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Introducing Glass Powder and Brick Dust as Mineral Filler to Evaluate different properties of Bituminous specimen by Marshall Method of Mix Design

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Abstract

Among different flexible pavement layers surface course is the most important layer where bituminous concrete or asphaltic concrete is utilized. To ensure long term performance, it is essential to design the bituminous mixture properly to fulfill the standard requisite of stability and durability. It is known that bituminous mixture is composed of coarse aggregate, fine aggregate, mineral filler and bitumen as coating material. Mineral filler performs an important role by filling voids in paving mixture and improving cohesion property of bituminous binders. Marshall stability depends on the proportion of mineral fillers. In Bangladesh, use of common filler materials like limestone, cement, stone dust is reducing day by day as the cost increases. Here, waste materials like glass powder and brick dust is available which is cheaper than the usual filler materials. Applying Marshall method of mix design, this study compares different properties of bituminous paving mix where waste products like glass powder and brick dust is used rather than cement or stone dust. Among both of the fillers based on stability brick dust performed better stability than glass powdered where the obtained stability from 5% brick dust was 14.09 KN, 17.42 KN, 7.82 KN for bitumen proportion of 5%,6%, 7% respectively and obtained stability from 5% glass powder was 13.24 KN, 10.96 KN, 10.20 KN for bitumen proportion of 5%,6%, 7% respectively which fulfills the standard criteria of Marshall mix design. This study encourages the possible application of waste fillers like glass powder and brick dust in bituminous mix design instead of conventional cement or stone dust.

Keywords: *Glass Powder; Brick Dust; Filler; Bituminous specimen; Marshall Method of Mix Design*.

1 Introduction

In Construction, the roads in which bitumen is used as a binder material is defined as bituminous pavements. This road composed closely acquainted mixture of aggregate, mineral filler and bitumen. Mineral filler imparts an important role to enhance the strength, quality and durability of bituminous road. The dispersion of filler materials in asphalt lead asphaltic cement composition to stiffen more. As a mineral filler there are various materials such as cement, lime, granite powder, fine sand, stone sand which are used normally. Brick dust, glass powder finer that 0.075mm sieve size may be used as a filler material. Introducing waste products in pavement construction have been the main goal of several researches where conventional filler materials were replaced by different waste fillers like, Phosphate waste fillers (Katamine, 2000), Bag house fines (Lin et al., 2006), recycled waste lime (Sung Do et al., 2008), Jordanian oil shale fly ash (Asi & Assa'ad, 2005), Municipal solid waste incineration ash (Xue et al., 2009) and waste ceramic materials (Huang et al., 2009). These researches have disclosed that these type of filler materials have provided improved results and could be used in asphalt mixture. Hence, this study focuses on the use of waste products like brick dust and glass powder to evaluate different parameters of bituminous mixes by using Marshall method of mix design.

Optimum proportion of bitumen and filler material is always necessary. Providing lower percentage bitumen content and higher percentage of filler material proportion may make the sample stiff and dry which reduce the workability of the sample, whereas providing higher proportion of bitumen and lower proportion of filler material is also not acceptable as it leads to bleeding action of bitumen. Generally filler material decrease the movement of particles inside the mix and also act as an active material to improve the mastic properties (Anderson, 1987). This study emphasis on the proper aggregate-bitumen mix with lower amount of void. Lower void provides less space for bitumen absorption. Lower bitumen content and results in compaction difficulties. Strength of the specimen will also reduce if void is lower as insufficient bitumen will not be able to coat all aggregates fully. Moreover, higher void may lead to lower stability as less dense bitumen replace aggregate resulting in less aggregate interlocking. (Géber & Gömze, 2010). Amount of filler material in a mix design also influence the mixture performance as it involves large surface area and depending on the type of filler material the absorption rate of bitumen may vary as filler material may absorb bitumen or not. Th workability also depends on the type of filler materials to some extent. (Zulkati et al., 2012)(Taylor, 2007)(Bahia, 2011). This study focuses on the use of waste filler materials in place of conventional filler materials to minimize the cost of construction works. Different properties were evaluated based on applying Marshall method of mix design. The possibility of using waste filler material have also been studied in this study.

2 Materials

A Flexible pavement consists of a surface layer of bitumen-bound aggregate (asphalt concrete) in which bitumen mixture is composed of aggregate and bitumen. And the aggregates are generally divided into coarse, fine and filler fractions according to the size of the particles. The following sections are included the description of the coarse aggregate, fine aggregate, mineral fillers and bitumen used in this study.

