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STUDY THE EFFECT OF ADDING HIGH-DENSITY POLYETHYLENE ON THE ASPHALT MIXTURE

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This paper aims at studying the impact of adding high-density polyethylene (HDPE) on the ¾" hot mix asphalt (HMA). Polyethylene is used as it forms a considerable amount of the existing plastic wastes in the world in general and in Palestine at specific. These plastic materials are used as additives to check the performance and the characteristics and properties of the HMA. Accordingly, six different batches of asphalt concrete (AC) samples are prepared using polyethylene as a percentage of the weight of optimum bitumen in varying proportions (0%, 2%, 4%,6% 8%, and 10%). The performance of the HA mixture is examined by checking different parameters such as stability, flow, air voids, VMA, density, etc. The dry process of binominal mixtures (Marshall Method) is used and the required and needed experiments are carried out according to the ASTM specifications. The results indicate that the addition of high-density polyethylene improves and refines the properties of the ¾ inch HMA considering medium traffic in terms of stability and the remaining Marshall parameters. The optimum plastic content is 4% by weight of bitumen which satisfies all specifications.

Keywords: HMA performance, Bitumen, Marshall method, Optimum plastic content.

1 INTRODUCTION

The good and strong road infrastructure of any country is considered as a vital demand for the development of the economic and social aspects from ancient nations to our time. Accordingly, the goal of planning and construction the roads are to provide and improve comfort and safety, long-lasting pedestrian facilities such as sidewalks, durable highways, as well as minimize maintenance costs. All previous objectives can be achieved by preparing, providing, and controlling a good asphalt mixture design (AMD).

As the road traffic volumes are increasing dramatically, along with inappropriate and not sufficient maintenance works due to the limited allocated budgets and funds for this purpose, and poor supervision, all these factors highlighted the problems in roads in Palestine as developing country. Moreover, from environmental point of view, the existing of huge amounts of plastic wastes (decompose accumulated in tons), is considered the main global problem that threatens and challenges human being in every side of the life. Hence, the solving of such problems is thought to be achieved by enhancing and encouraging the use of plastic wastes (high-density polyethylene-HDPE) in asphalt mixtures as a percentage of bitumen of 3/4 wearing course mix design (Grade (60/70)).

In order to comply with our main goal, the marshal test was applied considering the following different bitumen percentages: 4%, 4.5%, 5%, 5.5%, up to 6%. The optimum asphalt and corresponding HDPE contents are checked and investigated by implementing several trial mixes containing different bitumen and HDPE percentages: 98% AC and 2% HDPE, 96% AC and 4% HDPE, 94% AC and 6% HDPE, and 90% AC and 10%, respectively.

Based on experiments and lab test results and the investigated literature review, it was obvious that many researchers were recommended and encouraged to use such materials in the flexible pavement mix for paving of asphalt roads. The use of HDPE in asphalt mix is expected to contribute in minimizing the environmental problems and impacts resulting from the accumulation of tons of such wastes in the nature. Furthermore, the use of HDPE in AMD as a percentage and proportion of bitumen will reflect in minimizing the amount of bitumen reduces thereby reducing the cost of the asphalt mixture, as the bitumen is most expensive ingredient in the mix design on the one hand, and on the other reducing the maintenance cost. Moreover, the new mix is expected also to increase the durability and stability of the AMD as well as increase the resistance to cracking such as fatigue, low-temperature and rutting.

In Palestine, asphalt concrete is used as one of the most common types of pavement surface materials Issa (2020). It composes of a mixture of asphalt binder (bitumen) and aggregates. Many degradation processes occur throughout a road's life as a result of wearing out and deterioration. Consequently, bitumen becomes more brittle, causing a microcrack, and in the near future, a crack at the interface between bitumen and aggregates occurs. The bitumen binder properties affect the properties of pavement performance.

In this paper, some main characteristics of the HMA, including stability, flow, air voids, unit weight, and voids of mineral aggregates, are investigated and checked with the added HDPE. The expected prospect benefits include social, economic, engineering, and environmental aspects.

2 LITERATURE REVIEW

El-Saikaly (2013) stated that significant benefit to the asphalt mixture will be achieved by the addition of HDPE to it. He assured that the additive materials are expected to help engineers by improving asphalt properties for some special required specifications and design criteria. For example, the production of Waste Plastic Bag (WPB) asphalt is either by a dry process- a portion of fine aggregates is used to replace the HDPE while mixing or by melting the HDPE in the liquid asphalt binder before mixing which is called a wet process. The using of such plastic wastes is expected to decrease the noise from traffic due to its flexibility. Finally, the author mentioned several studies with useful and beneficial findings and applications of plastic wastes products in roads and highways construction which contribute in increasing appropriateness, social and economic aspects, environmental concerns, rendering, benefit and feasibility of using the before mentioned material El-Saikaly (2013).

