Use of Waste Plastic and Glass in Glasphalt Mixture

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ABSTRACT

Waste and recycled materials have a significant part to play in highway works and has already highlighted several area of concern with regard to the use of secondary materials in relation to primary materials. This type of asphaltic mixture containing waste materials are not used in Egypt in spite of producing an attractive method for solid waste minimization. This paper provides a follow-up to previous work on role of the efficient use of plastics waste (polyethylene type) as an asphalt modifier in producing glasphalt mixture containing waste glass obtained from municipal refuse with the objective of converting the waste glass portion of our nation's refuse into a valuable resource, capitalize on the many beneficial properties that glass can impart to various road paving and finally produce glasphalt mixture of higher quality as compared to the conventional one using unmodified penetration grade asphalt of 60/70. In this work, laboratory studies have been conducted to determine the Marshall properties of all mixtures prepared. Waste plastics was used as 5% by weight of asphalt while, waste glass was used as part of solid materials (sand and filler). The waste glass and plastics were found to be suitable and satisfactory for highway works.

INTRODUCTION

The world today confronts with many problems, ranging from the widely publicized energy shortage to the lesser-known solid waste disposal. The use of disposal or nonreturnable items has steadily grown along with obvious implications of the ultimate disposition of the refuse as a result of this fact [1]. Municipal refuse generally consists of a number of different components, including paper, metal, glass, garbage, yard wastes, wood textile, plastics, and other minor extraneous materials.

The quantity of solid waste is often expressed in pounds per capita per day (pcd) so that waste streams in different areas can be compared. This quantity is typically calculated with the following equation[2]:

$$Pcd = 2000\ T/365P$$

Where:

Pcd = pounds per capita per day

T = number of tons of waste generated in a year

P = population of the area in which the waste is generated.

Municipal solid waste has potential negative effects[3] among which; promotion of microorganism that cause diseases, attraction and support of disease vectors, generation of noxious odors, degradation of the esthetic quality and increasing the pollution of the environment and occupation of space that could be used for other purpose. So, the fundamental challenge of solid waste management is to minimize the potential negative effects which maximize the recovery of useful materials from the waste at a reasonable cost[4].

Also, pollution problems has caused an impetus in reuse or secondary uses of materials like waste glass which disposed of in dumps as solid waste [5]. Container glass is the only glass being recycled today. Window pans, light bulbs, mirrors, glassware, crystal ovenware, and fiber glass are not recyclable with container glass. The consideration in container glass marketing is color separation. Only emerald or amber cullet crushed glass can be used for green and brown bottles respectively and this done according to ASTM E708/79 which illustrate specification for color sorted glass [6].

About 13 million tons of glass are disposed of in the USA every year, representing more than 7% of the total municipal solid waste that is generated. But only about 12% of the total glass production is recycled. In comparison, Japan recycled about 50% [3], according to energy shortages and high cost. The same is due in Egypt[7].

Glass is an ideal packing material because of its unique and chemical properties and because of its environmental compatibility. Thixotropic construction panels, glass wool, terrazzo, slurry seal and foamed glass are typical products that made from waste glass[8]. Also, salvaged glass has been used in bricks and paving mixtures. [9].

The use of waste glass as an aggregate in asphaltic mixtures has been investigated since 1969 at U.S.A.[8] and since glasphalt pavements have been used on state highways, city streets and parking. Conventional equipment for laydown and rolling has been used in all glasphalt pavement placed to date, without the need for modifications in the pavers or rollers. However the glasphalt mixture has the following advantages as compared to the conventional asphalt mixture [5&8].

1. The surface of a glasphalt mixture does have some particles of glass laying in such a way that they give some reflection, which may be a benefit to traffic safety.
2. Glasphalt may have a slight bit more skid resistance..
3. It requires less heat and retains it longer than normal asphalt. it was suggested that the mixing temperature of the glasphaltic mixtures be reduced to between 121-135 °C. The reduction in mixing temperatures will have a tendency to minimize the delays in compacting due to the tendency of a very hot asphaltic mixture to crawl during breakdown rolling operation .