2.1 Coarse Aggregate

Aggregates that are passing 25mm and retained #8 sieve termed as coarse aggregate including crushed gravel, crushed stone, crushed boulder. It contains major part of the volume mix. Value of Marshall test depends on coarse aggregate. The shape of this aggregates is round, angular or irregular due to lower surface area rounded aggregate has the lowest water demand and also requires lower mortar paste.

Figure 1: Coarse Aggregate

Figure 2: Fine Aggregate

2.2. Fine Aggregate

Aggregates that passing #8 and retained #200 are termed as fine aggregates. It is widely used in construction industry to increase the volume. Fine aggregates provide dimensional stability to the mixture. Quality of fine aggregates influence the mixture proportion and hardening properties.

2.3. Filler

Glass powder and brick dust size between 30 µm down to as fine as 0.1 µm were used as filler in the bituminous mixes for analysis the strength properties.

Figure 3. Brick Dust

Figure 4. Glass Powder

Figure 5. Bitumen

2.4. Bitumen

Bitumen can be produced to different specifications depending on how it's going to be used but, in all cases, bitumen is created by distilling crude oil. This process removes the lighter liquid and leaves a thick sticky substance that, in the case of asphalt, will hold heavy aggregate like stones and gravel with sand. Most refined bitumen is used in the construction industry. 85% of all bitumen is used for binder in asphalts in roads, runways, parking lots and foot paths. In this research 60-70 penetration grade is used.

3 Methodology

3.1. Properties of Materials

3.1.1. Properties of Aggregates

Laboratory tests were conducted to find the Aggregate impact value, crushing value and specific gravity of aggregate sample according to the British standard 812 and AASHTO T85.

Table 1. Physical Properties of Aggregate

Properties	Specification	Obtained Result
AIV	BS 812	18
ACV	BS 812	16
Specific Gravity	ASTM C-128	2.68

3.1.2 Properties of Filler Material

Laboratory tests were conducted to determine the specific gravity of brick dust and glass powder which was used as mineral filler in this study.

Table 2. Physical Properties of Filler Materials

Filler	Specification	Specific Gravity
Brick Dust	AASHTO T85	2.4
Glass Powder	AASHTO T85	2.6

3.2. Marshall Mix Design

In paving job routine testing procedures, the marshal test is extensively used. The stability of a mix is defined as the greatest load carried by a compacted specimen at a standard test temperature of 60°C. The flow is measured in units of 0.25 mm during a stability test as the difference in deformation between no load and the utmost load borne by the specimen (flow value may also be measured by deformation units of 0.1 mm).

In this research work, tests were performed to study the change in performance while using waste products as mineral filler. Specific gravity of mixture, percent air voids, stability and flow value, air void, VMA and VFA are studied to assess the changes. For this test 3 different percentages of asphalt contents are used and these are 5%,6% and 7%. and total number of specimens are 18 where 9 specimens are for brick dust and 9 specimens are for glass powder. Preparation of specimen, compaction and testing were performed according ASTM D1559 (Marshall Mix Design Method). The aggregates and bitumen were rapidly mixed to yield a mixture having a uniform distribution of bitumen throughout. The bulk specific gravity and density, theoretical maximum specific gravity was determined according to ASTM D2726, ASTM D2041 respectively. After determination of specific gravities of the compacted specimens were immersed in the thermostatically controlled water bath maintained at a temperature of 60ºC for 30 minutes. Marshall Stability and flow test were performed afterwards for each specimen by testing machine. Marshall testing machine is an electrically powered compression testing device. Load was applied to the test specimens through cylindrical segment testing heads at a constant rate of vertical strain of 51 mm (2inch) per minute until the maximum load was reached. The maximum load resistance and respective flow value were recorded and percent air voids were determined according to Asphalt Institute.

4 Result and Discussion

Following Marshall method of mix design the obtained result of compacted mix specimen where brick dust and glass powder have been used as filler material is tabulated below respectively. The tables contain the percentage of asphalt content used, observed unit weight, Marshall stability value in pounds, flow value, percentage of air voids present in the compacted mix, (%V_a), percentage of voids in mineral aggregate (%VMA) and percentage of voids filled with asphalt (%VFA).

