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Effect of Fillers on Bituminous Paving Mixes

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Abstract: **Fillers play an important role on engineering properties of the bituminous paving mixes. Conventionally, cement, lime and stone dust are used as fillers. In this study, an attempt has been made to assess the effects of different types of fillers on the Marshall properties of bituminous paving mixes. All of these materials were tested according to the standard test procedure of AASHTO. The Asphalt Institute recommends the use of 4 to 8% filler in bituminous concrete. The bituminous mixes are properly designed to satisfy the design requirements of the stability and durability. The mixture contains dense grading of coarse aggregate, fine aggregate and mineral filler coated with bitumen binder. The mineral filler passing through 0.075 mm sieve performs some important roles in bituminous mixes. Marshall Stability of bituminous mix increases as the amount of filler increases. The Marshall method of mix design was used for the comparison. The percentage of air voids were found to be decreased with the increase of bitumen content.**

Keywords: Bituminous paving mixes, Cement, Filler, Marshall Mix design

1 INTRODUCTION

Highway construction activities have taken a big leap in the developing countries since last decade. Construction of highway involves huge outlay of investment .Basically, highway pavements can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These can be either in the form of pavement surface treatments (such as a bituminous surface treatment (BST) generally found on lower volume roads) or, HMA surface courses (generally used on higher volume roads such as the Interstate highway network). These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this "flexing". On the other hand, rigid pavements are composed of a PCC surface course. Such pavements are substantially "stiffer" than flexible pavements due to the high modulus of elasticity of the PCC material. Flexible pavements being economical are extensively used as far as possible. A precise engineering design of a flexible pavement may save considerable investment; as well as reliable performance of the in-service highway pavement can be achieved..

1.1 Objectives of bituminous paving mix design

The overall objective of the design of bitumen pavement mixtures is to determine an economical blend of stone aggregate, sand and fillers such as fly ash and brick dust that yields a mix having · Sufficient bitumen to ensure a durable pavement. · Sufficient mix stability to satisfy the demands of traffic without distortion or displacement. · Sufficient void in total compaction mix to allow for a slight amount of additional compaction and traffic loading without flushing bleeding and lost of stability yet low enough to keep out harmful air and moisture. · Sufficient workability to permit sufficient placement of the mix without segregation .

1.2 Functions of different highway materials

Coarse aggregate : The coarse aggregate should have good crashing strength, abrasion value, impact value. Its function is to bear stresses coming from wheels. It has a resist wear due to abrasive action of traffic.

Fine aggregate : It shall be fraction passing 600 microns and retained on 75 microns sieve consisting of crushed stone or natural sand. Its function is to fill up the voids of the coarse aggregate.

Fillers: The fillers should be inert materials which pass 75 micron sieve. Fillers may be limestone dust, cement, stone dust, brick dust, fly ash or pond ash and its function is to fill up the voids.

Bitumen: It is used as a binding material as well as water proofing material

1.2.1 Aggregate for bitumen mixes: The mineral aggregates most widely used in bitumen mixes or crushed stone, slag, crushed or uncrushed gravel, sands and mineral fillers. Since mineral aggregates constitutes of approximately 88% to 96% by weight and approximately 80% by volume of the total mix. Their influence upon the final characteristics of bituminous mixes is very great.

1.2.2 Desirable aggregate characteristics: The choice of an aggregate for use in bitumen construction depends upon the aggregates availability, their cost and the type aggregate for use in bitumen constructions should have the following characteristics:

· Gradation and size appropriate to type of constructions , Strength and toughness , Cubical shape , Low porosity Proper surface texture ,Hydrophobic characteristic

a.Gradation and size: One of the most important aspects of an aggregate affecting the stability and working properties of a mix is the gradation. Maximum aggregate size also has a great effect upon workability and density of bituminous mixtures. It is also observed that use of a maximum aggregate greater than 1 micron in graded mixture often results in harsh or non-workable bituminous mixtures that tend to segregate in the handing operation. This result in pavement surface that have an objectionable surface voids which may lead to raveling. The dense graded mix used in this project includes appropriate amount of all sizes from coarse to fine including the dust of the materials. Dense

graded mixes tend to have large number of points of contact between individual aggregate pieces resulting in high frictional resistances.
The gradation aggregates used in this project are as per IRC grading 2 as given in the following table (MORTH: Specifications for Road and Bridge works 2003)

