Feasibility of [Brick dust + Hydrated lime] as a Filler Composite in the Bituminous Mixes

Mr. Sagar K. Sonawane[1] Dr. M. R. Vyawahare[2] Mrs. C. A. Chitkeshwar[3]
[1]ME Student [2]Professor & Head [3]Assistant Professor
[1,2,3]Department of Civil Engineering
[1,2,3]DRGIT & R, Amravati (MH), India

Abstract— As we know that the fillers plays vital role in the bituminous paving mixes. It is not only fill up the voids but also increases the engineering properties of the bituminous mixture in great extent. For this only single conventional fillers are used such as stone dust, cement etc. An attempt has been made in this investigation to assess the feasibility of non-conventional and cheap fillers such as brick dust along with conventional fillers in bitumen paving mixes. This study deals with the combined effect of conventional and non-conventional fillers on the bituminous mixes for varying bitumen content of 4%, 5%, 6% & 6.5%. It has been observed as a result of this study that bituminous mixes with these conventional and non-conventional fillers result in satisfactory Marshall Properties though requiring a same bitumen content compare with the single conventional filler. These results also shows that bituminous mix containing [Brick dust + Hydrated lime] composite is suitable substitute to traditional filler and are acceptable materials for bituminous concrete of flexible pavement construction. Also, the optimum binder content is find out for this composite to satisfy economic consideration. The fillers used in this study are likely to partly solve the solid waste disposal of the environment.

Key words: Bituminous Paving Mixes, Bitumen, Fillers, Brick Dust, Hydrated Lime, Optimum Binder Content, Marshall Properties

I. INTRODUCTION

India is fast growing country in all the sectors including transportation and industrialization. From recent few years, the population and industrialization of our country grow rapidly which increases the road traffic and demands the more network of roads for passenger and goods transportation. To satisfy the increasing demand of traffic we have to construct the road pavements more durable and economical. The durability and economy of road pavements depend on pavement design and mix design of various materials used for its effective construction. This study focused on the mix design considerations. A good design of bituminous mix is expected to result in a mix which is adequately strong, durable and resistive to fatigue, permanent deformation and at the same time environment friendly and economical. While achieving this criteria we have to also concern about the cost of construction. The use of single traditional filler in the bituminous mixes cannot give us economy during construction. So the combined use of conventional and non-conventional fillers in the bituminous mixes were studied to increase the Marshall properties for varying bitumen content. The utilization of [Brick dust + Hydrated lime] as a filler composite in the bituminous mixes were checked for its effective implementation in the actual practices.

II. MATERIALS USED

A bituminous mixture is generally composed of aggregate and bitumen. According to the size of the particles, the aggregates are generally classify into coarse aggregates, fine aggregates and filler fractions. The following sections gives the details of the coarse aggregate, fine aggregate, bitumen and mineral fillers used in the study.

A. Coarse aggregate

The coarse aggregates should have good abrasion value, impact value and also crushing strength. The functions of coarse aggregates are to bear the stresses due to wheels and also resisting wear due to abrasion. That portion of the mixture which is retained on 2.36 mm (No. 08) sieve according to the Asphalt Institute is termed as coarse aggregates. Locally available Basalt rock was used as coarse aggregate which borrowed from stone crusher plant. Fig. 1 shows the appearance of coarse aggregates used for the study.

Fig. 1: Experimental coarse aggregates

B. Fine Aggregate

Voids which remain in the coarse aggregates are filled by the fine aggregates. So the function of fine aggregates is to fill the voids of coarse aggregates. Fine aggregates consist of crushed stone or natural sand. For this study, aggregates that passed through 2.36 mm sieve and retained on 0.15 mm sieve were selected as fine aggregate. Locally available natural sand was used as fine aggregate which borrowed from Girana River (MH). Fig. 2 shows the appearance of fine aggregates used for the study.

