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Influence of Filler Combination on the Bituminous Mixes

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Abstract: Fillers play an important role in the engineering properties of bituminous paving mixes. Conventionally stone dust, cement and lime are used as fillers. An attempt has been made in this investigation to assess the influence of non-conventional and cheap fillers such as brick dust and fly ash 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, thus substantiating the need for its use. These results also shows that bituminous mix containing (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) composites are 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 composites to satisfy economic consideration. The fillers used in this investigation are likely to partly solve the solid waste disposal of the environment which the most serious problem faced by worldwide.

Keywords: Bituminous paving mixes, Bitumen, Fillers, Brick dust, Hydrated lime, Concrete dust, Fly ash, Optimum binder content, Marshall properties

I. Introduction

Construction of highway involves huge spending of investment. A precise engineering design may save considerable investment; as well as reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard – pavement design and the mix design. Our 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. A mix designer tries to meet these requirements through a number of tests on the mix with varied proportions of material combinations and finalizes the best one. This frequently involves a stability between mutually conflicting parameters. The Marshall properties of bituminous mixes are mostly affected by filler percentage and its type. Also the use of single conventional 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 feasibility of these filler composites 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 categorised 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.

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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, fillers used are brick dust and fly ash as non-conventional fillers. Also concrete dust and hydrated lime 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.

(a) 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

(b) Concrete dust

Sanding, grinding or cutting concrete can also release large amounts of dust containing high levels of crystalline silica. Concrete dust finer than 0.15 - 0.075 mm size sieve were used in the bituminous mixes which was obtained from waste concrete grinding plant. Fig. 4 shows the appearance of concrete dust.

Fig. 4. Experimental concrete dust

(c) Fly ash

It is one of the residues generated in combustion of coal. Fly ash for the present investigation was collected from the coal based thermal power plant located in Eklahare, Nashik district (MH). It was collected in dry form from the hoppers and transported in air tight double polythene bags. The chemical composition of experimental fly ash is given in Table 1 and Fig. 5 shows the appearance of fly ash.

TABLE 1
CHEMICAL COMPOSITION OF FLY ASH

Sr. No.	Chemical properties	% by mass
1	Silica (SiO_2)	58.66
2	Magnesia (MgO)	1.82
3	SO_3	0.76
4	Na_2O	0.62
5	(SiO_2 + AL_2O_3 + Fe_2O_3)	92.56
6	Total chloride	0.027
7	Loss on ignition	1.94
8	Moisture content	0.22

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Fig. 5. Experimental fly ash

(d) 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 2 and Fig. 6 shows the appearance of hydrated lime.

TABLE 2
CHEMICAL COMPOSITION 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

Fig. 6. Experimental hydrated lime

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. 7 shows the appearance of 80/100 grade bitumen.

Fig. 7. Experimental bitumen

III. EXPERIMENTAL METHODOLOGY

This study comprises of three stages: - characterization of materials, mixing of (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) as filler composites, suitability of filler composites in the bituminous mixes. In the first stage, properties of aggregates, fillers and bitumen were established while in second stage (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) were used as filler composites 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.

(a) 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 3.

TABLE 3
PRELIMINARY TEST RESULTS OF AGGREGATES

Sr. No.	Test conducted	Obtained result	Code for testing
1	Specific gravity test of coarse aggregates	02.64	IS:2386 (Part III) – 1963

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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

(b) 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 4.

TABLE 4
PRELIMINARY TEST RESULTS OF FILLER MATERIALS

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 concrete dust	02.43	
3	Specific gravity test of fly ash	02.62	
4	Specific gravity test of hydrated lime	02.24	

(c) 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 5.

TABLE 5
PRELIMINARY TEST RESULTS OF BITUMEN

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

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, concrete dust, hydrated lime, fly ash and brick 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 and composites 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) and (Concrete dust + Fly ash) as filler composites for varying bitumen contents have been presented in tables 6 and 7 respectively.

