Laboratory Study on Using Waste Glass as Filler in Bituminous Mixes

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Abstract - *The use of waste materials in road construction can reduce the difficulties in disposal of wastes. In the current study, the feasibility of improving the properties of Bituminous Concrete (BC) mix with waste glass as filler in place of conventional costly fillers like lime and cement was studied. BC mixes were prepared at OBC with three different fillers namely cement, lime and glass powder at three different dosages (4%, 6% and 8%). The Marshall and volumetric properties of these samples were investigated and compared. BC mixes with glass powder displayed nearly same properties as those of BC mixes with conventional fillers. Also at the optimum dosage of 6.2% glass modified BC mixes displayed higher stability, density and lower flow values as compared to normal BC mixes with quarry dust alone as filler. Thus glass powder waste from industries can be safely disposed by using as an alternative for conventional fillers to produce more stable and durable bituminous paving mixes.*

***Key Words*: BC Mix, Glass Waste, Marshall Mix Design, OBC, Optimum Dosage**

1. INTRODUCTION

Tremendous growth of world population and industries demands huge amount of natural resources and also generates large amount of waste materials. Using waste materials in road construction have great economic and environmental benefits. Energy consumption can be reduced by reuse of waste materials instead of natural materials. Also the environmental risk can be reduced by the use of waste materials instead of stockpiling them. High performance and environment friendly roads can be constructed by the use of many waste materials in bituminous paving mixes.

In this study, BC mixes were prepared at OBC with three different fillers namely cement, lime and glass powder at three different dosages (4%, 6% and 8%). The Marshall and volumetric properties of these samples were investigated and compared. BC mixes with glass powder as filler displayed higher stability, density and lower flow values as compared to normal BC mixes with quarry dust alone as filler. Also BC mixes with glass powder displayed nearly same properties as those of BC mixes with conventional fillers like lime and cement. Thus the feasibility of improving the properties of BC mix with waste glass as filler in place of conventional costly fillers like lime and cement was studied.

2. MATERIALS

Aggregates, VG-30 bitumen, glass waste, cement and lime were the materials used for preparing BC mixes of Grade 2 as per MORTH [1].

2.1 Aggregates

Aggregates were collected from a local crusher at Kalloorkad and from a construction site at Thodupuzha. Coarse aggregates of 20 mm down (Aggregate 1) and 10 mm down (Aggregate 2) and quarry dust were used. The physical properties such as the Aggregate Impact Value, Aggregate Crushing value, Water Absorption, Flakiness Index, Elongation Index and Specific Gravity were determined and are given in Table 1. The aggregates used in this investigation for BC mixes satisfied all the physical requirements specified by MORTH.

Table-1: Test Results of Aggregates

PROPERTY		RESULT
CRUSHING VALUE		35.65%
IMPACT VALUE		35%
SPECIFIC GRAVITY	Aggregate 1	1.966
	Aggregate 2	2.604
	Quarry Dust	2.670
WATER ABSORPTION	Aggregate 1	0.6%
	Aggregate 2	0%
	Quarry Dust	0%
FLAKINESS INDEX		10.2%
ELONGATION INDEX		16.45%
STRIPPING VALUE		0%

2.2 Bitumen

Tests were conducted on VG-30 bitumen collected from VJCET, Vazhakulam and the results are tabulated in Table 2.

Table-2: Test Results of Bitumen

TESTS	NORMAL BITUMEN
Softening Point (°C)	45.7
Ductility (cm)	81
Penatration	63
Specific Gravity	01

2.3 Cement

Ordinary Portland Cement (OPC) of specific gravity 2.81 bought from a shop at Muvattupuzha was used as a filler.

2.4 Glass Powder

Fine glass powder of specific gravity 2.75 was used as filler material and this glass waste was collected from a shop at Muvattupuzha.

2.5 Lime

Finely powdered lime of specific gravity 2.04 collected from a shop at Thodupuzha was used as filler.