Fig. 2: Experimental fine aggregates

C. Fillers

Fillers play an important role in the bituminous mixture. As the name indicates function of fillers is to fill up the voids. In this study, filler used is brick dust as non-conventional filler. Also hydrated lime and stone dust are used as conventional fillers. These materials finer than 0.15 mm & 0.075 mm size sieves were used in the bituminous mixes for comparison and also for economy point of view.

1) Brick dust

It is a dust of pounded or broken bricks. Brick dust finer than 0.15 - 0.075 mm size sieve were used in the bituminous mixes which was obtained from brick moulding mill. Fig. 3 shows the appearance of brick dust.

Fig. 3: Experimental brick dust

2) Hydrated lime

Hydrated lime is a type of dry powder made from limestone. It is created by adding water to quicklime in order to turn oxides into hydroxides. The hydrated lime used as filler was procured in 25 kg bag from a reputable chemical store which was stored in a cool & dry place away from weathering effects. The chemical composition of experimental hydrated lime is given in Table I and Fig. 4 shows the appearance of hydrated lime.

Sr. No.	Constituents	% Dry
1	Calcium Hydroxide, $Ca(OH)_2$	> 88
2	Magnesium Oxide, MgO	< 0.8
3	Iron Oxide, Fe_2O_3	< 0.3
4	Aluminium Oxide, Al_2O_3	0.4 - 0.8
5	Silicon Dioxide, SiO_2	< 1.3
6	Loss on ignition	< 26
7	Acid insolubles	< 3

Table 1: Chemical Composition of Hydrated Lime

Fig. 4: Experimental hydrated lime

3) Stone dust

Locally available stone dust was used as filler which obtained from stone crusher plant having frictions finer than 0.15 - 0.075 mm during the crushing process. Fig. 5 shows the appearance of stone dust.

Fig. 5: Experimental stone dust

D. Bitumen

Bitumen is used as a water repellent and adhesive material. 80/100 grade of bitumen was used in this study. Same bitumen was used for all the mixes so the type and grade of binder was kept constant. Fig. 6 shows the appearance of 80/100 grade bitumen.

Fig. 6: Experimental bitumen

III. EXPERIMENTAL METHODOLOGY

This study comprises of three stages: - characterization of materials, mixing of [Brick dust + Hydrated lime] as filler composite and stone dust as single filler, suitability of filler composite in the bituminous mixes in comparison with single conventional filler. In the first stage, properties of aggregates, fillers and bitumen were established while in second stage [Brick dust + Hydrated lime] were used as filler composite & stone dust as single filler by using adopted gradation and in the third stage Marshall mix design method was used to find stability value, flow value, unit weight values, % air voids & % VMA.

A. Laboratory tests for the Properties of Materials

Bituminous mix is composite material and engineering properties of it are depends on the materials used for its preparation. Therefore, it is essential to check its various physical properties and this are within the standard limit laid by various road organizations such as BIS, IRC and MORTH. This section cover the laboratory test results of aggregates, bitumen and filler materials.

1) Laboratory tests for aggregates

Tests were performed to determine the specific gravity, water absorption, crushing value, aggregate impact value, Los Angles abrasion value, elongation index and flakiness index of aggregates according to the procedures specified by BIS standards and results are summarized in Table II.

Sr. No.	Test conducted	Obtained result	Code for testing
1	Specific gravity test of coarse aggregates	02.64	IS:2386 (Part III) – 1963
2	Water absorption test of coarse aggregates	03.60	
3	Aggregate crushing value test	26.60%	IS:2386 (Part IV) – 1963
4	Aggregate impact value test	20.20%	
5	Aggregate abrasion value test	20.05%	
6	Flakiness index test	25.21%	IS:2386 (Part I) – 1963
7	Elongation index test	35.17%	
8	Specific gravity test of fine aggregates	02.58	IS:2386 (Part III) – 1963

Table 2: Preliminary Test Results of Aggregates

2) Laboratory tests for filler materials

Tests were performed to determine the specific gravity of different filler materials according to the procedures specified by BIS standards and results are summarized in Table III.

