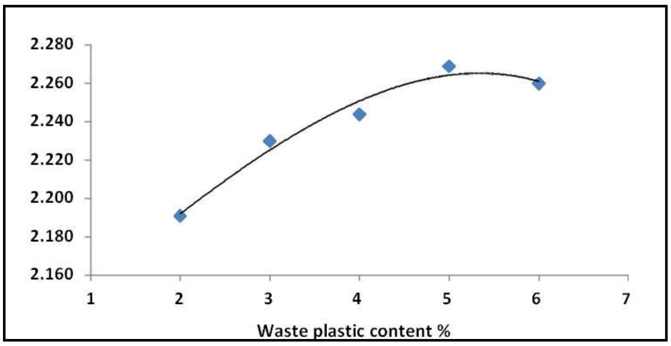

Fig. 10. Specific gravity (Kg) versus Waste plastic content (%)

Flow – versus wastes plastic content: Figure 11 shows the relation between flow and waste plastic content. It is obvious that as the waste plastic content increases the flow properties of the samples are decreasing continuously. The flow value extend from (11.7 mm) till it reach (8.9 mm) at waste plastic (WP) content of (6%).

Air voids (Va) versus wastes plastic content: As illustrated in figure 12 the modified asphalt mixtures have air voids Va% within specifications range which. The relation between void ratio and waste plastic content as shown in the figure 12 below is inversely proportional relationship. It is clear that as waste plastic content is increasing the void ratio is decreasing. The maximum void ratio is equaled to 9.425 at waste plastic content of 2%. On the other hand, the minimum void ratio is equaled to 3.912 % at (WP) of 6%. Three specimens were prepared with OAPWC %, the mechanical properties of modified asphalt are shown in Table (3).

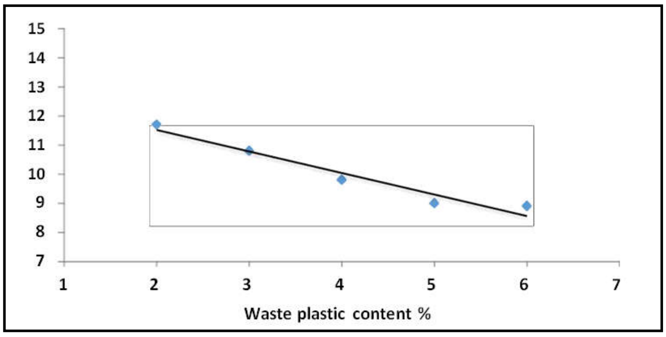

Fig. 11. Flow versus Waste plastic content (%)

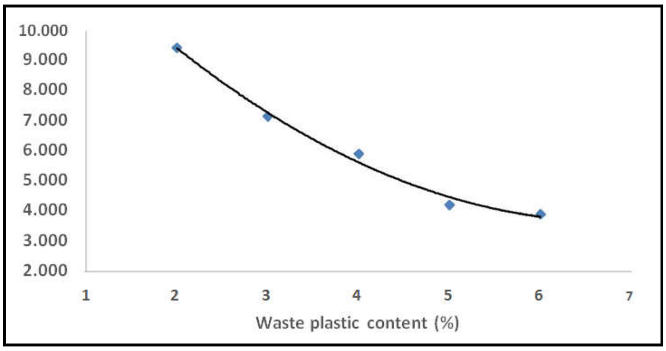

Fig. 12. Void ratio versus Waste plastic content (%)

Table 3. Marshal's optimal values for control samples at (3.5%) waste plastic content

No.	Property	Value	Unit
1	Stability	1745	Kg
2	Specific gravity (Gmb)	2.257	-
3	Flow	10.2	Mm
4	Voids ratio	4.42	%

Shah and Khan in 2016 found that the stabilities of the mixtures showed increasing trend up to 20% of plastic waste additives then sudden decrease in stabilities were observed. They suggested that this decrease in stability may be because of higher porosity of plastic aggregates. Most of the binder was used in filling the pores of plastic aggregates leaving behind insufficient quantity of asphalt to make stronger bond. The same results were achieved by (Yadav *et al.,* 2013 and Awwad and Shabeeb 2007).