3. METHODOLOGY

3.1 Aggregate Proportioning by Rothfutch Method

The sieve analysis of coarse aggregates 20 mm down (Aggregate 1), 10 mm down (Aggregate 2) and quarry dust was done. Aggregate mix proportioning was done using Rothfutch method. The percentage of aggregates A, B and C in total mix were obtained as given below:

Aggregate1= 7%, Aggregate2=28%, Quarry dust=65%

The mixes were then prepared in the obtained aggregate proportions.

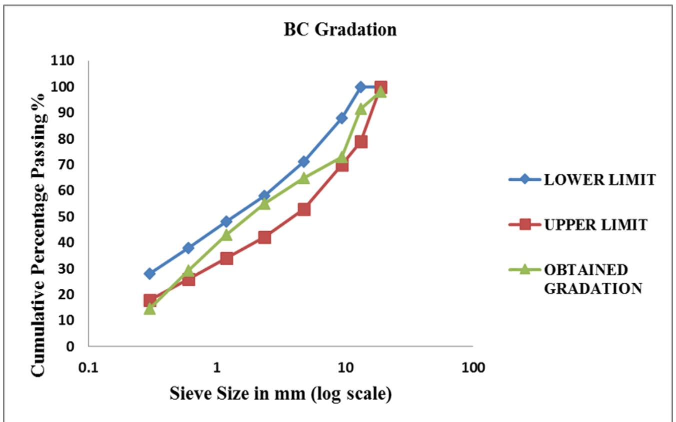

Chart -1: Aggregate Gradation

The gradation adopted was almost within the desired gradation for BC mix as specified in MORTH.

3.2 Marshall Mix Design

The aggregates were proportioned (total aggregate and quarry dust contribute to 1200gm). The aggregates were heated to a temperature of 150°C - 170°C. The bitumen was heated to 160°C, was added in required quantity i.e. 5.0, 5.5 and 6.0 percent by weight of aggregates and was thoroughly mixed at a desired temperature of 160°C. Then the mix was placed in a preheated mould of 10.16 cm diameter and 6.35cm height with a base plate. After leveling the top surface, the mix was compacted by a rammer of 4.54 kg weight and 45.7 cm height of fall with 75 blows on either side at a temperature of 150°C. The compacted specimens were removed after 24 hours using specimen extractor. For each bitumen content, 3 specimens were prepared. The diameter, mean height, weight in air, weight in water and saturated surface dry weight of the specimens were noted. The specimens to be tested are kept immersed under water in a thermostatically controlled water-bath maintained at 60˚C for 30 to 40 minutes. One specimen is taken out from the water bath and is placed in the Marshall test-head. The test head with the specimen is placed in position in the loading machine and the base-plate of the loading machine is raised until the top of the test head is in contact with the bottom of the proving ring or load cell. The deformation measuring dial gauge or flow meter is now placed in position and adjusted to read zero. The load is applied through the Marshal test setup maintaining a constant deformation rate of 51 mm per minute. The load and deformation readings are closely observed. The maximum load at failure and the corresponding deformation (or flow) readings are noted. The Marshall Stability value is calculated from the load at failure. The various volumetric properties like density, percentage of air voids (Vv), percentage of voids filled with bitumen (VFB), and percentage of voids in mineral aggregates (VMA) are determined. The results are tabulated in Table 3.

3.2.1Determination of Optimum Bitumen Content (OBC)

The optimum bitumen content (OBC) for the mix design is then found by taking the average of the following three:

1. Bitumen content corresponding to Maximum Stability
2. Bitumen content corresponding to Maximum Bulk Density
3. Bitumen content corresponding to the median of the design limits of Percent Air Voids in the total mix (4%).

Table-3: Marshall and Volumetric Properties of BC Mix

Bitumen Content (%)	Marshal Stability (KN)	Flow (mm)	Density (g/cc)	Vv (%)	VFB (%)	VMA (%)
5	8.48	1.863	2.308	5.462	66.695	16.343
5.5	9.669	2.9	2.327	4.027	75.928	16.04
6	9.363	3.55	2.315	3.862	77.356	16.836

Graphs were plotted with Marshall Stability, density and percentage air voids against bitumen content. Mixes with very high stability value and low flow value are not desirable as the pavements constructed with such mixes are likely to develop cracks due to heavy moving loads. Hence OBC was obtained by taking average of bitumen content corresponding to maximum Marshall Stability, maximum density and 4% air voids.