On the other hand, in order to improve the asphalt adhesion to the glass particles and to reduce the potential for asphalt stripping, commercial hydrated lime was added to the wearing surface mixture used [10]

This paper represents the results of laboratory investigation with regard the use of waste glass as solid material replacements in asphaltic mixture using modified penetration graded asphalt 60/70 with waste plastic previously used[11] .

EXPERIMENTAL WORK

A) Raw Materials Used:

The raw materials used in this research developing work were as follows:-

1. Coarse and fine aggregates are crushed siliceous limestone type, Secured from "Ataka" quarry at "Suez" governate, siliceous sand obtained from "Abu shalaby" quarry, sharkia governate, Artificial sand and limestone mineral filler, with properties as illustrated in Table (1).
2. Two samples of penetration graded asphalt 60/70 produced from El Nasr Petroleum Co. The first one in virgin form and the other is modified asphalt as previously knowing with properties shown in Table (2).

Knowing that: VAC = Virgin Asphalt cement

MAC = Modified Asphalt cement by using waste plastic (polyethylene type) as 5% by weight of it.

3. Waste glass obtained from municipal refuse was crushed through hummer mill followed by sizing.

B) Experimental work

The experimental program includs the following steps:

1. Characterization of the raw materials.
2. Preparation and characterization of asphalt paving mixtures using the two asphalt samples. The preparation was according to standard Marshall procedure (ASTM D1559), also, the mixes were designed according to the Standard Specification Limits of Asphalt Institute (MS-2)[12].
3. Preparation and characterization of glasphalt mixtures applying Marshall procedure containing waste glass as artificial sand or filler.
4. Analyzing the results.

1. Characterization of The Used Raw Materials :

The characteristics of aggregates and Asphalt are listed in Tables (1) and (2) respectively

2. Preparation and Characterization of Asphalt Paving Mixture without glass Material:

In this step; Laboratory studies have been conducted to determine the Marshall properties of asphaltic paving mixtures (control mixtures) using design method (ASTM D1559) The criterion selected was a 75 blow design Marshall compaction, also varying asphalt content (4,5,6 & 7% as weight of materials). The design gradation of mixture and Marshall properties at the optimum asphalt content are illustrated in Tables (3) & (4) respectively. According to the selected job mix formula, the composition of the control mixture was as follows:

Coarse and fine aggregates, natural sand, artificial sand and limestone mineral filler as 20,30,23,23 & 4 percent by weight respectively.

3. Preparation and Characterization of Glasphalt Mixtures:

In this step; Marshall test was applied on the laboratory compacted samples through using the waste glass as artificial sand or filler and using the same sizing of the original components. It must be mentioned here that; the glass was a relatively clean coarse mixture of different types of samples (bottles, drian cullet, dishes, laboratory tools, etc). The glass was crushed in a hummer mill. The specific gravities of waste glass which are used as sand and filler were 2.23 & 2.30 respectively The Marshall properties of all prepared mixtures are illustrated in Table (4) and shown in Figures (1 & 2)..

RESULTS AND DISCUSSION

A) Effect of Using Waste Glass in Asphalt Mixtures

From Table (4) and Figs (1&2) the following interpretations could be gained :-

- Glasphalt mixtures using VAC occurred a substantial decrease in Marshall characteristics. This fact could be expected since the smoother surface texture of glass-as compared to the natural siliceous sand or limestone powder which were replaced-decrease the internal friction in the mixture.
- Increasing the content of waste glass in the mixture (from 4% to 23%) will produce glasphalt mix with lower Marshall characteristics. This may due to as previously mentioned to the decrease in the internal friction in the mix. However the Marshall characteristics of all prepared glasphalt mixtures by using VAC were still above the minimum requirements which is established by the general the Asphalt Institute (MS-2)

B) Effect of Using Waste Glass as Artificial Sand:

From Table (4) and Fig (1) the following facts were obtained:

- For glasphalt mix using VAC, there was a noticeable decrease in stability, unit weight and flow in percentage of 35.9, 5.6 & 5.8 respectively. On the other hand, there was an increase in % of air voids in mix and solid aggregate in percentage of 32.3 & 5.7 respectively as compared to the control mix.
- Also, for glasphalt mix using MAC, There was decrease in stability, unit weight and flow in percentage of 46.1%, 3.4 & 2.8% respectively, while, there was an increase in % of air voids in mix and solid aggregate in percentage of 21.2 & 7.2 respectively as compared to the control mix.
- All the above results obtained my be due to the effect of using waste glass since it was very smooth. Therefore mechanical locking between particles was decreased.

C) Effect of Using Waste Glass as Filler:

From Table (4) and Fig (2), the previous remarks were recorded for glasphalt mixtures using waste glass as filler.

- As in case of using VAC, there was a decrease in stability, unit weight and flow in percentages of 13.4, 1.1 & 4.3% respectively. While there was an increase in % of air voids in mix and solid aggregate in percentage 17.6 & 3.8% respectively as compared to the control mixture.
- As in case of using MAC, there was a decrease in stability, unit weight and flow in percentages of 26.4, 1.1 & 3.0% respectively. On the other hand there was an increase

in % of air voids in mix and solid aggregate in percentage of 12.1 & 3.3 % respectively as compared to the control mix.

All the above result as previously mentioned may be due to the effect of characteristics of glass.

D) Effect of Using Modified Asphalt in Glasphalt Mix.:

- From Table (4) and Figs (1) & (2) it is noticed that, the glasphalt mixes prepared by using MAC have higher quality at lower asphalt content as compared to these using VAC. These improvements content may be due to that, the waste plastics is very soft and soluble in the asphalt at the mixing temperature (160-180°C for 2 hours using 3 blades mixer rotating at 330rpm) and have the effect of rising the viscosity of the asphalt as seen in Table (2). The waste plastics previously was found to be effective in improving the Marshall characteristics of the asphalt paving mixtures[11].
- Also, using MAC with waste glass as filler or sand will produce glasphalt mixes have nearly the same characteristics of conventional asphalt mixture using VAC (control mix).
- It must be mentioned here that, the blend of crushed glass and stone would be advantageous for usage as an aggregate back fill for under stripping. Also, raveling of glasphalt was not found to be significant. The raveling was found where the void content was 10% and higher for specimens made with good aggregate. Specimens made with poor aggregate showed significant raveling at all void content [1].

CONCLUSION

1. Waste glass when properly sized can be used successfully as a component of asphalt paving mixtures without altering the mix standard specifications.
2. Using modified asphalt with waste plastics in glasphalt mix will produce paving mixes having nearly the same quality of conventional asphalt mix specified for both base and wearing course mixes.
3. The results of this research developing work should be of a value in determining the most economical and efficient means by using waste plastics and glass in asphalt paving. Also, the results help in reducing the quantity of materials entering the solid waste management system.
4.

RECOMMENDATIONS

1. The results of the laboratory test gave sufficient proof that the field implementation of base and wearing course mixes using waste glass and plastics would be possible

2. Glasphalt mix could be used as a wear course for roads having low traffic volume and as a base course or a back-fill metrical for roads have high or medium traffic volume.
3. Development of specifications to promote the use of waste and recycled materials in construction and demonstration projects have to be done.

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Table (1) : Physical Properties of Used Solid Materials

