

Sustainable Performance of Iraqi Asphalt Base Course Using Recycled Glass as Aggregate Replacement

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Abstract

Nowadays, a lot of waste glass produced through different sides of life. Applying sustainability has been widely used in different construction materials and flexible pavement was contained different crushed materials through different studies. Crushed glass, where it is nonmetallic and inorganic, it can neither be incinerated nor decomposed, so it may be difficult to reclaim, has been used as filler, fine and coarse aggregates in the asphalt base course. In this study, various standard asphalt tests, such as stability, flow, density and air voids, have been conducted on reference mix asphalt and mix asphalt with different percentages of crushed glass when it has been used as filler, fine and coarse aggregates in the base course. Generally, the results show good indication, especially when using 10% of the crushed glass instead of coarse aggregate with 40-50 asphalt grades. This percentage improves most characteristics such as strength retained index which indicates better performance than reference mix.

Keywords: Hot mix asphalt, Crushed glass, Base course, Stability and Flow.

الخلاصة

في الوقت الحاضر كميات كبيرة من نفايات الزجاج تنتج في مختلف جوانب الحياة. وتطبيق مبدأ الاستدامة يستخدم عالمياً بصورة واسعة في مختلف المواد الانشائية ومواد التبليط المرن والتي احتوت على مواد معادة (مستخدمة) عبر دراسات مختلفة. الزجاج المستخدم والذي هو مادة غير معدنية ولا عضوية ولا محروقه ولا متحلله والتي من الصعب اعادة تدويرها قد استخدمت كمادة مألثة وركام ناعم وخشن في طبقة الاساس. في هذه الدراسة عدة فحوصات تم اجرائها كفحص الثبات والجريان والكثافة ونسبة الفراغات الهوائية في الخلطة المرجعية وفي الخلطات التي تحتوي نسب مختلفة من الزجاج عند استخدامه كمادة مألثة او ركام ناعم او خشن في طبقة الاساس. النتائج بصورة عامة بينت مؤشر جيد عند استخدام 10% من الزجاج المكسر استخدامه بدلاً من الركام الخشن مع اسفلت نوع 40-50. هذه النسبة حسنت الكثير من الخصائص مثل مؤشر مقاومة الرجوع والتي كان ادائها افضل من الخلطة المرجعية.

الكلمات المفتاحية: الخلطة الاسفلتية العادية، الزجاج المكسر، طبقة الاساس، الثباتية والجريان.

1. Introduction

Hot Mix Asphalt (HMA) pavements are being increasingly constructed in the world, as the governments are allocating a huge amount of resources to construct and upgrade the existing road network. However, the use of fresh (primary) aggregate in the asphalt mixture layers of a road or airfield pavement is seen as a wasteful use of a finite natural resource. Using waste glass in the HMA has sustainable and economic benefits as long as the roads have the same characteristics to serve traffic (Anochie-Boateng and George, 2016).

A large amount of glass waste from industry has been an urgent subject at both national and global levels. Glass recycling can save energy and decrease environmental waste. Nearly 10 million tons of glass waste have been generated every year around the world. Hundreds of tons are generated in Jordan (Abu Salem *et.al.*, 2017). Table 1 indicates an overview of how the glass has been used by different studies.

Act of crushed glass in the performance of the mixture is up to 30% by mass of aggregate as reported by (Issa, 2016). The author also referred that several researchers found that the stability decreases with increases of glass replacement. On the other hand, the mixture of 2% glass grinds in addition, 3% plastic polymer could enhance the mechanical properties of asphalt mixture significantly as reported by (Ghasemi and Marandi, 2013). (Issa, 2016) conducted experimental works using several samples with three percentages of crushed glass 5%, 10%, and 15% by aggregate weight. The optimal percentage of crushed glass was 10% of total aggregate weight. (Abu Salem *et.al.*, 2017) conducted experimental works to investigate the effect of crushed glass instead of fine aggregate by different percentages of crashed glass materials of 5%, 10%, 15% and 20 % with AC (85-100). The Marshall design method had been utilized for testing the effect belongs to the optimum asphalt content (OAC) at different fine glass percentages and the resistance against water. Mixtures characteristics are enhanced through use a hydrated lime admixture and other mixtures. They found that the ability of using crushed glass (2.36 mm) max. size of particles in asphalt mixtures in addition to the ideal substitution of glass is 10%.

Table 1 Overview in previous studies for using glass in the HMA.

The authors	Characteristics of materials	Results
(Wu <i>et.al.</i> , 2004)	Modified asphalt Limestone aggregate AH-70 asphalt from Korea penetration, reclaimed beer bottles waste glass uses the maximum glass particles size is 4.75mm with 0, 5, 10, 15 and 20% replacement.	The optimal replacement ratio of 10%.
(Anochie-Boateng and George , 2016)	The waste glass ratio 15% and Max. nominal size 9.5 mm	The dynamic modulus increases by 25% from the reference mix.
(Jony <i>et.al.</i> , 2011)	The glass is used with percent (4, 7, 10) %; (40-50) asphalt grade.	The optimum glass content is 7%.
(Abed and Abbas , 2011)	Asphalt grade (40-50) and 19 mm aggregate max. size. The glass added 3,6,9 % and max nominal size # 200	The creep strain decreases with increases percent of crushed glass
(AL- Saffar, 2013)	Fillers of cement lime stone powder, and glass at 4%, 6% and 8% by weight of total aggregates asphalt grade 40-50 and passing from sieve No. 200 is 92	Using the waste glass powder with 8% with optimum content.
(Bachand , 2017)	The glass size is smaller than 4.75 mm. The optimal binder content for a 10% of glass 10mm nominal maximum aggregate size	Stripping resistance decreases.
(Issa, 2016)	Crushed glass in rate 5%, 10%, and 15% by aggregate weight waste car windscreen glass with diameter less than 4.75 mm	a significant improvement in the Marshall properties of asphalt mixtures using a crushed glass modifier

(Arabani, 2011) conducted experimental works to investigate the behavior of asphalt mixture by using the various percentages of content of the additive and grade of aggregate in various temperatures. The outcomes demonstrated that the dynamic manner of glass-asphalt blend compare with conventional mixture is enhanced and a large internal friction may be the main act to increase the stiffness of glass-asphalt. Glass-asphalt in various percentages of glass doesn't indicate the same behavior for changing in temperatures. The effect of addition also demonstrates, the sensitivity of glass-asphalt mixture for changing in temperatures is lower than conventional mixture. The penetration of bitumen was 60 -70 grades and the glass content (5, 10, 15, 20) % with maximum size 4.75 mm. The percentage 3%–5% wt. of hydrated lime was used such as the anti-stripping agent in this study.