Chart-2 shows the variation of Marshall Stability with bitumen content where it is seen that with the increase in bitumen content, the stability value initially increases and then decreases. Maximum stability value of 9.669 kN is observed at 5.6% bitumen content.

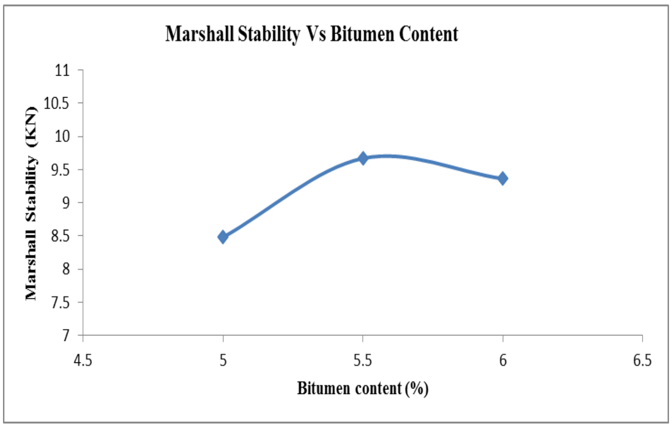

Chart-2: Marshall Stability Vs Bitumen Content

Chart-3 shows the variation of bulk density with bitumen content where it is seen that with the increase in bitumen content, bulk density increases initially and then decreases. Maximum density of 2.327 g/cc is observed at 5.5% bitumen content.

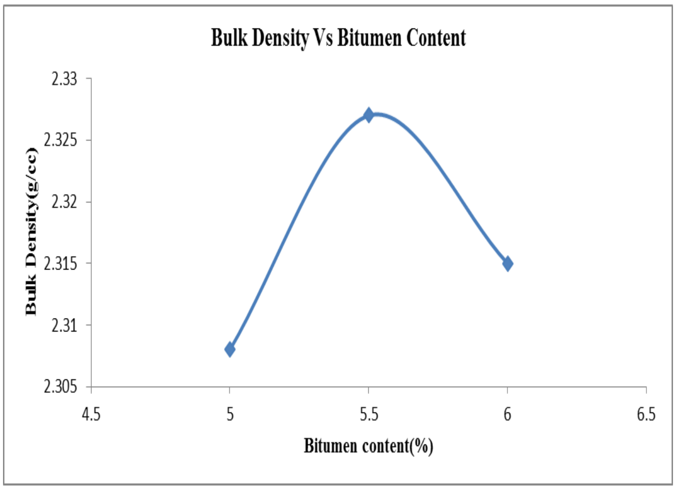

Chart-3: Bulk density Vs Bitumen Content

Chart 4 shows the variation of air voids with variation in percentage of bitumen content. The bitumen content corresponding to 4% air voids is 5.5%

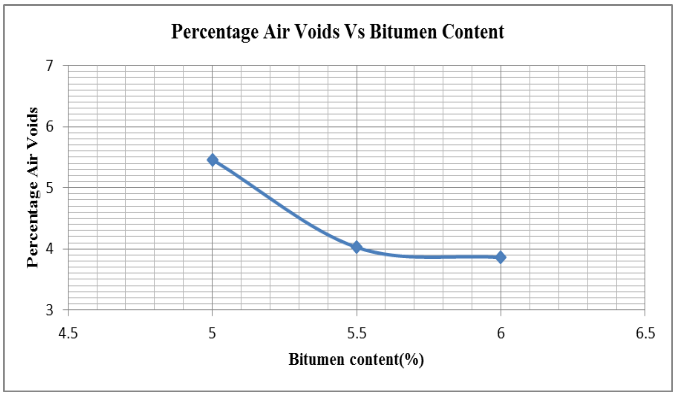

Chart-4: Percentage Air Void Vs Bitumen Content

Table 4: Determination of Optimum Bitumen Content

	Bitumen Content (%)
Max Stability	**5.6**
Max Density	**5.5**
4% Air voids	**5.5**
OBC	**5.53**

The OBC was found to be 5.5%.