TABLE 6
MARSHALL PROPERTIES OF SAMPLES WITH (BRICK DUST + HYDRATED LIME)

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 7
MARSHALL PROPERTIES OF SAMPLES WITH (CONCRETE DUST + FLY ASH)

Bitumen % / Marshall Properties	4.00	5.00	6.00	6.50
Stability value (kN)	21.26	21.93	22.46	23.35
Flow value (mm)	1.925	2.28	3.08	3.23
Unit wt. (gm/cc)	2.013	2.063	2.067	2.143
Air voids, %	17.061	13.753	12.303	8.407
VMA, %	25.280	24.278	24.951	22.622

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V. Discussions of Marshall Test Results

C. Comparison of (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) as a filler composites specimen's Marshall test results

The results of Marshall test of specimens prepared with (Brick dust + Hydrated lime) given in Table 6 and specimens prepared with (Concrete dust + Fly ash) as filler composite given in Table 7 have been presented graphically for comparison in figures 8 to 12.

(a) Marshall stability curves for specimens with (BD + HL) and (CD + FA) as a filler composites

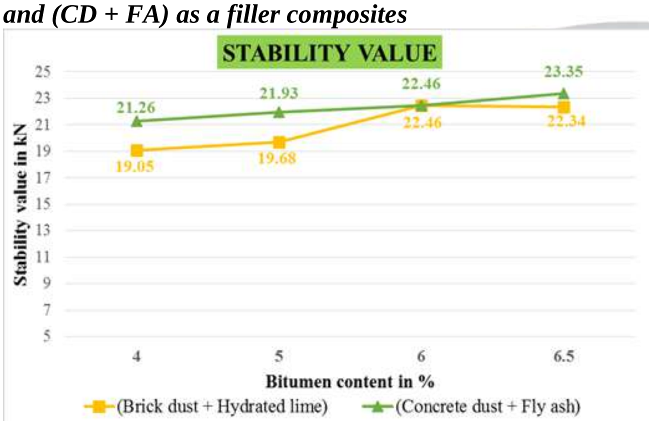

Fig. 8. Variation of Marshall stability with different %age of bitumen for (BD + HL) and (CD + FA) as a fillers

Fig. 8 shows the variation of Marshall stability with different percentage of bitumen for (BD + HL) and (CD + FA) as a fillers where it is seen that as usual the stability value increases with bitumen content initially and then decreases. Maximum stability value of 22.46 kN is observed at 6% bitumen content in case of both the filler combination. A lower value of stability in case of (BD + HL) specimen in comparison with (CD + FA) may be attributed due to higher bitumen content.

(b) Marshall flow value curves for specimens with (BD + HL) and (CD + FA) as a filler composites

Fig. 9 shows the variation of Marshall flow value with different percentage of bitumen for (BD + HL) and (CD + FA) as a fillers where it is seen that usually an increasing trend is followed with increase in bitumen content and on comparing (BD + HL) and (CD + FA) results graphically, it can be seen that both the specimens are found to display same flow values. From here we can speculate that this might be due to a higher bonding in both the specimens with (BD + HL) and (CD + FA) as a filler materials. The maximum flow values of 3.225 mm and 3.23 mm which are nearly the same values observed at 6.5% bitumen content in case of (BD + HL) & (CD + FA) as a filler combinations respectively.

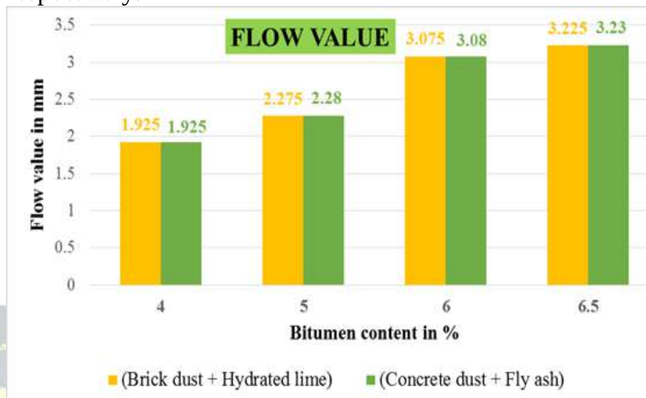

Fig. 9. Variation of Marshall flow values with different %age of bitumen for (BD + HL) and (CD + FA) as a fillers