The demand for more effective and convenient construction materials and safe and economic get rid of waste materials was discussed and introduced by several studies. Currently, the use of recycled and retreated materials in road and highway pavements improves appropriateness and is considered as an appealing and cute option in terms of providing enhanced and practical performance Sharma and Dubey (2018).

An additional other study through literature was investigated which aimed to study the effect of adding Low and high DPE to the flexible pavement mixture. For example, Awwad and Shbeeb (2007) added two different types of polymers in order to cover HMA in two different states. They used crushed and not grinded Low DPE and High DPE. The authors prepared 105 samples distributed as: 21 samples were aimed to determine the binder content, whereas investigating and examining the effect of modifying asphalt mixtures was through testing the residual samples. They used 5.4% as an asphalt optimum content. The authors selected and tested seven different ratios of PE of by weight of the optimum binder content considering the following percentages: six, eight, ten, twelve, fourteen, sixteen, and eighteen, respectively. The results revealed that the recommended proportion of the modifier is 12%. Moreover, other different indicators such as bulk

density, flow and stability were also determined in the applied tests. Finally, the results indicated that grinded HDPE modifier improves and provides better engineering properties.

Arabani and Pedram (2016) investigated the impact of different HDPE proportions on HMA in terms of dynamic characteristics. The authors assess the rutting and fatigue impact on HMA through using different tests such as RLA, ITSM and ITFT. The resulting percentage of optimum content of HDPE was ten. The rendering and performance of HDPE was functional on moderate temperature comparing with at high temperatures. Finally, the authors concluded that the using of HDPE could be more feasible in terms of minimizing pavement failure.

El Saikaly (2013) examined the modification of asphalt mixture of binder layer by using waste plastic bags (WPB). He prepared Twenty-eight samples in Optimum Bitumen Content (OBC) and assessed the impact of adding WPB to the asphalt mixture samples at (OBC = 1.5%). The author considered seven different percentages of WPB including six, eight, ten, twelve, fourteen, sixteen and eighteen% by weight of OBC. The results proved that WPB can be effectively used as a modifier for HMA which contributes in sustainable and durable management in terms of improving HMA performance by utilizing 9% of WPB. The results revealed also that the stability improved by twenty-four % using the indicated % 0f WPB comparing with traditional HMA. Finally, the flow and hardness were also improved by increasing the percentage of WPB.

Akter *et al*. (2019) used shredded waste plastic bottles in preparing four different percentages of HMA samples of zero, quarter, half, and three quarters by weight of total aggregate and corresponding five different percentages of asphalt four and half, five, five and half, six and six and half, respectively. The results revealed that the maximum stability with the minimum OAC were achieved by using three quarter percentage of WP bottles. The results revealed also that the stability and VFA increase as the percentage of WP increases. However, the values of air voids, flow, and VMA were decreased. Finally, the authors indicated that WP bottles can effectively be used as a modifier in AC.

3 EXPERIMENTAL WORKS AND RESULTS

3.1 Introduction

Asphalt samples were prepared utilizing different percentages of bitumen for a 3/4-inch asphalt mix, then the Marshall test was performed and the results were compared with specifications to find that the optimal bitumen percentage for this mix is 4.70.

3.2 Tests Applied on Asphalt with High-Density Polyethylene

Marshall test (ASTM 2015): The gross weight for the mix design used to prepare the asphalt specimens is 1200gm. The weight of aggregate was 1143.6 gm which forms about 95.3% of the total mix. The percentage of aggregates = 95.30%. Table 1 and Figure 1 depict the course, small size, and crushed fine aggregate amounts used in the test.

Table 1. Aggregate quantities by weight used in the test.

Ingredient	% Of Total Aggregate	Weight of aggregate (gm)
Coarse aggregate type I	12.9%	147.6
Coarse aggregate type II	19.9%	228
Small size aggregate	23.1%	264
Crushed fine aggregate	44.1%	504
Total	**100.0%**	**1143.6**

The percentage of bitumen and corresponding high-density polyethylene (HDP) by weight used in the test (OAC= 4.70%) are illustrated in Table 2. Moreover, the bulk specific gravity, unit weight, the air voids, the voids in mineral aggregates (VMA), Marshall Stability, flow, and corresponding percentage of HDP are illustrated in Table 3, respectively.

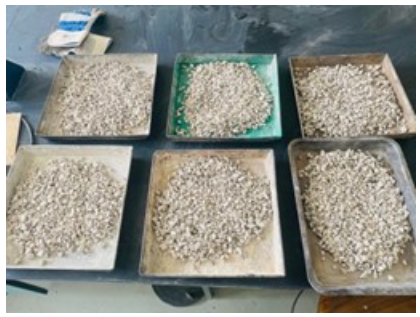

Figure 1. Percentage of bitumen and corresponding % of HDP used in the test.