Sr. No.	Test conducted	Obtained result	Code for testing
1	Specific gravity test of brick dust	02.34	IS:2386 (Part III) – 1963
2	Specific gravity test of stone dust	02.50	
3	Specific gravity test of hydrated lime	02.24	

Table 3: Preliminary Test Results of Filler Materials

3) Laboratory tests for bitumen

Tests were performed to determine the softening point, penetration value, specific gravity, ductility value and viscosity value of 80/100 grade of bitumen according to the procedures specified by BIS standards and results are summarized in Table IV.

Sr. No.	Test conducted	Obtained result	Code for testing
1	Softening point test	47.25°C	IS:1205 – 1978
2	Penetration test	85.33 mm	IS:1203 – 1978
3	Specific gravity test	0.98	IS:1202 – 1978
4	Ductility test	82 mm	IS:1208 – 1978
5	Absolute viscosity	1057.92 Poise	IS:1206 (Part II) – 1978
6	Kinematic viscosity at 135°C	271 cSt	IS:1206 (Part III) – 1978

Table 4: Preliminary Test Results of Bitumen

B. Mixing of Materials and Specimen Preparation

The compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 145ºC. About 1200 gm of sample aggregates were taken and kept in oven until it dried. Heating of aggregates was done up to 140ºC before the addition of bitumen. Also the fillers; hydrated lime, brick dust and stone dust were added as per design. Bitumen was added varying from 4%, 5%, 6% and 6.5% which is heated to temperature 138ºC. The mixture thoroughly mixed by hand mixing with trowel maintains the temperature of mix up to 154ºC-160ºC. For each binder content having filler composite and single traditional filler 4 samples were prepared by compacting to 75 blows on both sides of sample in Marshall compactor. Then the sample was de-moulded and the weight of sample in air and in water was noted down to determine the bulk density of mix. Also the average thickness and diameter of the specimen are noted.

For the determination of stability and flow value on Marshall apparatus, sample was immersed in water bath at 60ºC for 40 minutes before testing. The specimens are taken out one by one, placed in the Marshall Test head and the Marshall stability and flow values are noted.

IV. RESULTS OF MARSHALL TEST

The results of the Marshall test of specimens prepared with [Brick dust + Hydrated lime] as filler composite and stone dust alone as filler for varying bitumen contents have been presented in Tables V and VI respectively.

Bitumen % Marshall Properties	4.00	5.00	6.00	6.50
Stability value (kN)	19.05	19.68	22.46	22.34
Flow value (mm)	1.925	2.275	3.075	3.225
Unit wt. (gm/cc)	1.909	1.983	2.024	2.085
Air voids, %	19.395	15.134	12.195	8.980
VMA, %	27.188	25.252	24.591	22.81

Table 5: Marshall Properties of Samples with [Brick dust + Hydrated lime]

Bitumen % Marshall Properties	4.00	5.00	6.00	6.50
Stability value (kN)	17.24	18.80	20.10	19.166
Flow value (mm)	1.29	1.33	2.08	2.55
Unit wt. (gm/cc)	2.059	2.07	2.097	2.159
Air voids, %	14.931	13.233	10.771	7.486
VMA, %	23.336	23.795	23.424	21.807

Table 6: Marshall Properties of Samples with Stone dust

V. DISCUSSIONS OF MARSHALL TEST RESULTS

A. Comparison of [Brick dust + Hydrated lime] as a filler composite and stone dust as a filler specimen's Marshall test results

The results of Marshall test of specimens prepared with [Brick dust + Hydrated lime] as filler composite given in Table V and specimens prepared with stone dust as filler given in Table VI have been presented graphically for comparison in figures 7 to 11.

1) Marshall Stability Curves for Specimens with Stone Dust and Filler Composite

Fig. 7 shows the variation of Marshall Stability with different %age of bitumen for specimens with stone dust and respective filler composite. In this figure, filler composite [BD + HL] is found to have given a higher stability value at same bitumen content in comparison with stone dust as a

conventional filler. Also filler composite shows same trend for Marshall Stability as that of conventional filler. Maximum stability values of 22.46 kN and 20.1 kN are observed at 6% bitumen content in case of both the filler combination and stone dust respectively. From this we can say that the conventional fillers stone dust can be replaced easily by filler composite [BD + HL] in the bituminous mixes.

