International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2018.33030

Volume 4, Issue 12
December - 2018

Experimental Study of using Waste Glass as additives in Asphalt Concrete Mixtures

Farag Khodary

Associate Professor, Civil Engineering Department, Qena Faculty of Engineering,

South Valley University,

Qena

Egypt

ABSTRACT

In road engineering, it is important to develop paving technology and improving asphalt pavement efficiency in terms of increasing their service life and reducing the damage caused by rutting, fatigue and thermal cracks. Waste glass can be used as asphalt modifiers, which can be add in certain properties to the asphalt mixture in ordered to modify some of the properties of the mechanical properties of asphalt concrete mixtures. The waste glass that is crushed can be used as a portion of fine aggregate in asphalt concrete mixtures. The aim of this research is to study the effect of using waste glass as asphalt concrete mixtures additives. From the review different portion of waste, glass can be used as asphalt concrete mixtures additives up to 15%. In this research fine natural aggregate replaced with crushed Waste glass in deferent percentage namely 6%, 9%, 12%, 15% and 18%. The mechanical properties of the glass-asphalt were evaluated using Marshall Stiffness, compressive strength and indirect tensile strength. Based on the results, it was found that 15% of crushed Waste glass improves the mechanical properties of asphalt concrete mixtures in the terms of Marshall Stiffness and compressive strength. On the other hand, no improvement in the tensile strength was noticed.

Key words: *Waste glass, Pavement Construction, Marshall Stiffness, Compressive strength, Tensile strength*.

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1. INTRODUCTION

Asphalt concrete is a composite material commonly used to surface roads, parking lots, and airports. It consists of mineral aggregate bound together with asphalt, laid in layers, and compacted. Paving and compaction must be performed while the asphalt is sufficiently hot. There are many problems occur to pavement layers as a result of the repeated loads and these loads or stresses which occurring at asphalted roads lead to the appearance of defects on the surface of the road may be caused by the appearance of those defects failed to asphalt surface. The properties of asphalt concrete mixtures depend on the properties of the used aggregate. Mineral aggregate constitutes approximately 95% of hot-mix asphalt (HMA) by weight [1]. Different type of aggregate used to produce asphalt concrete mixtures such as Crushed Basalt, Crushed Dolomite and Crushed Limestone [2]. There are a number of different (HMA) additives that can be used to modify its performance and there are many methods to blend these additions with asphalt by introduced directly to the asphalt cement (AC) as a binder modifier or can be added to the mixture with the aggregate. One of these methods of asphalt concrete mixtures improvement is to add a quality filler material such as waste tires by cutting and scraping them into small sizes down to powder particles (Crumb Rubber) and use them as additive for conventional asphalt for road pavement. Glass waste is a viable material for asphalt concrete that has been widely used in pavement that offers profound engineering and economic advantages [3]. Asphalt mix with crushed glass could outperform the conventional dense-graded mix in terms of rutting. The fatigue performance was comparable although the conventional mix performed marginally better than the glass asphalt mix [4]. effects of adding fifteen percent crushed glass for a portion of the fine aggregate in an asphalt paving mixture indicate that the mixtures containing either coarse or fine crushed glass had lower Marshall stabilities and dry tensile strengths compared to a control mixture[5]. On other hand increasing the glass fraction in the asphalt mixture decreased the density, stability, and void content of the mixture, as well as the proportion of voids filled with bitumen [6]. Using of asphalt additives in highway construction is known to give the conventional bitumen better engineering properties as well as it is helpful to extend the life span of asphalt concrete pavement[7]. The optimum glass powder content is 7%.Where it is found that using of glass powder as filler with such replacement leading to produce asphalt mixture with higher stability [8].

2. MATERIALS AND METHODS

The primary components in asphalt mixtures are typically defined as coarse aggregate, fine aggregate, mineral filler, and asphalt binder. In this study, the materials used to prepare asphalt concrete specimens are coarse aggregate, fine aggregate, (lime stone powder and waste glass) and asphalt binder.