Table-1 IRC Grading 2 for bituminous concrete mixes

Grading	2
Nominal aggregate size	13mm
Layer thickness	30-45mm
I.S sieve	Cumulative percent by weight of total aggregate passing .
19	100
13.2	79-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	34-48
0.6	26-38
0.3	18-28
0.15	12-20
0.075	4-10
Bitumen content by mass of total mix	5.0-7.0
Bitumen Grade (penetration)	80/100

b.Strength& Toughness: The aggregate in bituminous mixtures supplies most of the mechanical stability. It supports the load imposed by the traffic and at the same time distributes this loads to a sub-base at a reduced intensity. The aggregate used in bituminous mixes tend to break or degrade by the loads imposed upon them during construction and later by the action of traffic. Degradation may take place by compression failure from a concentrated load at points of contact between aggregate particles and by abrasion action by the individual pieces move with respect to others. The amount of the gradation is affected by both magnitude of the applied loads and the resistance of crushing and abrasion aggregates.
c.Particle shape: Irregular angular pieces when compacted tend to interlock and this possesses a mechanical resistance to displacement. This interlock is best obtained by cubicle particles. The stability of open type mixes where the coarse aggregates is in only contact at few points is almost entirely due to effects of mechanical interlock regardless of the grading of the aggregates for those mixes containing fine and coarse aggregates , the angularity of fine aggregate is more important to mixture stability than angularity of the coarse aggregate . Addition of the crushed fine aggregate is as low as 25% based on total fine aggregate.
1.3 Scope of project In order to achieve the desirable engineering properties of bituminous paving mixes mainly in form of Marshall test results it has been planned to carry out the project in the following phased manner.
· IRC grading 2 with stone aggregates from 19 mm to 600 micron, granulated blast furnace slag from 600 micron to 75 micron and fly ash/ brick dust constitute the aggregate grading.
· Bitumen 80/100 has been used as an alternative to 60/70 as used in case of normal paving mixes. ·
Bitumen content has been varied depending on the type of filler till changes in the trend of Marshall Properties are observed.
· Mixing and Compaction temperature of bitumen has been decided based on viscosity tests on 80/100 bitumen at various temperatures.

2 METHODOLOGY

This Research consists of three stages: characterizing the material, designing mixtures for the two different fillers and suitability of fillers in the bituminous mixtures. In the first step, properties of bitumen, fillers and aggregates were established while in second step, optimum bitumen content for each of these mixtures was determined according to Marshall Mix design method, and in the third level, suitability of different fillers was evaluated.

Conventional bitumen grade VG10 is used in the present laboratory work .For the preparation of bituminous mixes ,aggregate gradation is done according to the MORT&H specifications Gradation should be within the limits as per MORT&H .The sieves are arranged with one another according to the size.About 2.5 to 3kg of aggregates are then sieve through various sizes. The percent passing through each siev es is observed. When tested, the combined grading of coarse and fine aggregates and for the specific mixture shall be within the limits.

3. EXPERIMENTAL INVESTIGATION

3.1. TESTS ON BITUMEN:

3.1.1. Penetration

Table No 2. Results of penetration test of Bitumen 80/100

Sample	Reading-1	Reading -2	Reading-3	Reading-4	Final Average
1	104	84	81	89.67	85.33
2	89	84	70	81.60	

3.1.2.Softening point test

Table .3. Results of Softening Point test

Specimen no(80/100)	Softening point(^{0} c)	Average
1	48	47
2	46	

3.1.3. Specific gravityGrade 80/100=1.03.

3.1.4. Ductility= 75 cm

3.2. TESTS ON AGGREGATES:

3.2.1. CRUSHING TEST:

S.no	Total weight of dry sample(w1gms)	Weight of sample retained on 2.36 sieve	Weight of passing 2.36 i.s seive (w2 gms)	Aggregate crushing value(w2/w1 *100)
1	2827	2337	490	13.01
2	2740	2256	484	13.03
			AVG	13.02