Table 3. Properties of Compacted specimens with brick dust as filler material

% Asphalt content	Unit weight (PCF)	Stability (KN)	Flow Value (mm)	Air Void (%)	VMA (%)	VFA (%)
5	147.76	14.09	13.5	4.76	15.109	67.48
6	145.3	17.42	14.6	4.93	17.403	71.65
7	142.82	7.82	15.8	5.16	19.675	73.77

Table 4. Properties of Compacted specimens with glass powder as filler material

% Asphalt content	Unit weight (PCF)	Stability (KN)	Flow Value (mm)	Air Void (%)	VMA (%)	VFA (%)
5	148.1	13.24	14.5	4.55	14.917	69.51
6	144.47	10.96	15.4	5.48	17.878	69.35
7	141.83	10.2	17.8	5.82	20.231	71.24

In the following figures the variation due to different filler materials have been represented among unit weight, Marshall stability, air voids, flow value, voids in mineral aggregates and voids filled with asphalt. Figure 6 depicts the relationship between unit weight and asphalt content where both brick dust and glass powder showed similar properties. With the increase of asphalt content in the mixture unit weight decreases. At 5% asphalt content glass powder achieved higher unit weight than brick dust. As the bitumen content increases brick dust gained more unit weight compared to glass powder. Here for 5% asphalt content, the unit weight of the compacted brick dust specimen is less than that of the glass powder specimen. Whereas for 6% and 7% asphalt content, the unit weight of the compacted brick dust specimen is more than that of the glass powder specimen. The possible reason could be is that at higher bitumen contents, the brick dust particles might have a stronger affinity for the bitumen, leading to better adhesion and bonding between the particles. This improved bonding may lead to denser compaction, resulting in a higher unit weight compared to the glass powder specimen. Additionally, the bitumen might be filling voids between the brick dust particles more effectively, contributing to the increased unit weight. Surface area and porosity analysis, adhesion test should be commenced to assess the bonding properties between the mineral filler and asphalt.

Figure 7 showing the relationship in between Marshall stability and asphalt content which shows that brick dust achieved maximum stability at 6% asphalt content an reduces rapidly as the proportion of bitumen increases. Glass Powder also showed similar properties like brick dust, gradual decrease of stability with increment of asphalt content. Brick dust achieved better stability than glass powder. This does not follow the common trend of stability vs asphalt content nature. Aggregate gradation and properties might be the reason for this issue.

Figure 8 represents the amount of air voids that varies with the proportion of asphalt content. Both brick dust and glass powder showed similar characteristics. As it is already proven that higher bitumen content creates more void and decrease aggregate interlocking. Figure 8 also shows that with the increase of asphalt content air void increases. Among both of these fillers glass powder showed higher proportion of air void as compared to brick dust. This figure also does not represent the usual scenario. The temperature of mixing could be a possible reason for inadequate coating and bonding which increased the amount of air voids with the increment of asphalt content.Figure 9 represents the voids in mineral aggregate which in both fillers showed similar behavior. With the increment of asphalt content voids in mineral aggregate increases which actually leads to bleeding action. Both brick dust and glass powder achieved lower voids in mineral aggregate at lower asphalt content proportion. Glass powder showed better performance in compare to brick dust by achieving lower VMA value at lower asphalt content. Figure 10 shows the flow value that changes with the proportion of asphalt content. Increasing the amount of bitumen in the mixture makes the specimen soft which results in higher flow value. Brick dust showed better flow properties as compared to glass powder though both the filler material showed similar behavior an increasing rate of flow value with the increase of asphalt content.