(Dalloul, 2013) used the crushed glass from bottles in HMA instead of fine aggregate and filler in binder coarse. The author conducted his experimental works by replacing the glass by 2.5-15% from both the weight of filler and fine aggregate. The results indicated that 7.5% was the optimum value for all asphalt mix characteristics.

As indicated through the literature review, the previous studies indicated that the glass was used as filler, fine and coarse aggregate with percent not more than 25%. Therefore, this study has focused on using different percentages from 0% to 100% of waste glass and comparing the results to benefit from it in the future to determine the best use of waste glass in asphalt mixture.

2. Used materials

The aggregate, filler and bitumen were obtained from an asphalt plant for Hammurabi company project highway–R6 in Diwanayah city located in southeast of Iraq. The physical characteristics of aggregate in both types coarse and fine that utilized in this study are exhibited in Table 2 and 3. The combined gradations of aggregates were chosen to approximately meet the middle job mix limits of the gradation which is specified by the (SCRB/R9) for dense graded paving mixtures of base coarse.

Table 2 Coarse aggregate physical properties and specifications

No.	Test Description	Test Method	Result			Specification Requirements
			37.5-19 mm	19-12.5 mm	12.5-4.75 mm	
1	Los Angeles Abrasion, %	AASHTO -T96	15.6	16.5	16.3	<40
2	Soundness, %	AASHTO- T104	3.102	2.119	4.63	<12
3	Specific Gravity (Bulk)	AASHTO -T85	2.610	2.612	2.622	-
4	Particle Shape, Flakiness, %	AASHTO-M323, ASTM D4791	2.1	0.55	0.31	<10
5	Water Absorption, %	ASTM C 127	1.09	0.97	1.23	<2
6	Clay lumps & Friable Particles	AASHTO T -112	0.58	0.24	0.221	<2

Table 3 Fine aggregate physical properties and specifications

No.	Test Description	Test Method	Result	Specification Requirements
1	Liquid Limit of sand Plastic Index of sand	AASHTO –T89 AASHTO –T90	Non Non	- <
2	Soundness, %	AASHTO- T104	-	<12
3	Specific Gravity (Bulk)	AASHTO -T85	2.576	-
4	Water Absorption, %	ASTM C 127	1.64	<2
5	Clay lumps & Friable Particles	AASHTO T -112	1.8	<2
6	Sand Equivalent	AASHTO T -176	51	>45

3. The asphalt required tests

Several tests have been conducted in this study. These tests were shown in Table 4 and 5:

Table 4 Physical properties of used asphalt

Test	Unit	Specification	Result	Specification Limits
Penetration at 25	1/10 mm	ASTM D5	48	40-50
Ductility at 25	cm	ASTM D113	150	100 Min.
Softening Point	°C	ASTM D36	48	-
Flash Point	°C	ASTM D92	+232	232 Min.
Solubility	%	ASTM D2042	99.4	Min. 99
Specific Gravity at 25	g/cm ³	ASTM D70	1.029	-
Retained of original	Penetration	%	ASTM D5	>55
	Ductility	cm	ASTM D113	>25

Table 5 Kinematic viscosity test results of used asphalt

Temperature °C	130	150	170
Kinematic Viscosity, centistoke	720	260	120

4. The used waste glass

The waste broken glass used in the study was factitious crushed into required particles. The first step is to clean the waste glass, crushing it manually in the next step to achieve the needed grade. Figure 1 and 2 show the gradation curve of the broken glass particles where glass in the next step crushed mechanically and sieved to get the required gradation. From other hand, Los Angeles Abrasion test and soundness test are achieved on the waste glass as shown in Table 6 and Figure 3 for glass sample for making sure that

the waste glass meets with specified requirements. The results show the value of Los Angeles of the broken glass is higher than the obtained value for the aggregate. It is worth mentioning that the waste glass has been obtained from glass shops, Table 7 shows the specific gravity of glass used in this study.



Figure 1 Size of crushed waste glass

Table 6 Properties of broken glass particles

Los Angeles Abrasion %	22
Soundness %	3.877

Table 7 Specific gravity for crushed waste glass.

Size of Glass Particles	Specific Gravity (AASHTO-T85)
(12.5 – 4.75) mm	2.497
(4.75 – 0.075) mm	2.500
(0.6 – 0.075) mm	2.497

Depending on Figure 2, the curve of crushed glass is similar to dense- graded curve in types of aggregate gradations curve, subsequently the crushed glass is used in this research having the same properties of dense- graded aggregate.