The aggregate crushing value of the given sample=13.02%

3.2.2. IMPACT TEST:

S. no	Total weight of dry sample (w 1 gms)	Weight of sample retained on 2.36 sieve	Weight of passing 2.36 i.s seive (w2 gms)	Aggregate impactvalue(w2/w1 *100)
1	320	262	60	14
2	310	245	65	14.6
			AVG	14.3

3.2.3.ELONGATION INDEX

SEIVE SIZE (mm)	PASSING(gm)	RETAINED (gm)
6.3-9.5	165.2	169.2
9.5-13.2	670.4	13.2
13.2-19	382.8	540
>19	1194	456.4
Total	Passing:2412.4 g	Retained:1308.8 g

Elongation = T. retained x 100/T.weight=1308.8 x 100/3721.2 = 35.17%

3.2.4. FLAKINESS INDEX

SEIVE SIZE (mm)	PASSING(gm)	RETAINED (gm)
6.3-9.5	30	284.4
9.5-13.2	184.4	635.6
13.2-19	177.2	725.2
Total	Passing: 909.6	Retained:2697.6 g

Flakiness index = 909.6 x 100/ 3607.2 = 25.21%

3.2.5. Specific gravity of an aggregate= 2.64

3.3. BITUMEN CONCRETE MIX DESIGN

Figure 3.1: Marshall Apparatus Setup

Table 4: Calculation of quantity of aggregates (having fly ash as filler)

Sieves (mm)	Material	5%Bitumen	5.5%Bitumen	6%Bitumen	6.5%Bitumen
19	**Stone chip**	**125**	**125**	**124**	**124**
13.2		**114**	**113**	**113**	**113**
9.5		**194**	**193**	**192**	**191**
4.75		**137**	**136**	**135**	**134**
2.36		**102.5**	**102**	**101.5**	**101**
1.18	**slag**	**102.5**	**102**	**101.5**	**101**
0.6		**102.5**	**102**	**101.5**	**101**
0.3		**80**	**79.5**	**79**	**78.5**
0.15	**Fly ash**	**102.5**	**102**	**101.5**	**101**
0.075		**80**	**79.5**	**79**	**78.5**
Total Aggregate		**1140**	**1134**	**1128**	**1122**
Bitumen		**60**	**66**	**70**	**78**

Table 5: Calculation of Quantity of Aggregates (Having Brick Dust As Filler)

Sieves (mm)	Material	5% Bitumen	5.5% Bitumen	6% Bitumen	6.5% Bitumen	7% Bitumen	7.5% Bitumen
19	**Stone chip**	**125**	**125**	**124**	**124**	**123**	**121**
13.2		**114**	**113**	**113**	**113**	**112**	**110**
9.5		**194**	**193**	**192**	**191**	**190**	**188**
4.75		**137**	**136**	**165**	**134**	**134**	**132**
2.36		**102.5**	**102**	**101.5**	**101**	**100**	**100**
1.18	**slag**	**102.5**	**102**	**101.5**	**101**	**100**	**100**
0.6		**102.5**	**102**	**101.5**	**101**	**100**	**100**
0.3		**80**	**79.5**	**79**	**78.5**	**78**	**76.5**
0.15	**Brick dust**	**102.5**	**102**	**101.5**	**102.5**	**101**	**101.5**
0.075		**80**	**79.5**	**79**	**78.5**	**78**	**76.5**
Total Aggregate		**1140**	**1134**	**1128**	**1122**	**1112**	**1104**
Bitumen		**60**	**66**	**70**	**78**	**88**	**96**

Table 6: Calculation of quantity of bitumen

percentage	Quantity of bitumen required
0.5	1200-1146=54
1.0	1200-2240=60
1.5	1200-1134=66
2.0	1200-1128=72

4. MARSHALL TEST RESULTS

Table: 7: Results of Marshall test(Specimens with fly ash)