Item	Test method (ASTM)	Sample No (1)	Sample No (2)	Sample No (3)	Sample No (4)	Sample No (5)	Standard Specification Limits
1. Type		Crushed Siliceous limestone type	Crushed Siliceous limestone type	Natural Sand	Artificial sand	Limestone powder	
2. Size	C136						
3. Gradation							
Sieve Analysis (% wt passing)							
Sieve size (mm)							
1" (25.4)		100					
3/4" (22.4)		82	100				
½" (12.50)		18	99				
3/8" (6.30)		4	72	100	100		
No.4 (4.75)			16	81	99		
No.8 (2.36)			4	49	92		
No.16 (1.18)			2	33	70		
No.30 (0.600)			0.7	15	63	100	100*
No.50 (0.300)			0.5	9	43	100	--
No.100 (0.150)			0.5	5.8	22	90	more than 85*
No.200 (0.075)			0.4	4.2	12.6	69.5	more than 65*
4. Abrasion Resistance (loss % wt)	C131						
- After 100 revolutions		5	6				Not less than 10**
- After 500 revolutions		25	26				Not less than 40**
5. Specific Gravity	C127						
- Bulk specific gravity		2.541	2.477	2.65	2.81	2.75	
- Bulk specific gravity (SSD basis)***		2.585	2.553				
- Apparent specific gravity		2.657	2.682				
6. Absorption (%wt)	C127	1.7	3.1				Note more than 5**
7. Disintegration (% wt)	C127	0.9	0.4				--
8. Plastic & Liquid limits				Nil	Nil	Nil	Less than 8**** Less than 32****

NB: (*) Standard specification limits of limestone mineral filler
(**) Standard specification limits of mineral aggregates
(***) Standard surface Dry basis
(****) Standard specification limits of plastic and liquid limits respectively of sand and mineral filler

Table (2): Physical Properties of Used Asphalt

Test	(ASTM) Designation No	Results	
		VAC (*)	MAC(**)
- Penetration (@ 25°C, 100g, 5s), 0.1mm	D5	61	45
- Softening Point, (Ring & Ball) °C	D36	51	69
- Kinematic Viscosity (@ 135°C), cSt	D2171	400	1620
- Specific Gravity (@ 25/25 °C)	D70	1.02	0.8679

NB : (*) Virgin Asphalt Cement

: (**) Modified Asphalt Cement

Table (3) : Design Gradation of Mixture Used

Sieve Size, inches (mm)	Design Gradation	Standard Specification Limits	
		(4 c)*	(4 d)**
1½ "(37.5)	--	--	100
1" (25)	100	100	80/100
¾ " (22.4)	96.4	80/100	70/90
½ " (12.5)	83.3	--	--
3/8 " (6.300)	72.4	60/80	55/75
No.4 (4.750)	50.2	48/65	45/62
No.8 (2.360)	37.7	35/50	35/50
No.30 (0.600)	22.2	19/30	19/30
No.50 (0.300)	16.2	13/23	13./23
No.100 (0.150)	10.2	7/15	7/15
No.200 (0.075)	6.8	3/8	0/8

N.B: (*) for wearing course

(**) for base course (asphaltic type)

Table (4) : Marshall Characteristics of Mixtures Prepared

Characteristics	Control Mixtures Using		Glasphalt Mixtures using waste Glass as Artificial sand		Glasphalt Mixtures using waste Glass as Filler		Marshall Design criteria (***)
	VAC*	MAC**	VAC	MAC	VAC	MAC	
- Optimum Asphalt content (%)*	5.50 ± 0.25	5.35 ± 0.25	6.0 ± 0.25	5.90 ± 0.25	5.95 ± 0.25	5.85 ± 0.25	
- Stability of the mix, (lbs)	2875	3900	1875	2100	2490	2870	minimum 1800
- Unit weight of the mix (t/m^3)	2.306	2.331	2.178	2.251	2.82	2.305	
- Flow of the mix (0.01 in.)	13.8	14.2	13.0	13.8	13.2	13.7	8-14
- Air voids in the mix (%)	3.4	3.3	4.5	4.0	4	3.7	3-5
- Air voids in the mineral aggregates. (%)	15.7	15.3	16.6	16.4	16.3	15.8	*minimum* 13.5

NB : (*) Virgin Asphalt content
(**) Modified Asphalt content
(***) Asphalt Institute Standard Specifications for surface and Bas course in case of roads heavy traffic volumes.