3.3 Comparison of Marshall and Volumetric Properties of BC Mixes with Different Fillers

The BC samples were prepared at OBC with different fillers namely lime, cement and glass powder at different dosages of 4%, 6% and 8% by weight of aggregates. The volumetric and Marshall properties of these samples were determined and compared. The comparisons are shown in **chart 5, chart 6 and chart 7.**

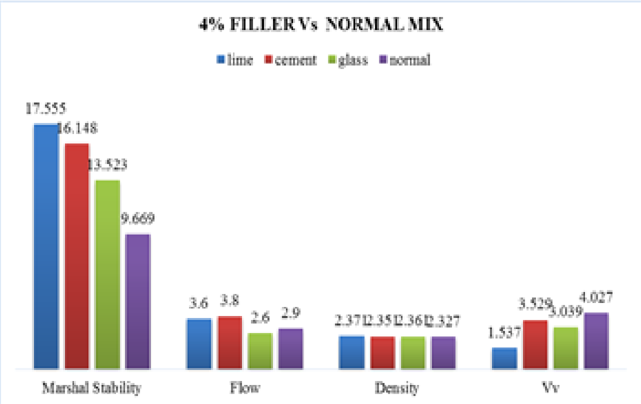

Chart -5: Comparison of Marshall and Volumetric Properties - 4% Filler

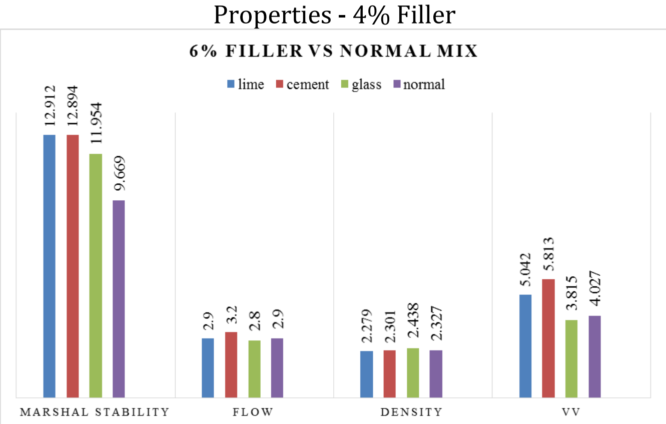

Chart-6: Comparison of Marshall and Volumetric Properties - 6% Filler

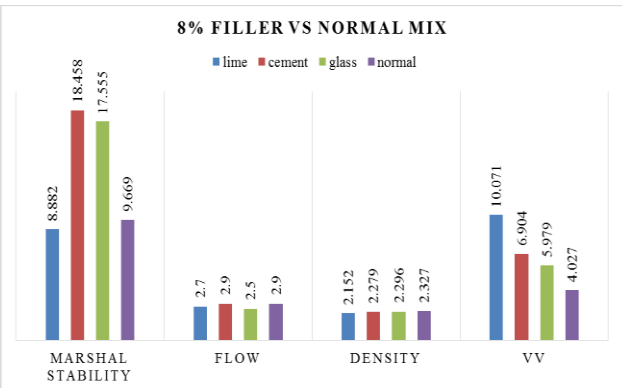

Chart-7: Comparison of Marshall and Volumetric Properties - 8% Filler

BC mixes with fillers (lime, cement & glass powder) gave relatively higher stability values compared to normal BC mix. Though the stability values of glass modified BC mixes are not higher than that of BC mixes with conventional fillers like lime and cement, still glass modified BC mixes have relatively higher stability values than normal BC mixes. Also glass modified BC mixes has slightly lower flow values compared to normal BC mixes. Hence glass powder can be used as an alternative for conventional fillers