Marshal's properties of polyethylene versus waste plastic contents

Comparison of results: This part of research is aiming to compare the achieved mechanical properties of polyethylene content and waste plastic content in asphalt mixtures. Those comparisons are shown graphically in Figs. 13, 14, 15, and 16 below.

Optimal polyethylene versus waste plastic contents in asphalt mixture

Optimal polyethylene content. To determine the optimal content value of polyethylene additive used as a part of asphalt content of 7% totally, three samples were prepared and tested

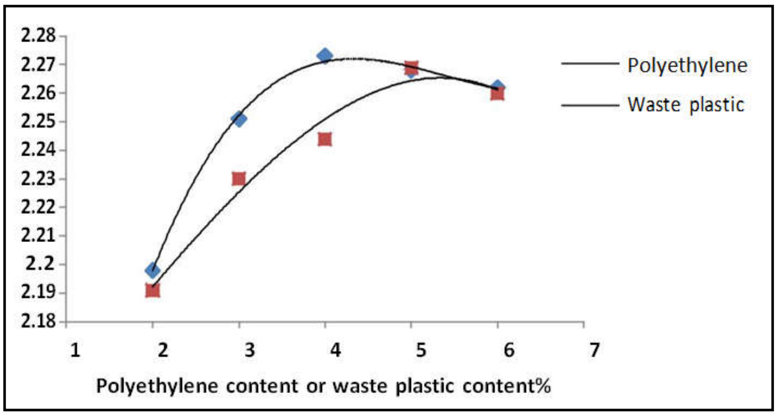

Fig. 14. Specific gravity for polyethylene versus waste plastic contents

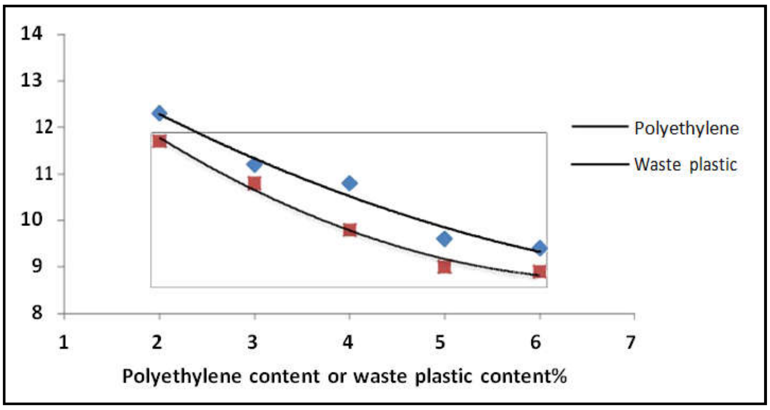

Fig. 15. Flow for polyethylene versus waste plastic contents

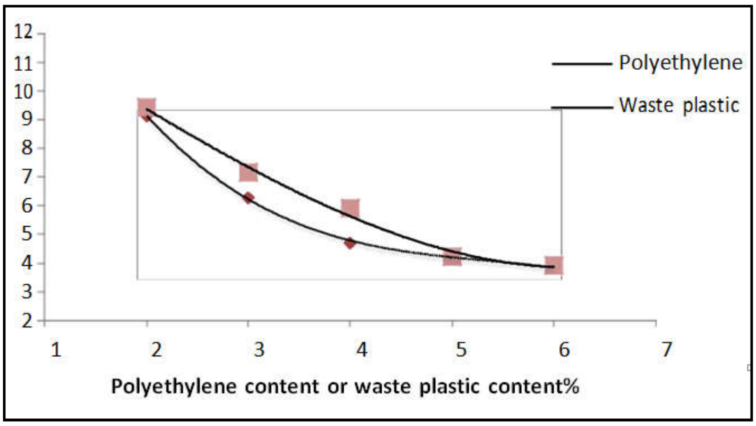

Fig. 16. Void ratio for polyethylene versus waste plastic contents

Table 4. Marshal Results for hot asphalt mixture @ optimum asphalt contents OAC

Property	Value		
	Asphalt	Asphalt / Polyethylene	Asphalt / Plastic Waste
(Asphalt / Additive) Ratio (w/w)	7 / 0	95.9 / (4.1)	95.4 / (4.6)
Stability (kg)	1367	1805	1745
Specific Gravity Gmb	2.182	2.270	2.257
Flow (mm)	11.90	10.4	10.2
Voids ratio (%)	3.89	4.3	4.42

with different polyethylene content for the three Marshals' properties as mentioned before. Optimal value then calculated as the average of the three readings as follows = (3.25 + 4 + 4.8) / 3 = 4.1 %.