2.1 Bitumen

Bitumen (sometimes termed as binder/asphalt) is a general description for the adhesive or glue used asphalt pavements, either petroleum derived or naturally occurring material. The asphalt binder is what gives an asphalt pavement its flexibility, binds the aggregate together, and gives waterproofing properties to the pavement. In this study, Bitumen with penetration grade 60/70 produced from Alex. Industry is used. The properties of bitumen are shown in table (1).

Table (1) Properties of bitumen (60 / 70)

Test	Results	Specifications
Penetration at 25 oC.	67	60-70
Kinematics Viscosity (centistokes at 135 oC)	280	320
Ring and Ball softening point	51.9 ^{o}C	45-55
Specific gravity	1.03	1-1.1
Flash point	245 ^{o}C	250

2.2 Aggregate

Aggregate gradation is important in the characterization of an asphalt mixture. The relative amounts of the component aggregate materials will govern the material properties of the resulting mixture where aggregates represent the largest proportion of asphalt concrete mixture approximately (75 - 85) % by volume or (90-95) % by weight of HMA. These aggregate components are ostensibly combined to provide an aggregate skeleton that will resist permanent deformation and cracking. Aggregates are divided into types; Coarse and fine aggregates. Coarse aggregates are retained on a sieve (No.4) while fine aggregates are passing from a sieve (No.4) and retained on a sieve (No.200). The properties of the used aggregates are shown in table (2&3)

Table 2: Physical properties of aggregate materials (Los Angeles Abrasion)

Test	Aggr. (2)	Aggr. (1)	AASHTO Designation No.	Specifications
Loss rate after 100 revolution %	5	6	T- 96	≤ 10
Loss rate after 500 revolution(after washing) %	21	22		≤ 40

Table 3 : Physical properties of aggregate materials (specific gravity, water absorption and crushing)

Test	Aggr. (2)	Aggr. (1)	Sand	AASHTO Designation No.	Specifications
Bulk Specific Gravity %	2.657	2.650	2.393	T-85	2.5 - 2.8
Specific Gravity Saturated surface-dry (SSD)	2.7	2.696	2.457	T-85	
Apparent Specific Gravity	2.775	2.780	2.556	T-85	
Water Absorption %	1.6	1.8	2.6	T-85	≤ 5 %
Crushing %	0.2	0.2	_	T-112	_

2.3 Aggregate Gradation

Aggregate gradations were selected with a nominal size of 19mm based on The Asphalt Institute Manual Series “Principles of Construction of Hot-Mix Asphalt Pavements “No.22 MS-22 (1983). Where the choice of gradient is one of the important factors in determining the behavior of the asphalt mix. The mixture is designed to withstand various traffic loads. The aggregate gradation presented in table (4).

DOI: 10.31695/IJASRE.2018.33030

Table 4: Gradation of the Aggregates and Filler.

Sieve size "Inch"	Aggr. (2)		Aggr. (1)		Sand		Filler	
	% P	29 %	% P	29 %	% P	37 %	% P	5 %
1	100	29	100	29	100	39	100	5
3/4	98	28.4	100	29	100	39	100	5
1/2	41	11.9	100	29	100	39	100	5
3/8	7	2	90	26.1	100	39	100	5
No.4	0	0	29	8.4	100	39	100	5
No.8	0	0	22.7	6.6	92	35.9	100	5
No.16	0	0	16.7	4.8	75	29.3	100	5
No.30	0	0	11.4	3.3	53	20.7	100	5
No.50	0	0	6.2	1.8	27	10.5	100	5
No.100	0	0	3.4	1	13	5.1	94	2.8
No.200	0	0	2.1	0.60	7	2.7	80	2.4

2.4 Optimum asphalt binder content

The average binder content for maximum density, maximum stability and specified percent air voids in the total mix was selected. Asphalt was added with rate (4.5 %, 5 %, 5.5 %, 6 %, and 6.5 %) of total weight of aggregate and filler. The characteristics of asphalt concrete mixtures as shown in table (5). By adding these results in curves, we can find that the optimum asphalt binder content (5.6 %±0.25)