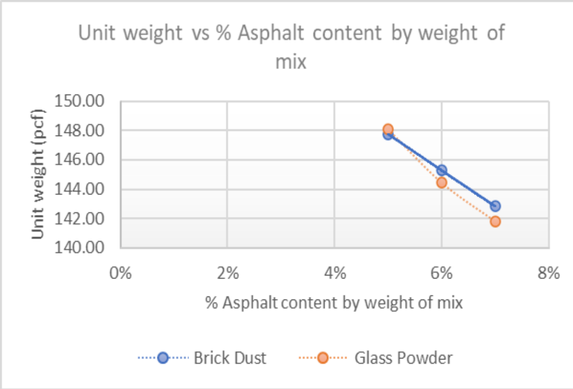

Figure 6. Variations of unit weight with asphalt content

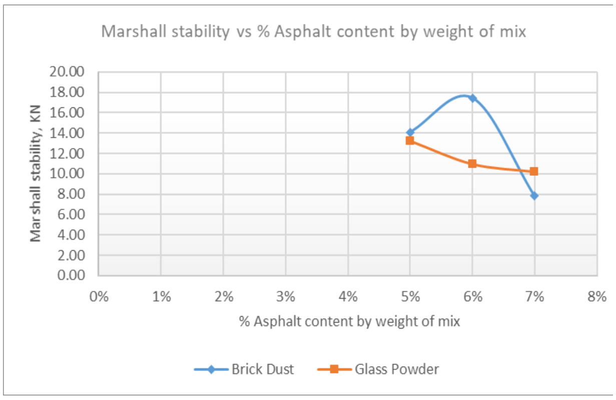

Figure 7. Variations of Marshall Stability with asphalt content

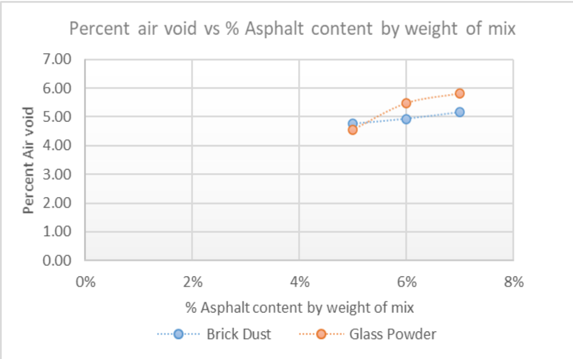

Figure 8. Variations of air void percentage with asphalt content

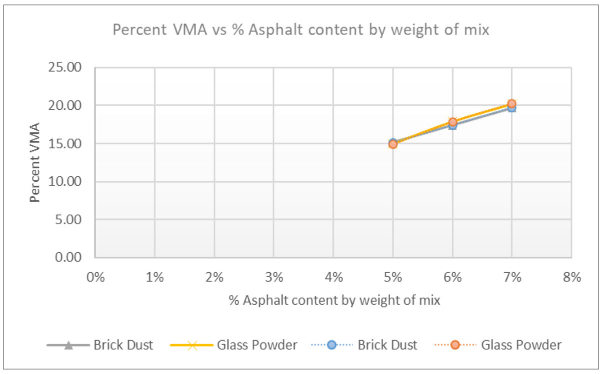

Figure 9. Variations of percent VMA with asphalt content

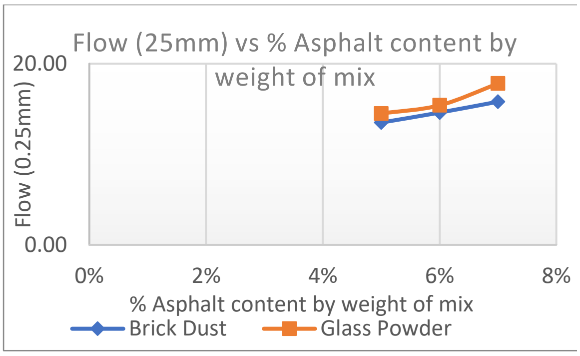

Figure 10. Variations of flow value with asphalt content

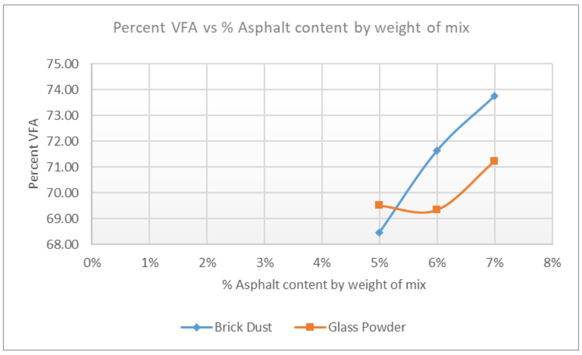

Figure 11. Variations of percent VFA with asphalt content

Figure 11 shows the variations in voids filled with asphalt. Brick dust shows a gradual increase of voids filled up with increment of asphalt content whereas glass powder shows a decrement initially but then a rapid increase with the increment of asphalt content. For brick dust mixture segregation could be a possible reason which leads to localized variations in VFA.

The obtained results for both fillers satisfy the standard range provided by asphalt institute. Some exception was also achieved. Flow value for glass powder at 7% asphalt content achieved slightly more that standard value and VMA value for both fillers were slightly above the standard value. Moreover, stability value, %VFA and %air void are within the prescribed standard range. These may indicate the possibility of applying such non-conventional filler material in mix design effectively.

5. Conclusion

To sum up, using waste non-conventional filler materials ensures similar properties like conventional fillers as the obtained results lies within the standard range. All samples have achieved higher stability value from 7.82 KN to 17.42 KN which is above the standard range of 5.33 KN and also the %VFA, %V_a, flow value attained are within the range.

Using waste products helps to enrich countries economy and reduces landfill. Hence, glass powder or brick dust can be a suitable solution based on availability and economy. Disposal of waste will not be a concern if fillers like brick dust and glass powder are introduced in the construction industry.

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