Optimal waste plastic content: Again the values of maximum stability, void ratio Va %, flow and specific gravity have calculated at the optimal value of waste plastic content of 4.6 %.

Optimal waste plastic content which is equaled to = (3.3 + 5.2 + 5.3) / 3 = 4.6 % was calculated as the average reading. Three samples were prepared and tested at 4.6 % content of waste plastic percentages by weight asphalt. Modified asphalt properties are shown in Table 3.

Marshal's properties of hot mixed asphalt samples tested. Table 4 below represents a summary of results at different asphalt compositions. It's clearly shown that asphalt mixtures modified with polyethylene of 4.1% w/w have higher stability of 1805 kg, followed by the asphalt mixed with 4.6 % w/w waste plastic. This means that the effect of polyethylene additive is more than that of waste plastic with the same percentage added to asphalt. Polymers are typically added to the mixture at a rate of 3.0–8.0% by weight of the binder (**Asi, 2005**). Other properties of modified mix are still within the allowed range of the specifications. Melted polyethylene provide a rougher surface texture for aggregate particles in modified asphalt mix that would enhance asphalt mix have engineering properties due to improved adhesion between asphalt and polyethylene coated aggregates. Improved stability would positively influence the fatigue and rutting resistance of the modified asphalt mix leading to more durable asphalt pavement. The results are similar to that mentioned by some researches such as (Robinson and Thagesen, 2004). They conclude that the polymers can increase the stiffness of asphalt due to loading at high and low temperature, and drain down resistance. In addition, it can also give better binder adhesion to the aggregates particularly in wet condition.

Conclusion

Optimal values of the additives are found to be 4.1 % w/w of polyethylene polymer asphalt mixture and 4.6 % w/w of waste plastic asphalt mixtures. All Marshal's properties of the asphalt mixtures are improved better. Stabilities of the asphalt are increased by increasing polyethylene or waste plastics content. Specific gravities have slightly different changes in most cases. For further increment increased of polyethylene or waste plastic to asphalt contents, specific gravity and stability were decreased. Flows of samples are deceased by increased of polyethylene or waste plastics contents. On the other hand, void ratios are increased by increased of polyethylene or waste plastics contents. In general the Marshal tests of the modified asphalt samples with waste plastic and polyethylene said that the properties of those specimens are increased in Marshal's stabilities values , decreased in optimum asphalt contents by around 20-30 % (w/w) ratio, increase in flows with decrease in plastic and polyethylene contents. In addition, there were many benefits achieved towards the environment protections in effective economical ways by utilizing the plastics and polyethylene wastes in asphalt modifications for paving purposes.

Recommendations

More investigations are recommended to carry further upon the materials used in this research to identify the engineering properties with using an alternative plastic types such as high density polypropylene. Conducting such research by using different types of aggregate and size distribution are useful for determination new and improved asphalt pavements mixtures. Testing of other than Marshal's properties are highly recommended.

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REFERENCES

Awwad, MT and Shbeeb, L. 2007. "The Use of Polyethylene in Hot Asphalt Mixtures", *American Journal of Applied Sciences,* 4(6), 390-396.

Budavari S, ed. 1989. "The Merck index — Encyclopedia of chemicals, drugs, and biological", 11th ed. Rahway, NJ, Merck and Co.

Falak O. Abas, Raghad U. Abass and Enas. A .A. 2014. "The Use of New Techniques in The Management of Waste Plastic by Reuse it in The Asphalt Mix". *Environmental Research Center, University Of Technology/Baghdad. Eng. &Tech. Journal,* Vol. 32, Part (A), No.10, 2014.

Fwa, T. F. 2006. "The handbook of highway engineering". Taylor & Francis Group, LLC. ISBN 0-8493-1986-2 (2006).