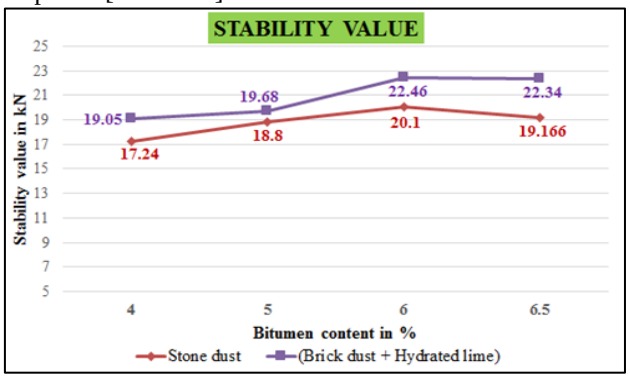

Fig. 7: Variation of Marshall Stability with different %age of bitumen for specimens with stone dust and respective filler composite

2) Marshall Flow Value Curves for Specimens with Stone Dust and Filler Composite

Fig. 8 shows the variation of Marshall Flow values with different %age of bitumen for specimens with stone dust and respective filler composite. In this figure, filler composites such as [BD + HL] is found to have given a higher flow value at same bitumen content in comparison with stone dust as a conventional filler. From this higher deformation values it can be concluded that filler composite specimens might be having lower values of modulus of elasticity. Maximum flow values are observed at 6.5% bitumen content in case of both the filler combination and stone dust. So the conventional fillers can be easily replaced by filler composite in the bituminous mixes.

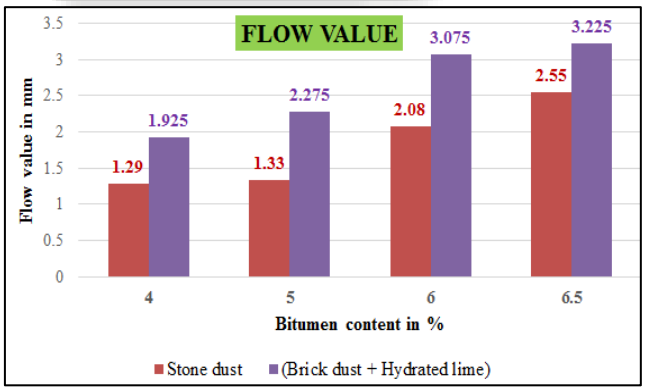

Fig. 8: Variation of Marshall flow values with different %age of bitumen for specimens with stone dust and respective filler composite

3) Marshall unit Weight Curves for Specimens with Stone Dust and Filler Composite

Fig. 9 shows the variation of Marshall unit weight values with different %age of bitumen for specimens with stone dust and respective filler composite. In this graph, we find that filler composite specimens have lower value of unit weight in comparison with stone dust as a conventional filler. It might be due to higher number of air voids in the filler composite specimens in comparison with stone dust as a conventional filler. The specimens with respective filler composite and stone dust shows higher value of unit weight at 6.5% bitumen content.

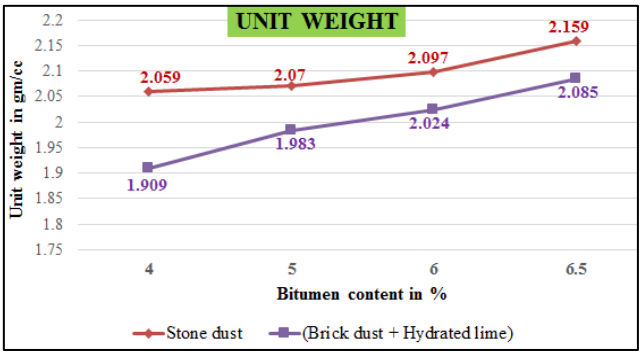

Fig. 9: Variation of Marshall unit weight values with different %age of bitumen for specimens with stone dust and respective filler composite

