Utilization of Brick Dust as Replacement of Fine Aggregates in Bituminous Concrete

Mridul Mehta, Nishant Sachdeva, Prachi Kushwaha
Department of Civil Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India
Email: mridul.m94@gmail.com, nishant.sachdeva@skit.ac.in, prachi.kushwaha@skit.ac.in

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Abstract- Waste is defined as material by-products of any kind that have no residual value from human or industrial activities. Elimination of brick dust landfills is a serious and important task that is being considered by many countries around the world. The reuse of brick dust for road construction is a sustainable solution to ecological problems. The reuse of brick dust reduces road construction and landfill costs. The purpose of this study was to examine the overall performance of a bituminous concrete mix in which brick dust replaced certain combinations of specific aggregates in different proportions. In this study, brick dust was used in proportions of 5%, 10%, and 15% as a substitute for natural sand. The optimum range of substitution was determined based on results obtained from Marshall Parameters. In general, studies have shown that the use of brick dust in bituminous Concrete mixes is acceptable.

Keywords: Marshall Stability, Brick Dust, Sustainable pavement material, Fine Aggregates

1. INTRODUCTION

1.1 General

Roads are very important for the social as well as economic growth of a country. India is having second largest road network in the world. India is having a total road network of 6,215,797 km (3,862,317 miles) as of 31 March 2020. [1]
There are two types of pavements normally constructed viz. flexible and rigid pavement. In the construction of roads, bridge decks, highways and other structures in India flexible pavements are frequently constructed. They have Low construction and maintenance cost, good load carrying capacity, skid resistance; ease of maintenance and repair and the ability to accommodate movement of underlying layers due to climatic changes or load-deformation are all reasons for the widespread use of flexible pavement is preferred. Bituminous concrete is used as a wearing course in flexible pavement.

Raw materials used in flexible pavements are coarse aggregates, fine aggregates and bitumen. The raw materials used in flexible pavement are procured from natural resources. This misbalances the ecosystem and creates a bad impact on the environment. To reduce the impact on the environment and to move a step toward sustainability, we decide to use some waste material as a replacement of fine aggregates.

India is having around 100,000 brick kilns that manufacture more than 150 million bricks annually [2]. This manufacturing creates a large amount of brick dust which is creating a huge problem for disposal. To overcome this issue, we utilized brick dust as a partial replacement for sand in bituminous concrete. Reusing waste materials is the most environmentally benign and sustainable disposal approach, with numerous advantages.

1.2 Objectives of this study

1. Characterization of aggregate and bitumen binder.
2. To finalize the Job mix formula for Bituminous Concrete (Grading 1).
3. To check the effect of brick dust as a partial replacement of fine aggregates on Marshall Parameters.

2. METHODOLOGY & EXPERIMENTAL WORK

In the present research work, stone aggregates of sizes 20 mm and 10 mm, sand, and bitumen of grade VG-30 were used. Stone aggregates were procured from a local crusher in the Jagatpura area of Jaipur city and bitumen was purchased from a local vendor. Physical properties of aggregates and bitumen were determined as per the procedure given in relevant IS codes.

For Bituminous Concrete (Grade 1), proportioning of aggregates was done as per the table given in "Specifications of road and bridge works – MoRTH" [3]. Marshall Stability test was used to determine the optimum binder content (OBC) of Bituminous Concrete (BC). OBC was determined by taking an average of bitumen content corresponding to maximum bulk density, maximum stability and 4 % air voids.

At OBC, brick dust was used in a proportion of 5 %, 10 % and 15 % as a replacement for fine aggregates. Marshall stability test was conducted as per the procedure specified in ASTM D6927 - 06. All the properties of Marshall test were compared with the desirable limits specified by MoRTH and optimum dosage of brick dust was determined.

2.1 Experimental Work

Using applicable IS codes, physical parameters of aggregates and bitumen were determined, and the test results are shown in Tables 1 and 2.