Hassani A1, Ganjidoust H, Maghanaki AA. 2005. "Use of plastic waste (poly-ethylene terephthalate) in asphalt concrete mixture as aggregate replacement". *Waste Management & Research.* 2005 Aug; 23(4):322-7 (SAGE Journals).

Hinislioglu, S and Agar, E, 2004. "Use of waste high density polyethylene as bitumen modifier in asphalt concrete mix", *Journal of Materials letters,* 58, 267-271.

Ibrahim M. Asi 2005. "Laboratory comparison study for the use of stone matrix asphalt in hot weather climates". Department of Civil Engineering, Hashemite University, Zarqa, Jordan. Construction and Building MATERIAL. Elsevier, www.sciencedirect.com, 2005.

International Chemical Program for Safety (IPCS) 2004. "ASPHALT (BITUMEN) - Concise International Chemical Assessment Document 59". Corrigenda published by 12 April 2005, World Health Organization, Geneva, 2004. ISBN 92 4 153059 6 (LC/NLM Classification: QV 633). ISSN 1020-6167. WHO Library Cataloguing-in-Publication Data.

Jew, P, and Woodhams, RT, 1982. "Polyethylene modified bitumens for paving applications", Proceedings of the Association of Asphalt Paving Technologies 55-82, 541.

Khalid A. Ghuzlan, Ghazi G. Al-Khateeb and Yazeed Qasem, 2014. "Rheological Properties of Polyethylene-Modified Asphalt Binder", *Athens Journal of Technology & Engineering*, 2014.

Khanna S K, Justo C E G and Veeraragavan A. 2000. "Highway Material and Pavement Testing (Laboratory Manual)", Nemchand and Bros, Roorkee 2000.

Lewis RJ Sr, ed. 1993. "Hawley's condensed chemical dictionary", 12th ed. New York, NY, Van Nostrand Reinhold.

Little, DN, 1993. "Enhancement of Asphalt Concrete Mixtures to Meet Structural Requirements through the Addition of Recycled Polyethylene". Use of Waste Materials in Hot-Mix Asphalt, ASTM STP 1193, Fred Weller, H. (Ed.). ASTM International, Philadelphia, 210-306.

Md. Nobinur Rahman, Mohammad Ahmeduzzaman, M. A. Sobhan and T. U. Ahmed, 2013. "Performance Evaluation of Waste Polyethylene and PVC on Hot Asphalt Mixtures". *American Journal of Civil Engineering and Architecture*, 2013, Vol. 1, No. 5, 97-102.

Richard Robinson and Bent Thagesen 2004. "Road Engineering for Development ".Second edition First published 2004 by Spon Press 11 New Fetter Lane, London EC4P 4EE, ISBN 0-203-30198-6 Master e-book.

Roberts FL, Kandhal PS, Brown ER, Lee D-Y, Kennedy TW 1996. "Hot mix asphalt materials, mixture design and construction", 2nd ed. Lanham, MD, NAPA Research and Education Foundation.

Speight J. 1992. "Asphalt. In: Kirk-Othmer encyclopedia of chemical technology", 4th ed. Vol. 3. New York, NY, John Wiley & Sons, pp. 689–724.

Syed Shahan Ali Shah, Rawid Khan. 2016. "Re-Use of Hospital Plastic Waste in Asphalt Mixes as Partial Replacement of Coarse Aggregate". *Open Journal of Civil Engineering,* 2016, 6, 381-387 Published Online June 2016 in SciRes. http://www.scirp.org/journal/ojce,

US EPA. 2013. "Plastic Common Wastes & Materials". [Online]. Available: www.epa.gov/osw/conserve/material/ plastic. htm.

Yadav Santosh, Saxena Anil Kumar, Arora T.R. 2013. "Performance Evaluation of Waste Plastic and Bitumen Concrete mix in Flexible Pavements". *International Journal of Scientific & Engineering Research,* Volume 4, Issue 10, October-2013 398 ISSN 2229-5518.

Zahra Niloofar KALANTAR, Mohamad Rehan KARIM and Mahrez ABDEL AZIZ, 2011. "Effect of the Waste Plastic bottles on properties of asphalt". Proceedings of the Eastern Asia Society for Transportation Studies, Vol.8, 2011.

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