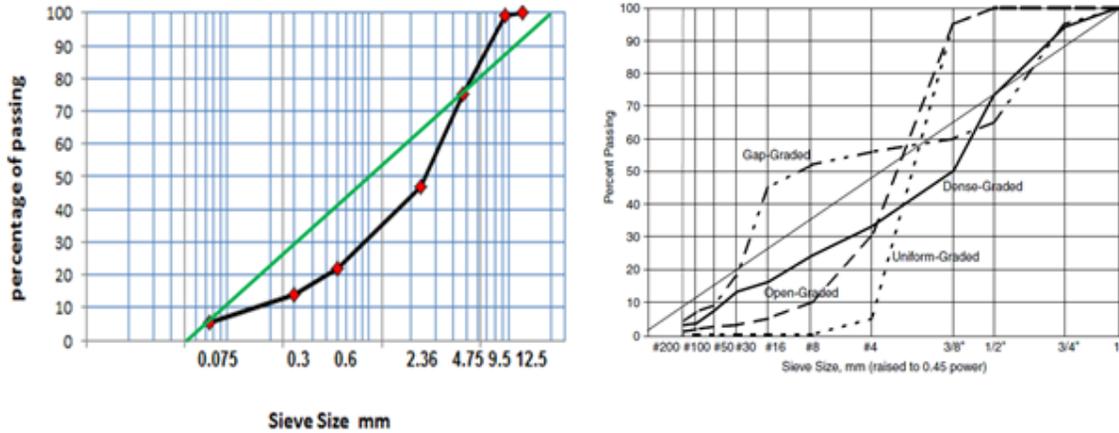


Figure 2 Gradation of broken glass particles curve & types of aggregate gradations curve



Figure 3 Los Angeles abrasion for glass sample.

5. Marshall Mix Design

Marshall Mix Design procedure has been employed to extract OAC and assess the stability for laboratory mixtures and other properties of asphalt mixture. An aggregate weighing about 1200gm and the 40/50 grade asphalt were heated to a temperature of 130°C and 180°C. Also, glass waste with different percent of replacement from 0 % to 100% of (filler, fine aggregate and coarse aggregate) weights have used. Then, these ingredients were mixed at a temperature of 158°C and 164°C depended on results of kinematic viscosity. The percent by weight of asphalt content for all mixes was taken with respect to the total weight of the mixture. The mixture was then placed in the preheated mold and compacted using 75 blows on either side of the specimen. After compaction, the specimen was allowed to cool for 24 hours and removed from the mold by means of an extrusion jack. In accordance with the Marshall procedure, each compacted test specimen was subjected to determination of unit weight, void analysis, stability and flow tests. Then, plots were made to determine values of each respective specimen prepared using different glass waste replacement rate.

5.1 Optimum Asphalt Content (OAC)

Through pervious information, the OAC is determined using Marshall mix design method. The percentages 3, 3.5,4, 4.5 and 5.0 of asphalt cement were used to prepare 15 specimens divided into three specimens for every percentage and then the perfect value of asphalt will use in the sequent steps.

The procedure for determining the OAC for a particular mixture under evaluation was adopted from the publication by the Asphalt Institute (Arabani, 2010) where both the American Society for Testing and Materials given by ASTM D6927 and American Association of State Highway and Transportation Officials given by AASHTO R-12 standardized it. Accordingly, the OAC can be computed from the mean values of asphalt which matching to the variables that explains in Eq. 1.

$$OAC(\%) = \frac{Ac \text{ for maximum stability} + AC \text{ maximum density} + AC \text{ median percent of air voids}}{3} \dots \text{Eq.1}$$

5.2 Moisture Susceptibility of Mixtures

The performance of HMA in the presence of water is a complex issue where it depends on various variables. Among the various types of quantitative tests, the Marshal Immersion test, whose conditioning process is similar to the same conditions test standardized in AASHTO T165-97 and ASTM D1075-94, is used for evaluating all the Marshall specimens prepared using different glass waste amount. The Marshall Immersion test uses the compressive strength done as per AASHTO T167-97 as a strength parameter (Petrarca, 1988).

Four groups (without glass added, as filler, as fine aggregate and as coarse aggregate) of six compacted cylindrical specimens 101.6 by 101.6-mm (4 by 4-in.) are used in this test for 10% glass waste content. Three specimens of each group are submerging inside a water bath for period 24 hours at 60C° and 2 hours at 25 C° and other is maintained dry in air bath for 4 hours at 25°C where this is adopted in this study. The retained compressive strength can be explained like a proportion for the ratio of conditioned compressive strength to controlled compressive strength.

$$\text{Index of Retained Strength \%} = \frac{S1}{S2} \dots \text{Eq. 2.}$$

Where:

- S1 = compressive strength of immersed specimens
- S2 = compressive strength of dry specimens

6. Indirect Tensile Strength of Bitumen Mixture

The dimensions of steel strip loading are (13 * 63) mm which used in 101 mm diameter specimens to produce a constant loading that will provide an approximately uniform stress distribution. ASTM D 6931 which used to submit indirect tensile strength of bitumen mixture. The rate of loading 51mm/minute is applied. Compressive failure

gets after tensile failure for any specimen. The compressive load indirectly produces in specimen a tensile loading in the level plane. By recording the maximum load and dividing it by proper geometrical factors to get IDT from formula:

$$\text{Indirect Tensile Strength} = \frac{2000P}{\pi t d} \dots\dots\dots \text{Eq. 3.}$$

Where:

P = maximum load, N

t = specimen height immediately before test, mm

D = specimen diameter, mm

7. The methodology

The methodology of this work could be mainly summarized as preparing the reference mix which represents the normal case. The effect of using crushed glass with specific characteristics will be investigated through using this waste glass instead of coarse, fine aggregates and filler at specific percentages. Then, comparing these results with the reference mix to find out the advantages and disadvantages of using such material. Marshall method has been adopted in this study due to availability than other methods.

8. Experimental work

8.1. Preparing Reference Mix

Five percentages of asphalt starting from 3 to 5 as indicated in Figure 4. The obtained results are within the acceptable limits reported by the (SORB, 2003 & 1983), notice Table 8.

Table 8 The properties of reference mixture.