3.4 Determination of Optimum Dosage of Glass Powder

The comparison of Marshall and volumetric properties of BC mixes with different dosages (4%, 6%, 8%) of glass powder is shown in Table 5

The optimum dosage of glass powder was determined by considering the requirements of BC mix as per MORTH**.** The three dosages of glass powder, gave satisfactory Marshal stability and flow values. It should be emphasized that the design range of air voids (3-5%) is a level desired after several years of traffic. The mixes that ultimately consolidate to less than 3% can be expected to rut and shove, similarly problems like brittleness, premature cracking, ravelling, stripping etc can occur if the final air void content is above 5%. The design % of air voids (4%) was obtained at a dosage of 6.2 %. Hence 6.2% was adopted as the optimum dosage of glass powder.

Table- 5: Marshall and Volumetric Properties of BC Mix with Glass Powder

%OF GLASS POWDER	MARSHALL STABILITY (KN)	FLOW (mm)	DENSITY (g/cc)	V_V (%)	VFB (%)
4	13.523	2.6	2.361	2.84	80.523
6	11.954	2.8	2.438	3.815	75.013
8	17.555	2.5	2.296	5.979	64.819

3.5 Comparison of Properties of Normal Mix and Glass Modified Mix

Chart-8 shows the comparison of glass modified mix (6.2%) with normal mix. On comparing glass modified mix with normal mix, Marshall Stability was found to increase by 44%.This shows that the addition of glass powder makes the bituminous mix more stable and stiff. Also the use of glass powder makes the bituminous mix more resistant to deformations. This is evident from the lower flow values (flow value decreased by 3.79%). The percentage of air voids

(V_v) of glass modified mix was found to be slightly lower than that of normal mix. This in turn contributes to the slightly higher density of glass modified mix.

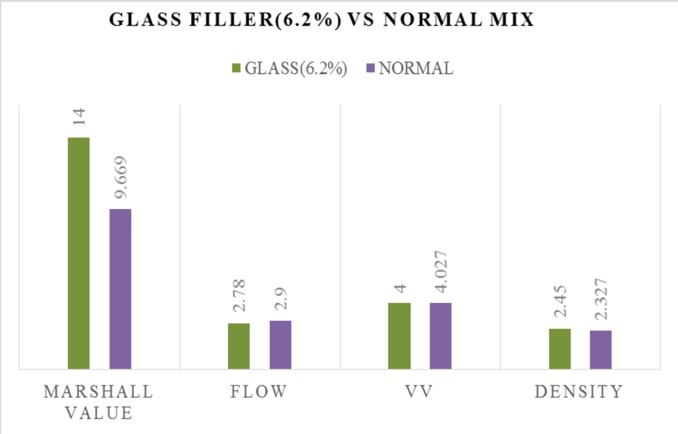

Chart-8: Comparison of Properties of Normal Mix and Glass Modified Mix

3. CONCLUSIONS

The use of waste materials in road construction can reduce the difficulties in disposal of wastes. In the current study, the feasibility of improving the properties of BC mix with waste glass as filler in place of conventional costly fillers like lime and cement was studied. BC mixes were prepared at OBC (5.5%) with three different fillers namely cement, lime and glass powder at three different dosages (4%, 6% and 8%). The Marshall and volumetric properties of these samples were investigated and compared. Bituminous mixes with glass powder as filler gave nearly same Marshall and volumetric properties as those of conventional fillers such as lime and cement. Also at the optimum dosage of 6.2%, glass modified bituminous mix displayed a higher stability value of about 44% and a lower flow value of about 3.79% than that of normal mixes with quarry dust alone. The addition of glass powder was thus found to make the bituminous mix more stable and resistant to deformations. Also, the slightly lower percentage of air voids (Vv) of glass modified mix contributed to the slightly higher density of glass modified mix. Thus considering the above mentioned benefits, glass powder waste from industries can be used an alternative for conventional fillers to produce more stable and durable bituminous paving mixes. Also, the use of waste glass in road construction provides a safe and efficient means to dispose glass waste.

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