4) Marshall Air Void Curves for Specimens with Stone Dust and Filler Composite

Fig. 10 shows the variation of Marshall Air void values with different %age of bitumen for specimens with stone dust and respective filler composite. This figure shows that specimens with filler composite display a higher number of air voids in comparison with stone dust as conventional filler still then these fillers composite are found to have given satisfactory results. The minimum air voids are observed at the 6.5% bitumen content in both the specimens with filler composite and specimens with stone dust.

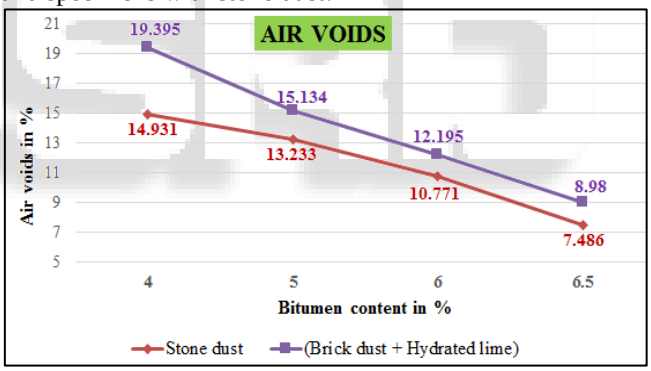

Fig. 10: Variation of Marshall air voids values with different %age of bitumen for specimens with stone dust and respective filler composite

5) Marshall VMA curves for specimens with stone dust and filler composite

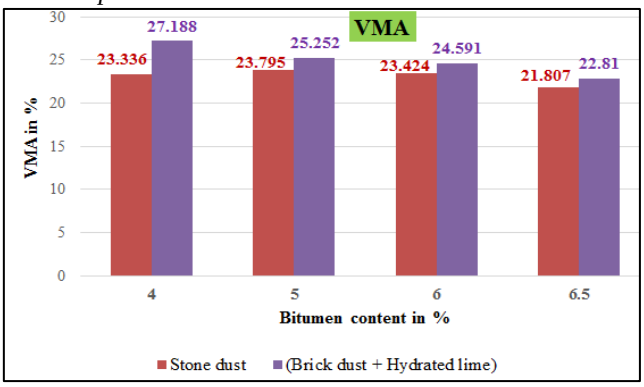

Fig. 11: Variation of Marshall VMA values with different %age of bitumen for specimens with stone dust and respective filler composite

Fig. 11 shows the variation of Marshall VMA values with different %age of bitumen for specimens with stone dust and respective filler composite. The % VMA curves showing that specimens with filler composite display higher VMA in comparison with stone dust as conventional filler. The minimum VMA values are observed at the 6.5% bitumen content in both the specimens with filler composite and specimens with stone dust. The results of the VMA for filler composite are also satisfactory compare with conventional fillers.

B. Comparison of Marshall Results for Finding Optimum Binder Content (OBC)

A comparison of results against various parameters for optimum bitumen content is tabulated in Table VII. From this, it can be seen that 6.38 % is the OBC for both the filler composite and the traditional filler i.e., stone dust.

Marshall Parameters Filler types	Max. stability value	Max. flow value	Max. unit weight	Min. air voids	O B C
[BD + HL]	6.00%	6.50%	6.50%	6.50%	6.38%
Stone dust	6.00%	6.50%	6.50%	6.50%	6.38%

Table 7: Comparison of Results against Various Parameters for Optimum Bitumen Content