(c) Marshall unit weight curves for specimens with (BD + HL) and (CD + FA) as a filler composites

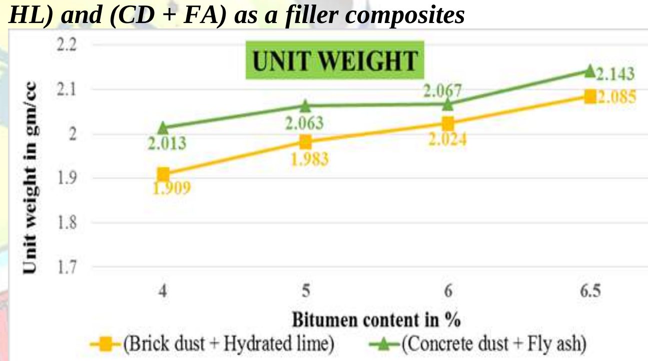

Fig. 10. Variation of Marshall unit weights with different %age of bitumen for (BD + HL) and (CD + FA) as a fillers

Fig. 10 shows the variation of Marshall unit weight values with different percentage of bitumen for (BD + HL) and (CD + FA) as a fillers. In this figure, (CD + FA) specimens are found to display a higher unit weight in comparison with (BD + HL) as filler combination due to lesser number of air voids in case of specimens having (CD + FA) as filler, this may be due to (CD + FA) acting as a filler material having better ability to fill up air voids than (BD + HL). In (CD + FA) specimens maximum unit weight obtained is 2.143 gm/cc at 6.5% bitumen content whereas in case of (BD + HL) specimens it is 2.085 gm/cc at 6.5% bitumen content showing an increasing trend in both the specimens which might tend to reduce at higher percentage of bitumen content.

(d) Marshall air voids curves for specimens with (BD + HL) and (CD + FA) as a filler composites

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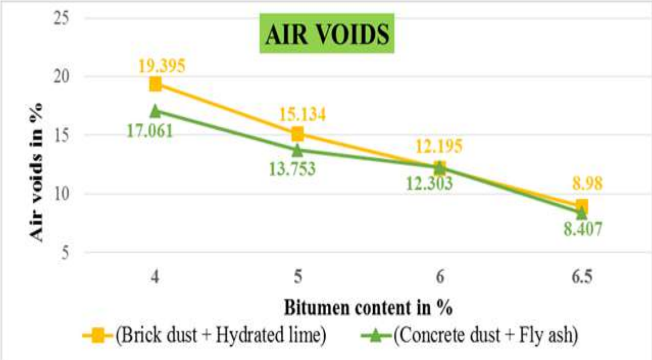

Fig. 11. Variation of Marshall air voids with different %age of bitumen for (BD + HL) and (CD + FA) as a fillers

Fig. 11 shows the variation of air void values with different percentage of bitumen for (BD + HL) and (CD + FA) as a fillers where it is seen that as usual the air void decreases with increase in bitumen content. Minimum air void of 8.407% is observed at 6.5% bitumen content in case of (CD + FA) as filler and in case of (BD + HL) a minimum air void of 8.98% is obtained at 6.5% bitumen content. The curve obtained in (CD + FA) specimen is found to have a decreasing trend displaying a greater bonding between (CD + FA) and bitumen thus showing a decreasing trend in case of air voids with increase in bitumen content.