Test	Results	Specifications
Marshall Stability (ASTM D 1559), (KN)	11.0	Min. 5
Marshall Flow, (0.25 mm)	2.8	2-4
Bulk density, (Gmb) , (gm/cm ³)	2.378	-
Air Voids in Total Mix, (VTM), (VA), %	3.4	3-6
Voids in Mineral Agg. ,(VMA), %	12.5	Min.12
Voids Filled with Asphalt, (VFA), %	73	60 - 80
Optimum Asphalt Content, (OAC) %	3.8	3 - 5.5

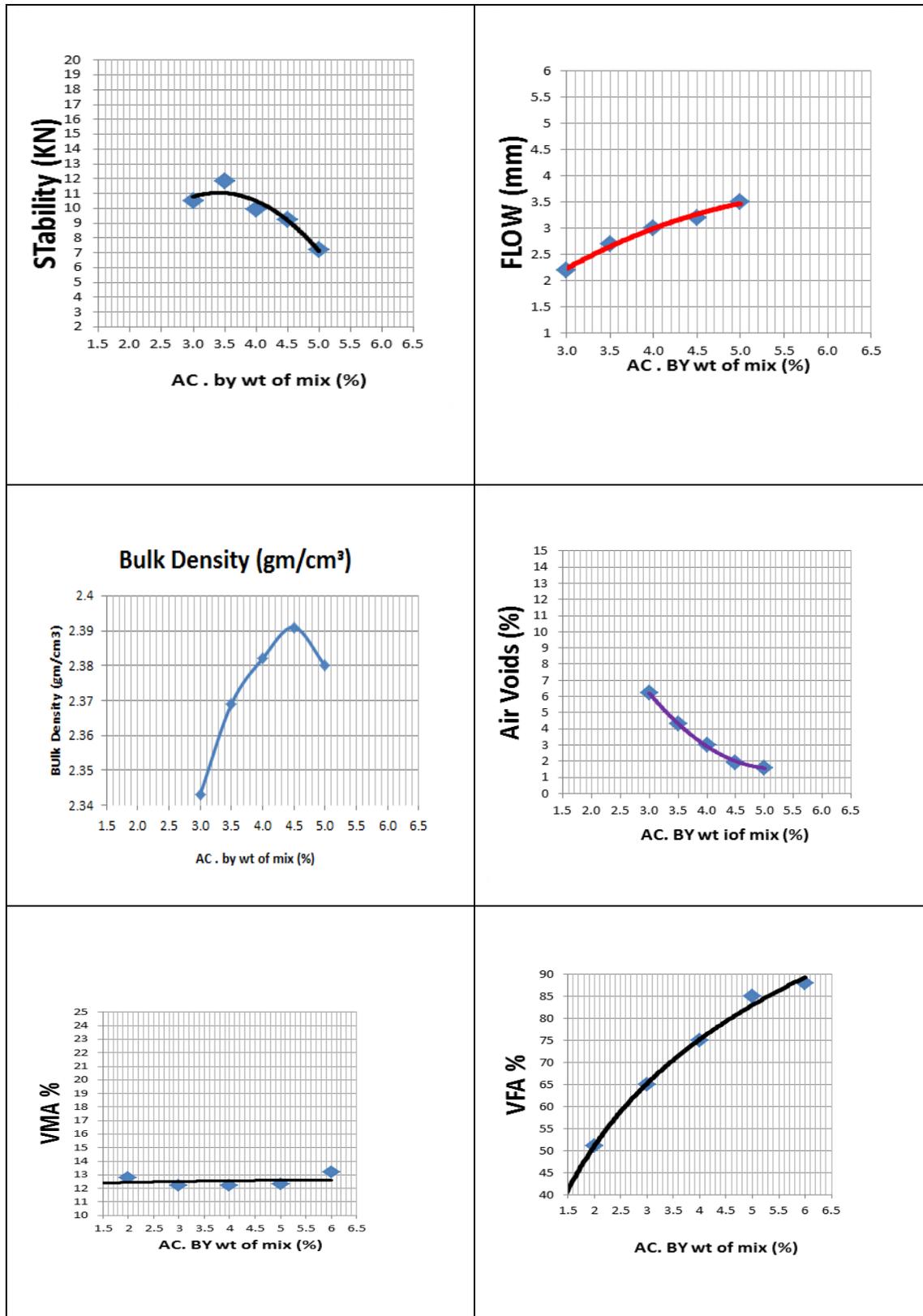


Figure 4 The relationships between binder content and the properties of mixtures.

8.2. Effect of glass on Marshall Characteristics

The characteristics of crushed glass were investigated. After preparing the reference mix with its characteristics determining in Table 8, the next step is to use the crushed glass with mix having the same materials characteristics.

8.2.1. Using crushed glass as filler

The crushed glass has been used as filler in the mix with different percentages starting from 0% to 100% from weight of filler in the mixture as indicated in Figure 5. This figure demonstrates clearly how different characteristics changing with different percentage of crushed glass and how these percentages significantly effect on the mix behaviors.

Figure 5 demonstrates that the stability increases slightly as the percentage of glass content increases up to 10%. Then, the stability decreases sharply by about 49% as the value of glass increases from 0% to 100% as indicated in Figure 5. This behavior may affect mainly on the durability and performance of asphalt pavement. Similarly, the same behavior is noticed for the bulk density. As the content of glass increases by 10% of the total filler, the bulk density decreases significantly from 2.378 to 2.370 and then this value increases to 2.376 at 20% of glass content even the percentage is higher however the density increases. After that, there is a constant behavior which could be summarized as the percentage of glass increases, the density value decreases as indicated in Figure 5. One could attribute this behavior to increase the glass content in the mixture lead to decrease the density value in different percentages.

On the other hand, the flow decreases with this increment of glass as shown in Figure 5. This figure also indicates how the using glass affecting on the air voids in the mix by increasing its value in the mix due to decrease the surface area of powder crushed glass compare with the filler using in reference mixture. On other side, the particle size for powder crushed glass is greater than the filler; therefore, the air voids increase gradually with increase the glass content.

Another effect for using the glass has been investigated which is the influence of glass on the VFA (voids filled with asphalt) as indicated in Figure 5. The figure shows how the VFA decreases slightly with increasing in percentage of crushed glass in the mix. Finally, the effect of VMA is also has been determined with different percentages of glass as demonstrated in Figure 5. But the important thing, VMA is meeting with limits Specification of SORB/R9. Generally, VMA increases with the increase in the proportion of glass comparing with reference mixture.