Bitumen (80/100)	Sample no	Weight in air	Weight in water	Flow value (mm)	stability	G_t	Unit wt (g/cc)	% air voids	VMA

5	1	1176	608.2	1.7	2080	2.25	2.07	8.69	18.74
	2	1182	618.1	1.9	2000		2.1	7.14	17.33
	3	1066	548.2	1.9	2220		2.06	9.2	19.2
	4	1172	611.5	2.2	1305		2.09	7.65	17.79
5.5	1	1182	623.3	2.4	2140	2.23	2.1	6.6	17.41
	2	1170	614.5	2.2	1910		2.09	6.69	17.85
	3	1174	616.5	2.7	2570		2.09	6.69	17.85
	4	1142	599.1	2.4	2380		2.08	7.21	18.31
6	1	1198	628.6	2.7	2000	2.19	2.1	4.28	16.51
	2	1164	612.5	3.1	2800		2.11	3.79	16.08
	3	1174	616.1	2.5	2500		2.1	4.28	16.51
	4	1182	619.5	2.9	2550		2.1	4.28	16.51
6.5	1	1098	570.4	3.3	2190	2.17	2.08	4.32	17.44
	2	1084	570.1	3.4	1970		2.1	3.33	16.58
	3	1082	564.1	3.8	2400		2.05	4.58	17.58
	4	1081	560	3.7	2100		2.06	4.59	16.55

Table 8: Average Marshall Properties of samples with fly ash

Bitumen (%)	5	5.5	6	6.5
Marshall properties				
Stability (kN)	18.64	22.07	23.53	21.39
Flowvalue (mm)	1.95	2.4	2.8	3.5
Unit wt (g/cc)	2.08	2.09	2.1	2.07
% air void	8.17	6.69	4.18	4.5
VMA (%)	18.27	17.88	16.41	17.6

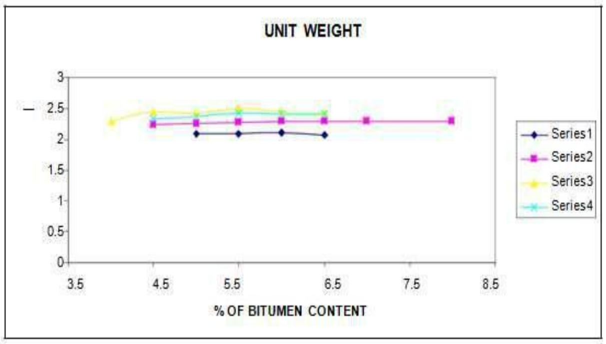
Table 9:Test results of Marshall Specimens (with brick dust as filler)

Bitumen (80/100)	Sample no	Weight in air	Weight in water	Flow value (mm)	Stability	G_t	Unit wt (g/cc)	% air voids	VMA
4.5	1	1194	661	1.8	1660	2.45	2.24	9.4	19.2
	2	1150	645	1.4	2016		2.27	7.9	17.78
	3	1180	651	1.6	1527		2.23	9.8	19.5
	4	1215	672	2.6	1558		2.24	9.4	19.15
5	1	1201	652	2.2	1581	2.44	2.24	8.9	19.6
	2	1201	658	2.6	1821		2.28	7.0	18.03
	3	1203	648	2.2	1788		2.29	6.6	17.72
	4	1200	653	2.5	1619		2.26	7.9	18.87
6	1	1204	656	3.6	1958	2.41	2.27	6.2	19.4
	2	1203	654	2.8	1833		2.26	6.6	19.76
	3	1189	653	3.2	1805		2.28	5.7	18.98
	4	1189	652	3.2	1826		2.28	4.8	18.3
6.5	1	1204	679	3.1	1938	2.4	2.29	4.8	19.2
	2	1190	666	4.0	1896		2.27	5.7	19.98
	3	1183	665	3.9	2144		2.28	5.2	19.54
	4	1196	676	3.9	1889		2.03	4.3	18.77
7	1	1217	688	3.9	2267	2.39	2.3	3.9	19.48
	2	1201	679	4.8	2035		2.3	3.9	19.48
	3	1179	659	4.3	2189		2.27	5.3	20.68
	4	1191	681	4.3	2033		2.33	2.5	18.33
8	1	1203	707	5.3	1972	2.38	2.33	2.14	20.18
	2	1191	679	5.4	1888		2.33	2.14	20.18
	3	1216	715	5.2	1962		2.33	2.14	20.18
	4	1288	695	5.1	18.95		2.31	3.03	20.90