Table 2. Percentage of bitumen and corresponding % of HDP used in the test.

Percentage of [Bitumen + HDP]	Weight of [Bitumen + HDP] (gm)
98%+2%	55.27+1.13
96%+4%	54.14+2.26
94%+6%	53.02+3.39
92%+8%	51.89+4.52
90%+10%	50.76+5.65

The results of the Marshall test in terms of percentage of HDPE and corresponding air voids, voids of mineral aggregates, stability, and flow are shown in Table 3. Moreover, Figure 2 and 3 illustrates the mixing process of aggregates and bitumen with HDP in the lab, while figure 3 illustrates the stability test.

Table 3. Mix design test results (ASTM: D6927-15 (2015); D2726M-21 (2021a); D2041M-19 (2019); D6995-21 (2021b); D3549M-18 (2018); and D3203M-17 (2017)).

%HDPE	Gb	Air void%	VMA %	Stability (kg)	Flow (mm)
2%	2.32	5.8%	16.41%	1357.80	3.50
4%	2.35	5.0%	15.38%	1630.48	4.00
6%	2.31	5.7%	15.99%	1452.60	5.12
8%	2.33	4.2%	14.24%	1598.03	4.20
10%	2.30	6.9%	16.71%	1243.63	3.81

Figure 2. The mixing process of aggregates and bitumen with HDP.

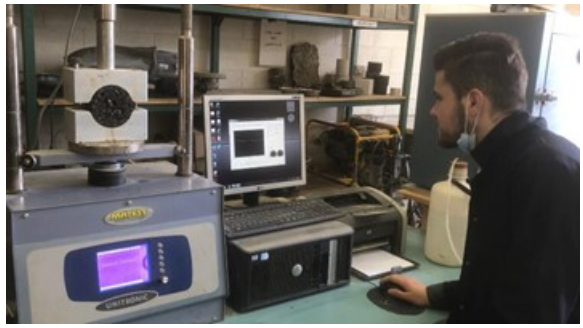

Figure 3. Stability test.

4 DISCUSSION AND RESULTS

The following highlighted points discuss and illustrate the results obtained from the last section.

- The stability values for the percentages 4% and 8% represent the highest values, which are equal to 1630.48 kg and 1598.03 kg, respectively.
- The flow increases by increasing HDPE percentage up to 6% and then the flow decreases up to 10%.
- All VMA values satisfy specifications.
- The air voids were only satisfied for two percentages; 4 and 8 of HDPE.

Furthermore, Table 4 illustrates the results of the various characteristics considering the diverse percentages of HDP (2% to 10%), and compares them with specifications (Federal Highway Administration 1992). From the Table, it is clear that only 4% of HDPE meet all specifications. However, the remaining percentages did not meet at least one of the specifications.

Table 4. Summary of test results and corresponding specifications (Source: Federal Highway Administration, U.S. Department of Transportation 1992).

%HDPE	Gb	Air voids (3-5)	VMA (>14)	Stability (>1000) kg	Flow (2-4) mm	Specifications (Yes/No)
0%	2.36	4.9 %	15.25%	1369.01	2.93	Yes
2%	2.32	5.8%	16.41%	1357.80	3.50	No
4%	**2.35**	**5.0%**	**15.38%**	**1630.48**	**4.00**	**Yes**
6%	2.31	5.7%	15.99%	1452.60	5.12	No
8%	2.33	4.2%	14.24%	1598.03	4.20	No
10%	2.30	6.9%	16.71%	1243.63	3.81	No

5 CONCLUSIONS AND RECOMMENDATIONS

The use of HDPE could be used as an additive to the asphalt mix design. The proposed amount is 4% by the weight of bitumen. The use of such material improves the stability and gives acceptable and satisfactory results in terms of other indicators such as air voids, VMA, and flow. Based on the results illustrated in Table 4, the following key points can be concluded:

1. The average stability for the four percentage HDPE with HMA mixture was greater than the zero percentage HDPE mixture. Accordingly, a considerable improvement occurred in the Marshall characteristics of HMA using an HDPE modifier.
2. HDPE could be utilized in HMA with optimum ratio (four percent by weight of total bitumen). This is mainly appropriate for Palestine considering ¾ inch HMA.
3. At 4%, HDPE Marshall Properties are consistent with the specification's limits.

The authors recommend checking the probability of benefiting from the large amounts of waste HDPE by implementing additional tests which in turn could contribute to reduce the cost of paving works.

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