8.2.2.Using Crushed Glass as Fine Aggregate

Having used the glass as filler, the next step is to use it as fine aggregate with different percentage of crushed plate glass as indicated in Figure 6. When viewed on graphical form in Figure 6, it is seen that flow results generally declined as the percentage

of glass was increased. Max. decreasing in flow was 25% which corresponds to 100% of replacement.

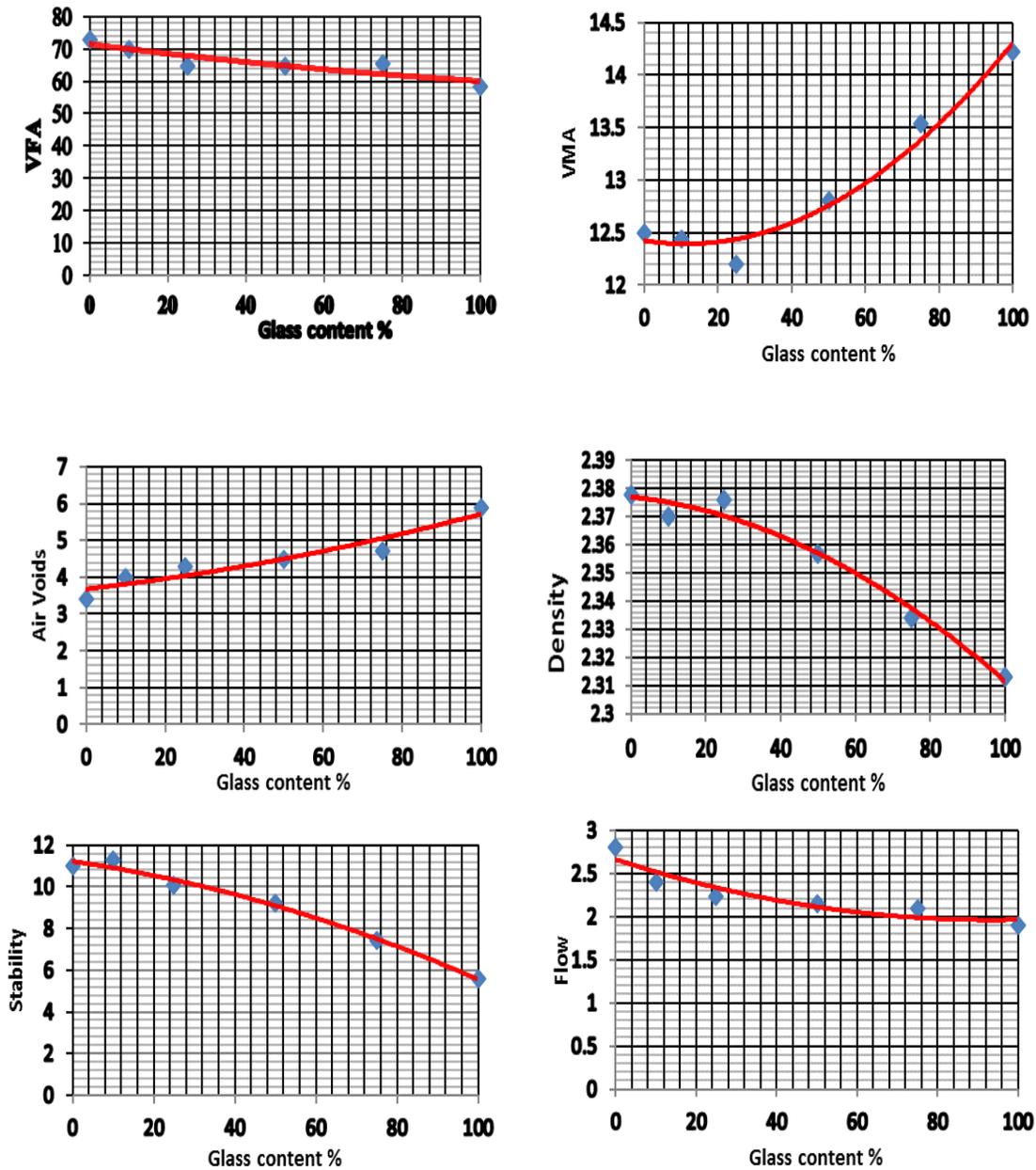


Figure 5 The relationship between the glass as filler replacement content and other asphalt characteristics.

In Figure 6, there are slight increase in density approximately (0.08% - 0.55 %) until 50% replacement crushed glass from sand. Then density decreases around 1.4% from the bulk density in reference mixture. Whereas, the Marshall stability decreases where it reduces in various rates and the max decreasing about 16.4 % in 100% glass proportion from fine aggregate. Probably the reason is the reduction in the surface area

due to replace the portion of sand by glass powder. Consequently, it reduces the adsorbing bitumen and effects on the stability.