Table 1: Results of Physical Properties of Aggregates

Properties	Test Method	Obtained Values	IS Specifications
Grain size Analysis	IS 2386 (Part 1)	3.18	Passing 0.075 mm (5 % max)
Flakiness index	IS 2386 (Part 1)	20.2	30 % (max)
Elongation Index	IS 2386 (Part 1)	16.9	25 % (max)
Stripping Value	IS 6241 (1971)	2.8%	10 % (max)
Impact-Value	IS 2386 (Part 4)	23.07%	24 % (max)
Water Absorption	IS 2386 (Part 3)	0.7%	2 % (max)
Specific-gravity	IS 2386 (Part 3)	2.60	2.5 - 3
Abrasion-Value	IS 2386 (Part 4)	27.85	30 % (max)

Table 2: Results of Physical Properties of Bitumen

Test of Bitumen	Test Method	Test Result	Specifications as per IS 73 (2013)
Ductility Test	IS 1208	85.5	40 cm (min)
Specific Gravity Test	IS 1202	1.03	0.99 (min)
Softening Point Test	IS 1205	54.35 ^{O}C	> 47 ^{O}C
Fire Point	IS 1209	235 ^{O}C	220 ^{O}C (min)
Flash Point	IS 1209	190 ^{O}C	175 ^{O}C (min)
Elastic Recovery	IS 1208	90%	50 % (min)

2.2 Proportioning of Aggregate

Aggregates make up 60 % to 80 % of a standard bituminous mix, so they must be carefully chosen for durability, mixed for maximum efficiency, and regulated to provide constant strength, workability, finishing, and durability. The majority of Jaipur City is connected with bituminous roads. Apart from the construction of new roads, the resurfacing of existing roads is a huge undertaking. Bituminous Concrete, Grade 1 is used for resurfacing.

The proportioning of aggregates was done using the trial-and-error method. As illustrated in Figure 1, the attained gradation is almost halfway between the upper and lower limits.

Table 3: Mix Proportions of Bituminous Concrete layer, Grading 1 (MoRTH: - 2013)

Sieve Size(mm)	20 mm (30%)	10 mm (30%)	Sand (40%)	Achieved Gradation	Desired Gradation
26.5	30	30	40.00	100.00	100
19	27.88	30	40.00	97.88	90-100
13.2	7.40	27.15	40.00	74.55	59-79
9.5	1.07	22.65	40.00	63.72	52-72
4.75	0.00	14.31	30.23	44.54	35-55
2.36	0.00	11.07	20.68	31.75	28-44
1.18	0.00	8.03	15.42	23.45	20-34
0.6	0.00	6.44	11.12	17.56	15-27
0.3	0.00	4.37	7072	12.09	10-20
.150	0.00	2.61	4.20	6.81	5-13
.075	0.00	1.14	2.01	3.18	2-8

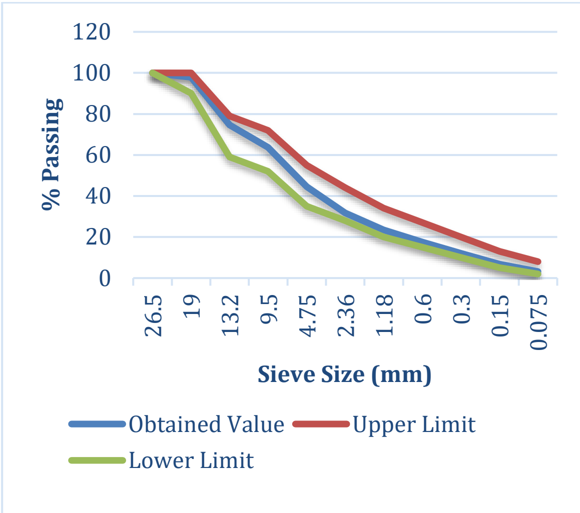

Figure 1: Proportioning of Aggregates for BC (Grade 1)

3. ANALYSIS OF RESULT

To determine the optimum binder content, Marshall Specimens were prepared at 4 %, 4.5 %, 5 %, 5.5 % and 6 % bitumen content. Using bitumen content at maximum bulk density, maximum stability and 4 % air voids Optimum binder content was determined.