(e) Marshall VMA curves for specimens with (BD + HL) and (CD + FA) as a filler composites

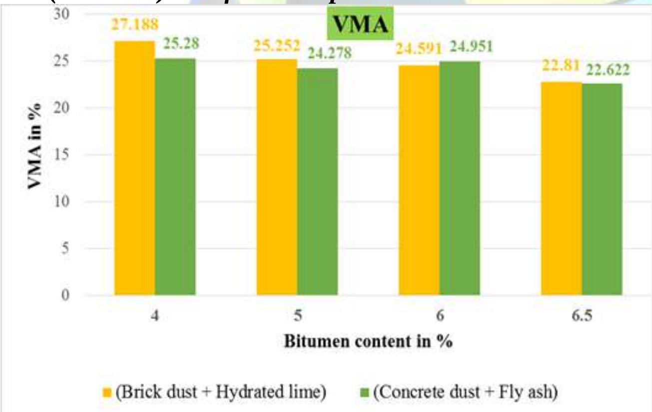

Fig. 12. Variation of Marshall VMA with different %age of bitumen for (BD + HL) and (CD + FA) as a fillers

Fig. 12 shows the variation of VMA values with different percentage of bitumen for (BD + HL) and (CD + FA) as a fillers where it is seen that as usual the VMA decreases with increase in bitumen content. In Fig. 12, (BD + HL) specimens are found to be displaying higher values of VMA than specimens (CD + FA) but in Fig. 11 they are found to display lesser amount of air voids thus leading to the conclusion that (CD + FA) absorbs higher amount of bitumen in comparison with (BD + HL) specimens. Minimum VMA of 22.81% is observed at 6.5% bitumen content in case of (BD + HL) as filler and in case of (CD + FA) a minimum air void of 22.622% is obtained at 6.5% bitumen content. Simply, (CD + FA) has a lesser VMA comparative to the (BD + HL).

D. 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 8. From this, it can be seen that 6.38 % is the OBC for both the filler composites.

TABLE 8
COMPARISON OF RESULTS AGAINST VARIOUS PARAMETERS FOR OPTIMUM BITUMEN CONTENT

Marshall Parameters / Filler types	Max. stability value	Max. flow value	Max. unit weight	Min. air voids	OBC
(BD + HL)	6.00%	6.50%	6.50%	6.50%	6.38%
(CD + FA)	6.00%	6.50%	6.50%	6.50%	6.38%

VI. CONCLUSIONS

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

(a) Bituminous mixes containing (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) as filler composites are found to have Marshall properties almost nearly same.

(b) Bituminous mixes containing (Brick dust + Hydrated lime) as filler composites 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%.

(c) Bituminous mixes containing (Concrete dust + Fly ash) as filler composites 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%.

(d) The minimum air voids are also showed at 6.5% content of bitumen having a decreasing trend in case of bituminous mixes with both the filler composites.

(e) It is found that bituminous mixes containing 6.38% of bitumen content which is OBC gives the satisfactory results in both the filler combinations.

(f) Same bitumen content is required in order to satisfy the design criteria and to get usual trends which considerably savings in economy.

(g) From the above remarks it is evident that (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) as filler composites can be utilized effectively in the making of bitumen concrete mixes for paving purposes.

(h) Further modification in design mixes can result in utilization of (Brick dust + Hydrated lime) and (Concrete dust + Fly ash) as filler composites in bituminous pavement thus partially solving the disposal of industrial and construction wastes.

(i) The use of single conventional filler in the bituminous mixes considerably improves the properties of it but the cost of these fillers are high. So the combined use of conventional and non-conventional fillers in the bituminous mixes not only improves the Marshall properties of them but also great saving in the overall cost of the paving mixes. The use of non-conventional fillers in such filler composites solves the problem of disposal of industrials waste by using these waste materials such as brick dust, concrete dust and fly ash.

VII. Future Scope

1. Filler combination can be studied by using the addition of scrap & low cost materials which are highly intense to the environment.
2. Instead of the addition of above two filler materials, the effect of filler composites studied by using combination of three or more filler materials.
3. Creep test and indirect tensile test of these bituminous mixes with filler composites can give us an idea about the tensile strength of the bituminous mixes.
4. We can also use the different types of binders and additives like rubber, plastic waste, polymers etc. for such filler combination study.
5. Filler combinations can be studied by using combined use of only two or more types conventional or non-conventional fillers.
6. Influence of these filler combinations can be studied by using other types of mix design approaches for bituminous pavements such as recipe method, analytical method and performance related approaches.

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BIOGRAPHY

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