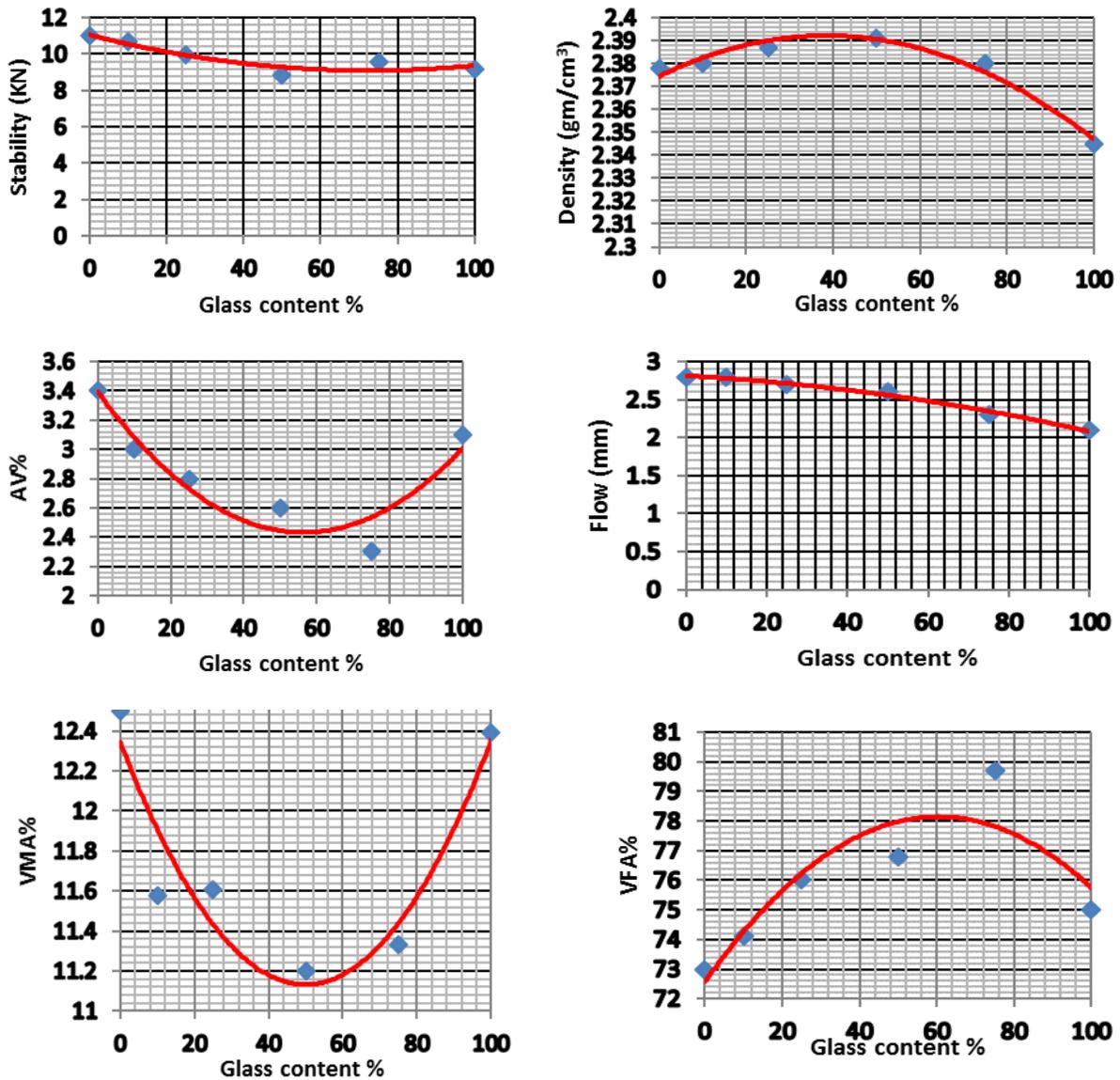


Figure 6 The effect of glass as fine aggregate replacement on different asphalt characteristics.

When viewed on graphical form in Figure 6, it is seen that flow results generally declined as the percentage of glass was increased. Max decreasing in flow is 25% in percentage 100% of replacement.

The parameters VA and VMA are generally dropping in different portion as indicated in Figure 6. The VFA characteristics increase when the glass percentage increases. This is normal behavior because the VFA reverse ratio with VA.

8.2.3. Using Crushed Glass as Coarse Aggregate

In the last stage of replacement, waste glass is crushed and sieved for obtaining samples passing 12.5mm sieve and retaining 4.75mm sieve which it is using as coarse aggregate by different percentage beside to other sizes 37.5-19 and 19-12.5 mm is constant weight . Figure 7 shows the results of the modified asphalt with crushed glass instead of coarse aggregate.