Table 4: Calculation for Optimum Binder Content

Maximum Bulk Density	6 %
Maximum Stability	5 %
Bitumen Content Corresponding to 4 % air voids	5.75 %
Average Bitumen Content	5.6 %
Bitumen Content corresponding to the total mix	5.3 %

At OBC i.e. 5.3 % Marshall Specimens were prepared by replacing sand from brick dust in proportions of 5 %, 10 % and 15 %. The optimum binder content at all the proportions was also calculated. The OBC value started increasing at a very slow rate that was observed with an increase in brick dust content. This might be due to the smaller size and larger surface area of the brick dust. So, more bitumen might be required to coat the brick dust. The OBC varies from 5.3 % at 0 % replacement to 5.6 % at 15 % replacement. These specimens were tested and all properties of the Marshall Stability test were analyzed. The analysis of all results is presented below:

3.1 Bulk Density

Most important mix design calculations, such as voids in mineral aggregates (VMA), voids filled with bitumen (VFB) and air voids uses bulk density. It has been observed that replacement of brick dust to sand results in relatively slight decrease in bulk density. When replacement increases further the bulk density again increases. This might happen due to increase in air voids initially and further decreases. Due to this, first volume of the mix increased, then decreased.

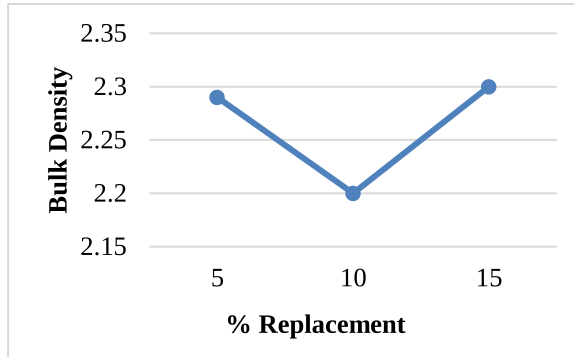

Figure 2: Graphical representation of Bulk Density

3.2 Air Voids

Air voids are small air pockets that exist between the coated aggregate particles in the final compacted mix. All bituminous mixes must have a specified percentage of air voids to allow extra pavement compaction under traffic and to provide space for small amounts of bitumen to flow during subsequent compaction. Figure 3 depicts the relationship between the percentage replacement and air voids. When the percentage replacement is increased from 5 % to 15 %, the proportion of air voids increases first and then decreases. As the right rearranging of particles takes place, air voids reduce in replacement from 10 % to 15 %, and brick dust also occupies the empty spaces in the mix. On further increasing the brick dust content, it violates the range of air voids specified by MoRTH.

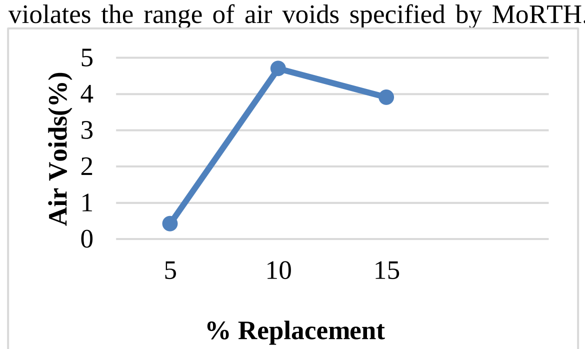

Figure 3: Graphical Representation of Air Voids

3.3 Voids in Mineral Aggregates (VMA)

VMA is defined as the amount of inter-granular voids present between the aggregate particles of the compressed mixture. The inter-granular voids consist of air voids and bitumen and is expressed as a percentage of the total volume of the sample. The relationship between percentage replacement and VMA is shown in Figure 5. When the percentage replacement increases from 5 % to 15 %, the value of VMA first increases then slightly decreases. This is due to the fact that VMA is proportional to the number of air voids. Minimum specifications for VMA is10 % which is fulfilled at every % replacement.

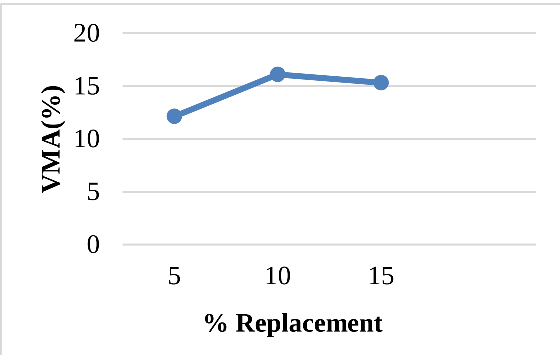

Figure 4: Graphical Representation of VMA

3.4 Voids Filled with Bitumen (VFB)

Bitumen-filled voids are a fraction of the intergranular void space between aggregate particles (VMA) i.e., occupied by bitumen. Figure 6 depicts the graph plotted between the percentage replacement of sand by brick dust and VFB. As the percentage replacement from 0 % to 15 % increases VFB first decreases and then increases. VFB varies in this way because it is inversely related to VMA, and when VMA rises, VFB falls, and vice versa. The values of VFB violate the MoRTH specifications at 5 % replacement. The values are within the limits at 10 % and 15 % replacement.