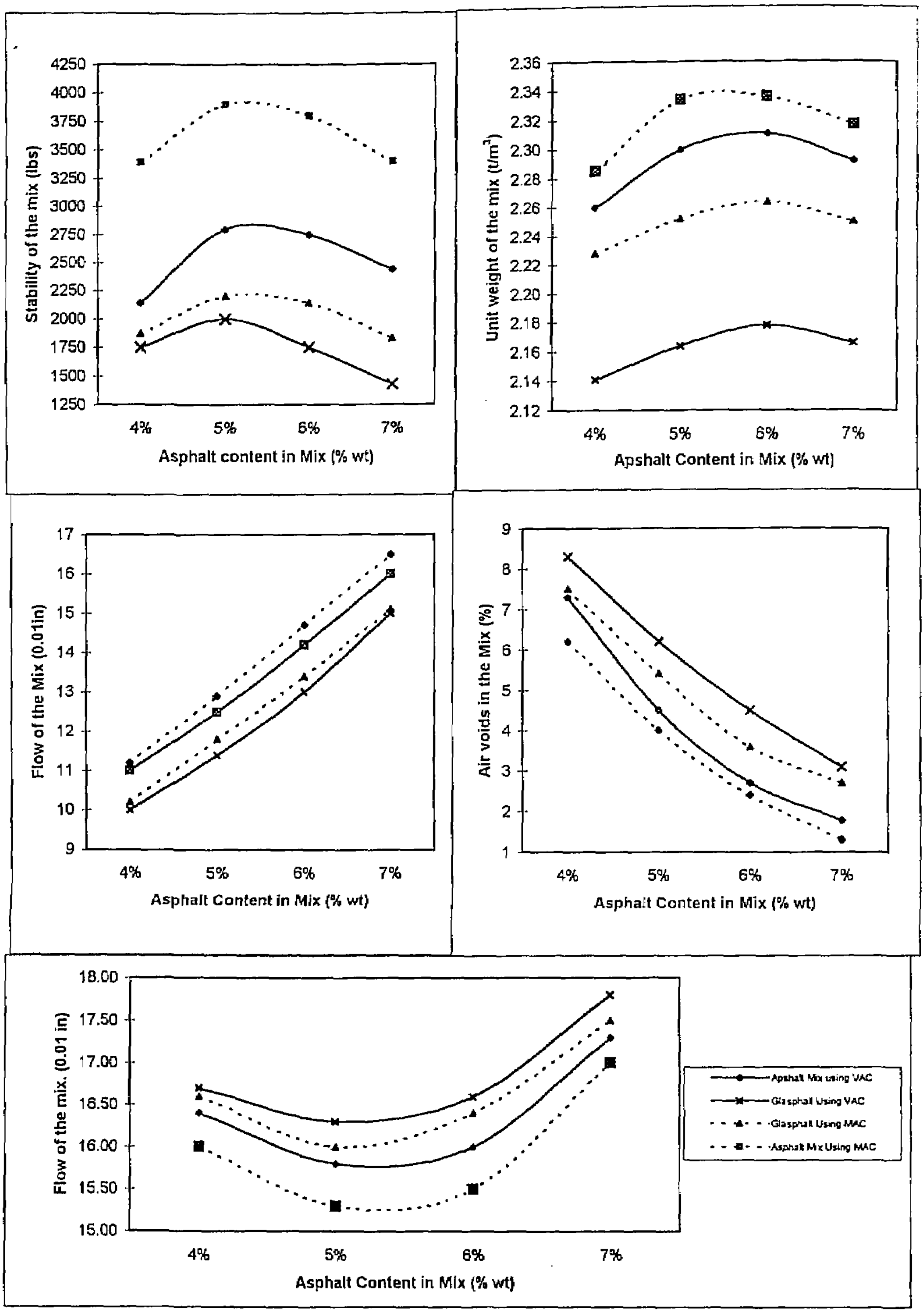

Fig. (1): Marshall Characteristics of Prepared Asphalt and Glasphalt Mixtures Using Waste Glass as Artificial Sand.