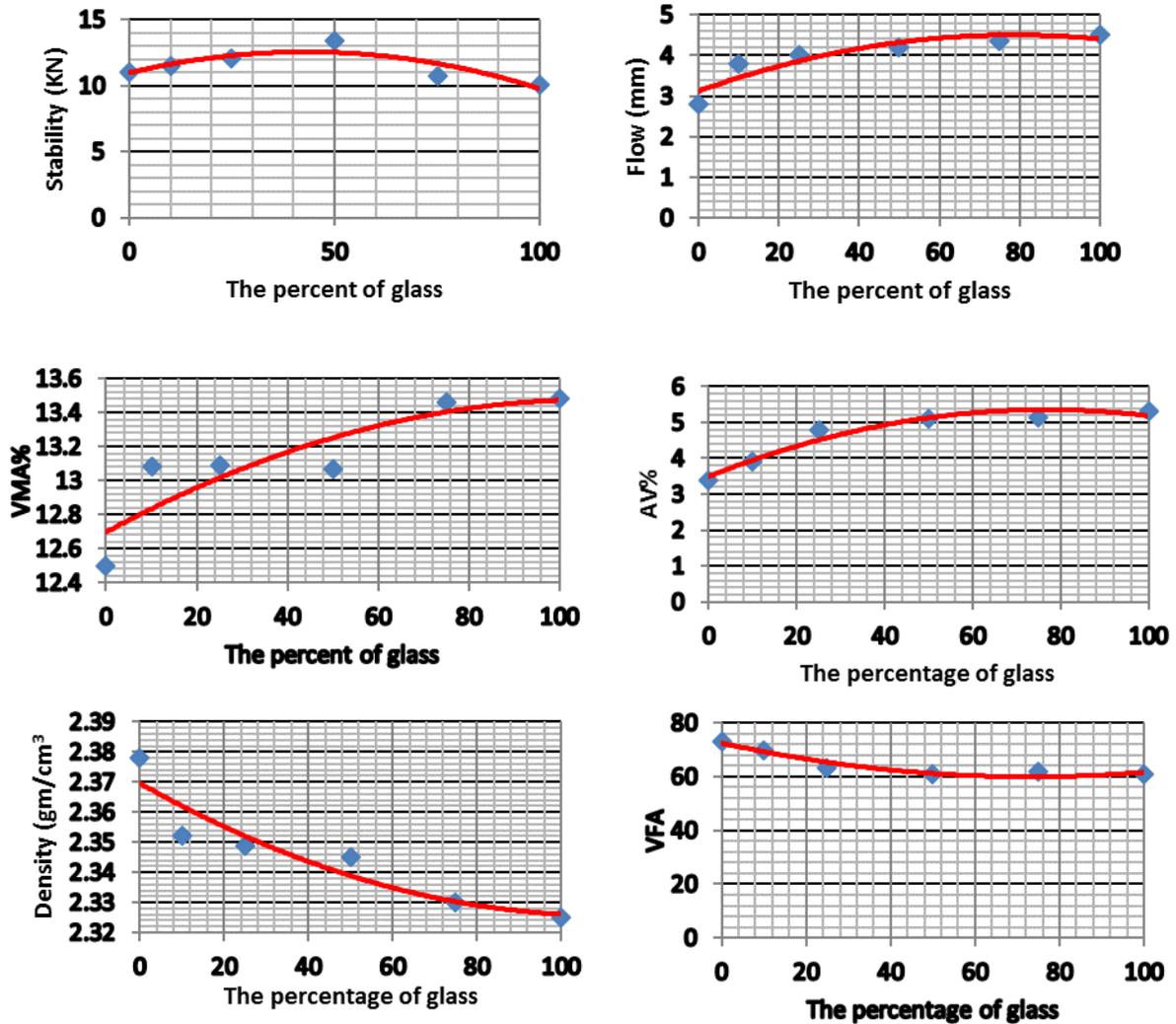


Figure 7 The effect glass as coarse aggregate replacement of different asphalt characteristics.

Regarding the stability in Figure 7, it is clear that stability in 10%, 25% and 50% (waste crushed glass replacement from coarse aggregate) increases approximately 4.6%, 10% and 22% respectively. Then the curve begins dropping in 75% and 100% (waste crushed glass replacement from coarse aggregate). This can explain behavior that crushed glass in current case has more angler edges compare with virgin coarse aggregate causing

more interlock between aggregate and other components of mixture, but gradually crushed glass is increasing and the coarse aggregate size (12.5- 4.75) mm is reducing. So, the crushing glass is carrying the applied load and it is less capability than coarse aggregate for bearing this load where the Los Angeles abrasion for coarse aggregate greater than crushed glass.

Referring to Figure 7, flow increases within the limits of specification (2-4) mm till 50% from addition, otherwise, the flow unsatisfactory in percent 75% and 100% from replacement. Perhaps, the soft texture of glass is leading to lack Cohesion in asphalt mixture. As the waste crushed glass increases more than optimal percentage, sliding waste glass particles gradually causes to increase flow on asphalt samples.

The volumetric properties VMA, VA and VFA in this case can summary that VA and VMA increase by increasing the percentage of crushed glass while VFA decreases also, as in Figure 7. Density for mixtures as shown in Figure 7. This refers to decrease Gmb when increase the portion of crushed glass which may be dropping the specific gravity for glass comparison with coarse aggregate.

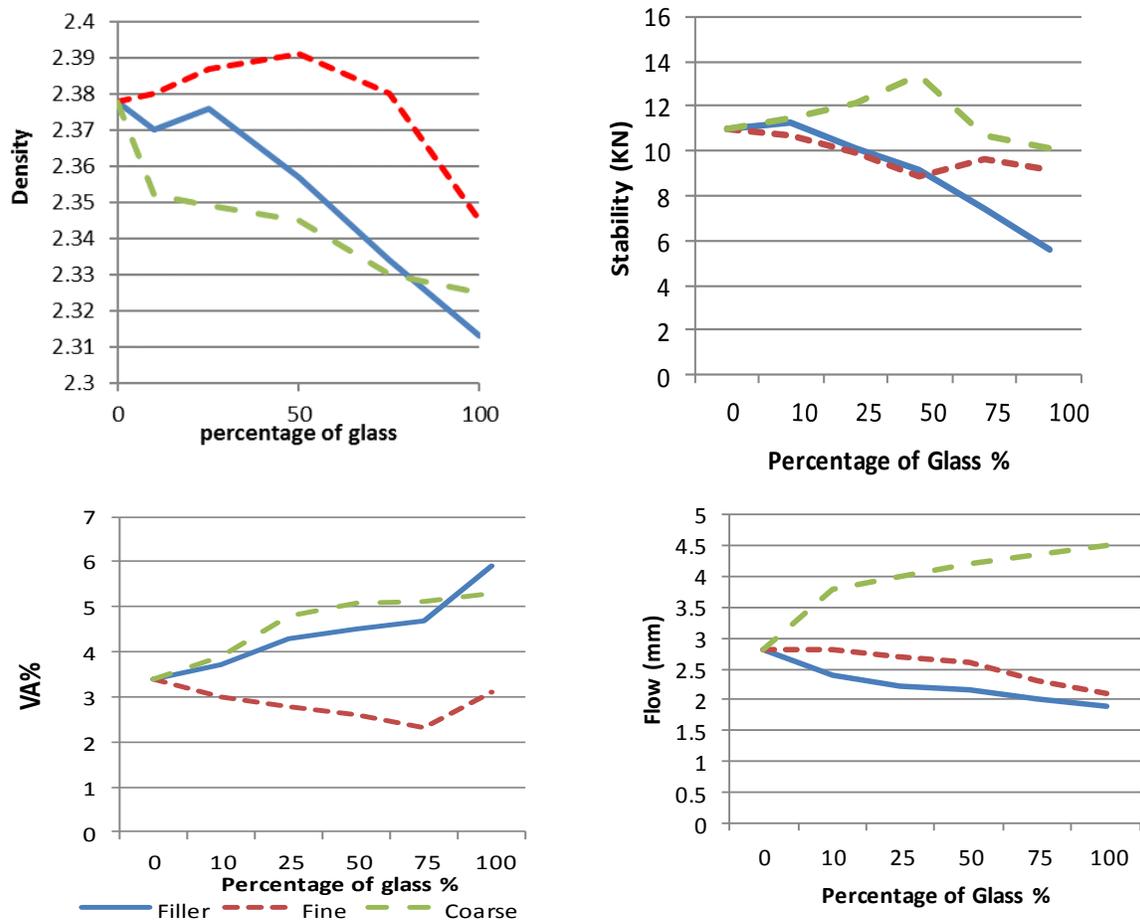


Figure 8 Stability, flow, Density and VA with different percentage of glass as filler, fine and coarse aggregates.