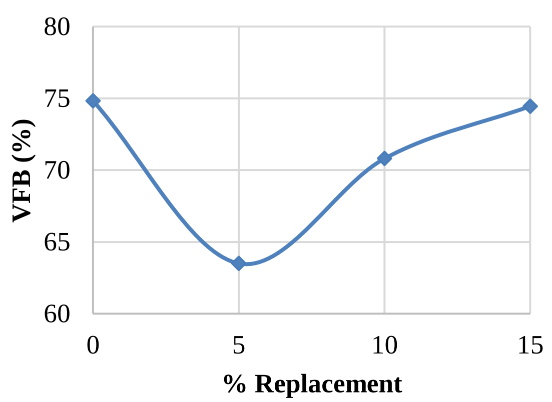

Figure 5: Graphical Representation of VFB

3.5 Marshall Stability

The greatest load that the bituminous mix can withstand is called stability. Figure 7 shows the relationship between percentage replacement and stability.

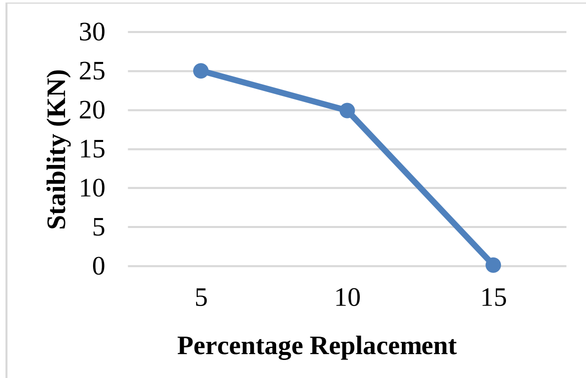

Figure 6: Graphical Representation of Stability

When the percentage replacement is increased from 5 % to 15 % the Marshall Stability value drops. This might be due to the reason that brick dust may have a low bearing capacity and interlocking capability (angular shape) as compared to sand. The minimum desired criteria by MoRTH for stability is 9kN which is violated at 15 % replacement.

3.6 Flow

The deformation of a Marshall specimen under load is known as flow. The relationship between percentage replacement and flow is presented in Figure 7. As the percentage replacement increases, the flow value first increases and then decreases. The acceptable range of flow value as prescribed by MoRTH is 2 mm – 4 mm which is violated at 15 % replacement.

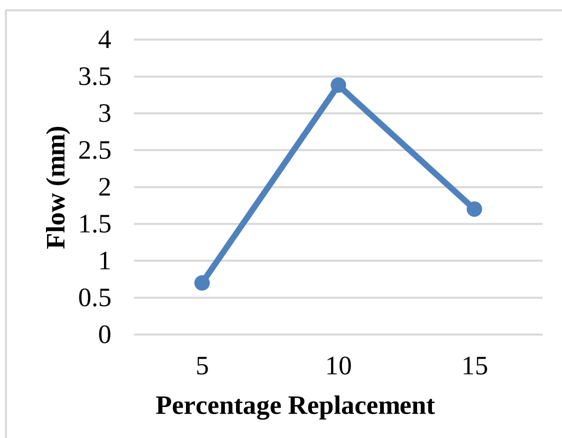

Figure 7: Graphical Representation of Flow

4 CONCLUSION

The following conclusions are drafted from the above research work:

1. When sand is replaced by brick dust, the majority of the important parameters improved.
2. Although the stability of the mix was reduced to 10 % replacement, it was within the limits specified by MoRTH.
3. VFB specifications of MoRTH are violated at 5 % replacement. So, 5 % replacement of brick dust is not recommended. Although VFB at 10 % replacement is within prescribed limits.
4. Observing the results presented, 10 % brick dust can be used as a replacement for fine aggregates in the hot mix asphalt (HMA).

5 FUTURE SCOPE OF WORK

- As the bitumen content was increasing, the cost analysis of brick dust as a replacement for sand must be carried out.
- Further studies can be done to study the effect of brick dust on the durability parameters of BC (Grade 1)
- Effect on performance of BC (Grade 1) can be checked at higher percentage replacements.

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