VI. CONCLUSIONS

Following conclusions have been carried out from the above experimental work-

1) Bituminous mixes containing [brick dust + hydrated lime] as filler composite is found to have Marshall properties almost nearly same as those of stone dust which is one of the famous conventional filler.
2) Bituminous mixes containing [brick dust + hydrated lime] as filler composite displayed maximum Marshall stability at 6% content of bitumen having an increasing trend up to 6% and then gradually decreasing to 6.5%. But the maximum unit weight or bulk density and flow value are displayed at 6.5% content of bitumen having an increasing path from 4%.
3) Bituminous mixes containing stone dust as single filler displayed maximum Marshall stability at 6% content of bitumen having an increasing trend up to 6% and then gradually decreasing to 6.5%. But the maximum unit weight or bulk density and flow value are displayed same trend as that of filler composite.
4) The minimum air voids are also showed at 6.5% content of bitumen having a decreasing trend in case of bituminous mixes with filler composite [BD + HL] and conventional filler.
5) It is found that bituminous mixes containing 6.38% of bitumen content which is OBC gives the satisfactory results in both the filler combination and the stone dust as conventional filler.
6) Same bitumen content is required in order to satisfy the design criteria and to get usual trends which considerably savings in economy.
7) From the above remarks it is evident that [brick dust + hydrated lime] as filler composite can be utilized effectively in the making of bitumen concrete mixes for paving purposes instead of conventional fillers.
8) Further modification in design mixes can result in utilization of [brick dust + hydrated lime] as filler composite in bituminous pavement thus partially solving the disposal of industrial and construction wastes.
9) From the above concluding points it is found that the filler composite i.e., [Brick dust + Hydrated lime] is the best solution to replace the conventional fillers in the bituminous paving mixes which satisfy the mix design criteria of bituminous pavements.

ACKNOWLEDGMENT

I wish to record my indebtedness and thankfulness to my parents who helped & support me all the ways to complete this paper titled “Feasibility of [Brick dust + Hydrated lime] as a Filler Composite in the Bituminous Mixes” in a satisfactory way. First and foremost I thank God Almighty for his providence.

I want to start expressing my thanks to my guide Dr. M. R. Vyawahare, Professor & Head, Department of Civil Engineering for his valuable advice and guidance towards this work. I received motivation, encouragement and hold up from them during the course of work. Also I want to express my thanks to my co-guide Mrs. C. A. Chitkeshwar, Assistant Professor, Department of Civil Engineering for her valuable guidance towards this work.

REFERENCES

[1] B.Durga Priyanka, P.V.Ajay Kumar & K.Dedeepya. “USE OF FLY ASH AS MINERAL FILLER FOR BITUMINOUS PAVING MIXES”, International Journal of Research in Engineering and Technology, Volume: 04, Special Issue: 01, NCRTCE-2014, Feb-2015.
[2] Antonio José Tenza-Abril, José Miguel Saval and Artemio Cuenca, “Using Sewage-Sludge Ash as Filler in Bituminous Mixes”, American Society of Civil Engineers, 04014141, July 2014.
[3] Brajesh Mishra, M.K. Gupta, “Use of Fly Ash Plastic Waste composite in Bituminous Concrete Mixes of Flexible Pavement”, American Journal of Engineering Research (AJER), Volume-6, Issue-9, pp-253-262, Sept. 2017.
[4] Aakash Jaiswal, Anoop Kumar Verma and Manjesh Srivastava, “Utilization of Fly Ash and Brick Dust on Bituminous Paving Mixes”, IJSTE - International Journal of Science Technology & Engineering, Volume 3, Issue 05, November 2016.
[5] Bianchetto, Miró and Pérez-Jiménez, “EFFECT OF CALCAREOUS FILLERS ON BITUMINOUS MIX AGING”, Presentation and Publication at the 2007 Annual Meeting of the Transportation Research Board.
[6] Debashish Kar, Mahabir Panda and Jyoti Prakash Giri, “INFLUENCE OF FLY-ASH AS A FILLER IN BITUMINOUS MIXES”, ARPN Journal of Engineering and Applied Sciences, VOL. 9, NO. 6, JUNE 2014.
[7] Raja Mistry, Tapas Kumar Roy, “Effect of using fly ash as alternative filler in hot mix asphalt”, ELSEVIER, Perspectives in Science (2016) 8, 307-309.