Table (5) characteristics of asphalt concrete mixtures

Asphalt binder ratio	4.5 %	5 %	5.5 %	6 %	6.5 %
Stability (pound)	2756	2999	3038	2885	2626
Unit weight (ton/m3)	2.268	2.287	2.316	2.325	2.319
Flow (1/100″)	11.6	12.8	14.3	15.5	17.2
Percent of air voids in total mix %	6.9	5.6	3.8	2.7	2.4
Percent of voids in aggregate %	16.5	16.3	15.6	15.6	16.3

3. 1 Laboratory Test - Marshal Stiffness (MS)

Marshall Stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/minute. With the test load exceeding the maximum limit, the load ends and the load begins to decrease. When the maximum load limit is obtained, we obtain the value of the vertical deformation. This test is considered one of the important tests that measure the bearing of the asphalt mixture to the loads. Therefore, it is considered the best when designing asphalt plans that are exposed to large quenched loads to have high stability [9].

$$MS = \frac{Si}{Fi * b} \quad \dots\dots..(1)$$

MS = Marshall Stiffness

Si = Marshall Stability

Fi = Marshall Flow

b = Thickness of the specimen

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3.2 Indirect Tensile Strength (ITS)

HMA tensile strength is important because it is a good indicator of cracking potential. The indirect tensile test is considered one of the most important tests that measure the tensile strength of the asphalt mixture, and this scale is considered an evidence of the resistance of the mixture to cracks. The more elastic of asphalt concrete mixtures, is the greater resistance to cracking [9].

$$ITS = \frac{2Pmax}{\pi DT} \quad \dots \dots . . (2)$$

Pmax = Max. Load at failure

D = Diameter of the specimen

T = Thickness of the specimen

3.3. Compressive Strength Test

This test method provides a method for measuring the compressive strength of compacted bituminous mixtures. It is for use with specimens weighed, batched, mixed, and fabricated in the laboratory, as well as for mixtures manufactured in a hot-mix plant. Normal stress was calculated by dividing the force on the cross sectional area and the normal strain was calculated by dividing the deformation on the specimen gauge length [9].

$$\sigma c = \frac{4Pmax}{\pi D^2} \quad \dots \dots . . (3)$$

σ_C = Compressive Strength
P_{max} = Failure Load
D = Specimen's Diameter

4. Test Result

The results of these tests were statistically analyzed to identify any significant change in the Mechanical properties of asphalt mixtures. The addition of waste glass generally improved the mechanical properties of the mixture Regardless of the percentage of the Crumb Rubber that added. Table (6) presents the test result for Indirect Tensile Strength and Compressive Strength.

Table (6) Test result

Waste glass	Mean Stiffness (psi)	Indirect Tensile Strength (ITS)(psi)	Compressive Strength
0 %	4343	56.3	27.4
6%	6756	56.4	33.2
9 %	8764	56.0	35.6
12%	8766	56.1	38.3
15%	8740	56.2	36.2
18%	8738	56.0	35.1

From the table (6) this work has shown the potential use of waste glass in pavement construction. 12 % waste glass gives significant improvement in Compressive Strength on the other hand no real improvement in tensile strength. it can be noticed that,

DOI: 10.31695/IJASRE.2018.33030

The addition of waste glass generally enhanced the results of Marshall Stiffness as compared to the control mixtures. The mixture with 12% of waste glass has a higher Marshall Stiffness than the other mixtures. The use of Waste glass in asphalt mixtures can prevent the accumulation of waste material and primary production costs as well as environmental pollution.

5. CONCLUSIONS

- The effect of adding waste glass on the mechanical performance of hot mix asphalt is clearly distinguishable taking into account the percentage of waste glass that added.
- The addition of waste glass increases the compressive strength of asphalt concrete mixtures as well as increases the strength to rutting.
- The modified asphalt concrete mixtures with waste glass has less workability and less tensile strength compared to unmodified asphalt concrete mixtures.
- 12% of crushed Waste glass improves the mechanical properties of asphalt concrete mixtures in the terms of Marshall Stiffness and compressive strength.
- No real improvement in tensile strength was noticed by adding waste glass as asphalt additives.

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