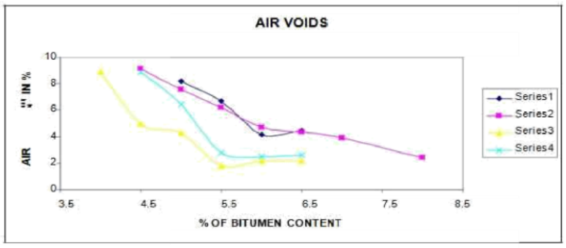
Table 10: Average Marshall properties of sample with brick dust

Bitumen (%) Marshall properties	4.5	5	6	6.5	7	8
Stability (KN)	15.69	16.67	18.35	19.42	20.6	17.66
Flow value (mm)	1.8	2.4	3.2	3.73	4.57	5.3
Unit wt (g/cc)	2.245	2.27	2.27	2.29	2.3	2.33
% air void	9.13	7.6	6.2	5	3.9	2.4
VMA (%)	19.91	18.35	19.35	19.8	19.5	20.4

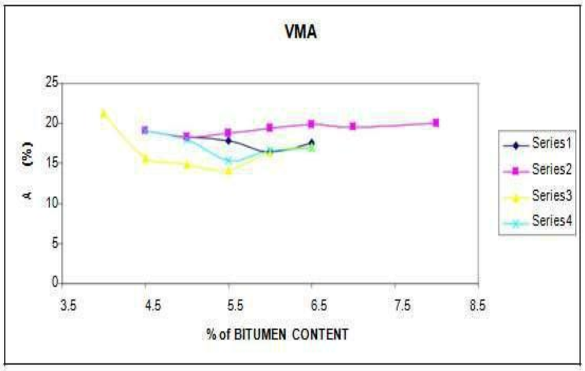
4.1 Marshall Unit weight curves



4.2 Marshall air void(%) curves



4.3 Marshall VMA(%) curves



5.CONCLUSIONS

1. Bituminous mixes containing fly ash and brick dust as fillers are found to have Marshall Properties almost nearly same as those of conventional fillers such as cement and lime.
2. Bituminous mixes containing fly ash as filler displayed maximum stability at 6% content of bitumen having an increasing trend up to 6% and then gradually decreasing, the unit weight/ bulk density also displayed a similar trend with flow value being satisfactory at 6% content of bitumen.
3. Bituminous mixes containing brick dust as filler showed maximum stability at 7% content of bitumen displaying an ascending trend up till 7% and then decreasing, the flow value showed an increasing trend and similar was the trend shown by unit weight/bulk density, the percentage of air voids obtained were seen to be decreasing with increase in bitumen content thus from here we can see that at 7% bitumen content we are obtaining satisfactory results.
4. These mixes were seen to display higher air voids than required for normal mixes.
5. Higher bitumen content is required in order to satisfy the design criteria and to get usual trends.
6. From the above discussion it is evident that with further tests fly ash and brick dust generated as waste materials can be utilized effectively in the making of bitumen concrete mixes for paving purposes. 7. Further modification in design mixes can result in utilization of fly ash and brick dust as fillers in bituminous pavement thus partially solving the disposal of industrial and construction wastes respectively.
8. Though cement and stone dust being conventional fillers however fly ash and brick dust can be utilized in their place effectively thus solving the waste material disposal substantially resulting in utilization of industrial space being consumed in disposal of industrial wastes
9.The cost effectiveness of these non conventional filler specimens can be realized after performing a cost analysis of these non conventional materials against the conventional specimens resulting in reduction of the construction costs considerably.
10. It is evident that with further tests fly ash and brick dust generated as waste materials be utilized effectively in the making of bitumen concrete mixes for paving purposes.

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