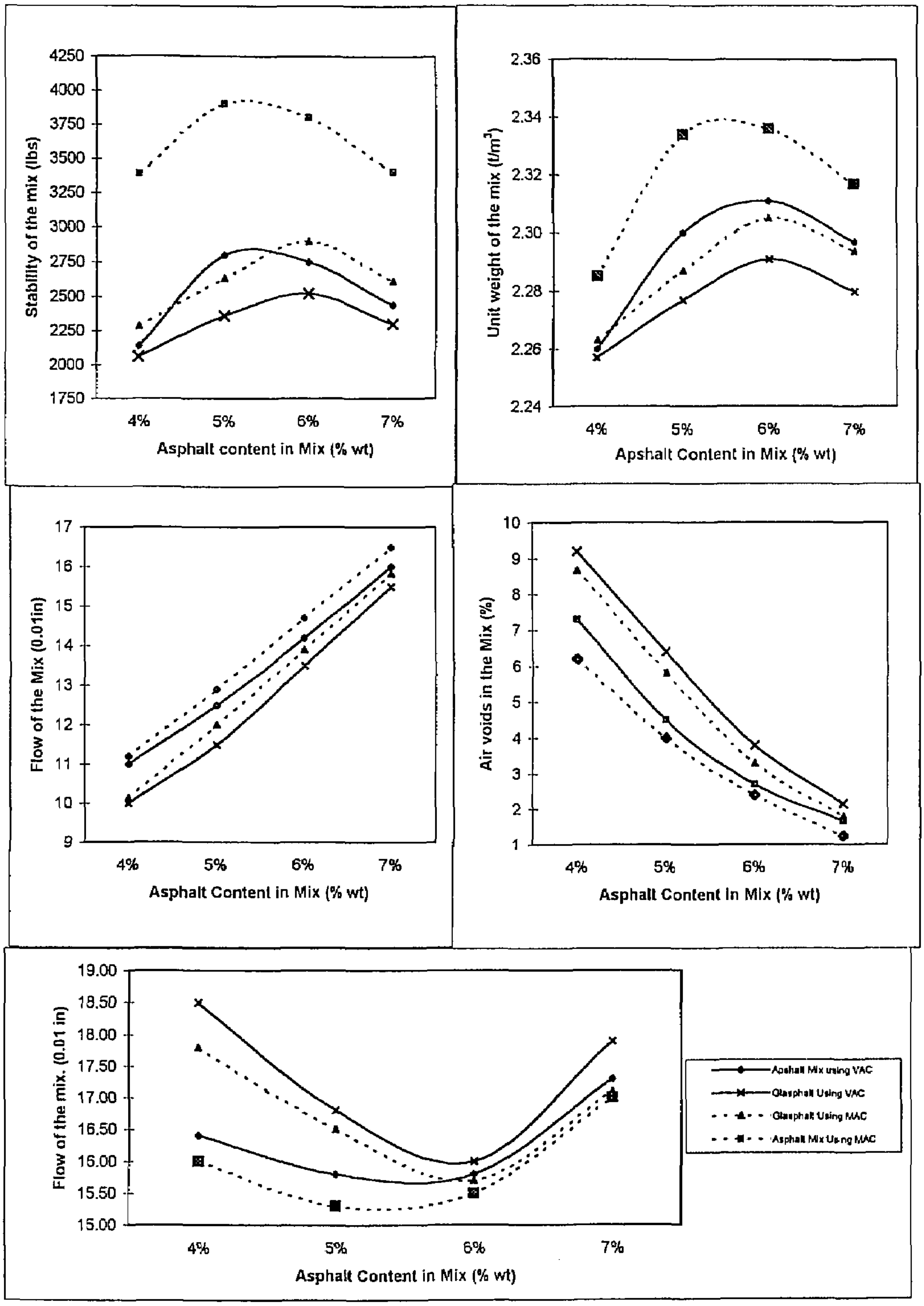

Fig. (2): Marshall Characteristics of Prepared Asphalt and Glasphalt Mixtures Using Waste Glass as Filler