In light of the above results obtained from reference mix and other mixes with different percentage of glass as filler, fine and coarse, three factors are stability, flow, density and VA as in Figures 8. The results indicate that 10% is the best value of glass for each case (i.e. filler, fine and coarse aggregates). For example, the value of stability for filler is 11.3 KN and 11.5KN for coarse aggregate whereas 10.7 KN for fine aggregate. This value could be the optimum value comparing with other characteristic such as flow; however, even the stability is 12.1 KN at 25% of glass as coarse aggregate but flow exceeds the specification which is 4mm. therefore the 10% is the optimum value of glass that may be added for each case. Accordingly, up to these tests, the using glass instead of coarse aggregate is the best case at which the stability is the highest value among all cases. Therefore, other tests will be conducted on the 10% of glass on all cases.

8.3. Index of Retained Strength

By using" Standard Test Method for Compressive Strength of Bituminous Mixtures" ASTM D 1074 to measure the loss of strength resulting from the effect of water on compacted bituminous mixtures (Immersion Compression Test).

Pervious results show that the percent 10% of additional waste glass satisfy the specified specification and beside the almost specifications recommends that the replacement portion of glass don't exceed 10%. The data indicate that the index of retained strength increase with increasing glass replacement ratio. According Table 9, the rate of increasing in the index of retained strength is improving significantly in the item 3 and 4. Generally, the processes of addition the waste glass to the asphalt mixture enhances its strength for damaging by water. Probably, the chemical composition glass provides mixtures with glass to increase strength for damaging where glass has high portion of SiO₂ reach more than 70%.

Additionally, asphalt containing glass, its surface tends for drying quickly rather than conventional asphalt surface beyond the rain. Probably, the low absorption percentage of glass particles is the reason. Where the period of retaining water on the surface is lesser than conventional and the effect of water damaging is lesser also.

Figure 9 Index of Retained Strength of asphalt mixes with and without crushed waste glass

Item	Condition	Dry Strength of Specimens MPa	Wet Strength of Specimens MPa	Index of Retained Strength %
1	Reference Mixture	32.3	23.5	72.8
2	Adding 10% of Glass as Filler	35.2	26.3	74.7
3	Adding 10% of Glass as Fine agg.	38.7	35.4	91.5
4	Adding 10% of Glass as Coarse agg.	39.4	36.43	92.5

8.4. Indirect Tensile Strength (ITS) Test

For this study, the ITS of the crushed glass determined using the AASHTO T 283 (2006) protocol, (unconditioned sample) kept at a temperature of 25°C for a period of 2 hours without soaking. Nine replicate samples were tested for the glass asphalt mix by 10% percentage of waste glass to compare with three sample of the reference mix without glass. In comparison, the average ITS value for the glass mix was increasing 9%, 17% compare with reference mixture as filler and coarse respectively ,while ITS decreases about 9% in fine case replacement . However, ITS value is increasing in case waste glass as filler and coarse aggregate but it slight decreases for using glass as portion of fine aggregate. In the case of increasing , the increase of interlock and surface roughness may be the reason.

Figure 9 represents the influence of using waste glass on ITS test for glass-asphalt compare with ITS test for reference mix. The use of glass as coarse aggregate has the highest effect on increasing the ITS. This means that the higher tensile strength leads to higher cracking resistance and higher strain prior to failure of pavement.

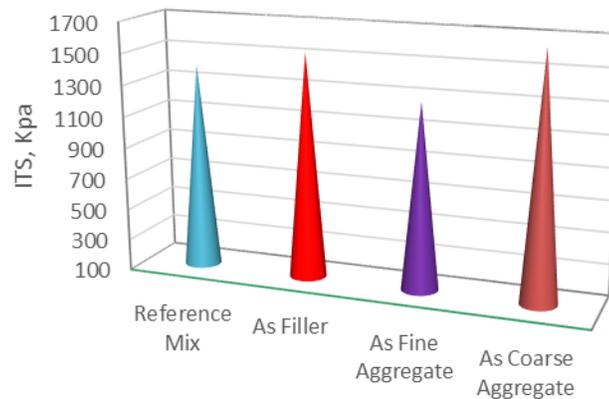


Figure 9 The effect of waste glass on ITS.

9. Conclusions and recommendations

This study has come up with the following results:

1. The percentage less than 25% of replacement crushed waste glass is safely and achieve the limitations of specifications, but the percent 10% is advised by most previous studies from side and the present study also proofs that.
2. The results of Marshall stability, flow, bulk density, VMA, VFA and VA of glasphalt are consistent with the specifications range at the different percentages of glass contents except at 100% for the flow and VFA values, where it's below the minimum specifications limit when using with crushed waste glass as filler and the flow at percent 50%, 75%, 100% in case utilizing as coarse aggregate is higher than up of the limit.

3. In accordance with the results of VA and VMA, the air voids increase when addition of crushed waste glass works as a part of filler or coarse aggregate and it decreases with fine aggregate, but VMA is comparable to the limit of specification in all cases.
4. The performances such as strength retained index, in percent 10% of glass is generally better than reference mixture. It is more likely that the glass asphalt mix can provide resistance to moisture damage.
5. Regarding the indirect tensile strength, the process of using crushed waste glass enhance it when using the glass as 10% from filler or coarse aggregate and it decrease slightly within replacement 10% of glass as fine aggregate.
6. The use of glass affects on Marshall compacted specimens properties; thus, the optimum asphalt content must with the target percent of glass to be used.

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