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Experimental Investigation of Bituminous Mixes Using Fly Ash as Filler Material

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Abstract: **The effect of addition of fly ash (as replacement of filler) in bituminous concrete mix on the rutting performance of the mix has been evaluated in the study. Different percentages of stone dust were replaced by fly ash to modify the bituminous mixes. Strength and durability tests like Marshall Stability Test, Retained stability and Static Creep Tests were conducted on unmodified or modified mixes and the results were analyzed and compared. Rheological properties of extracted binder from bituminous concrete mixes were evaluated and analyzed for rutting performance based on value of G*/ Sin(δ). The study indicated that increase the percentage of fly ash as filler material by replacing from stone dust, improves the rutting resistance and moisture susceptibility of bituminous concrete mixes.**

1. INTRODUCTION

Fly ash is one of the residues formed in combustion and consists of the fine particles that rise with the flue gases. It is a waste material and is dumped on the land. In India, 95 million ton of fly ash is generated every year which has occupied approximately 65,000 acres of land. Coal requirement and generation of fly ash estimated for the year 2031-2032 is around 1,800 million ton and 600 million ton respectively (MOST-2010). From the above figures, it is clear that there is huge amount of unused fly ash which has to be disposed of each year. Highway industry is capable of using waste material in large quantities if their effect on pavement performance proves to be technically, economically and environmentally satisfactory. Fly ash has successfully been used as filler for bitumen mixes for a long time and has the advantage of increasing the resistance of bitumen mixes to moisture damage. In addition to filling voids, fly ash was reported to have the ability to work as a bitumen extender [6].

2. METHODS AND MATERIALS

Fly ash was used as filler material replaced by stone dust at different percentage (0%, 50% and 100%) and prepared Marshall sample with different percentage of binder.

2.1 Fly ash

Class F type fly ash was used as filler material with specific gravity of 2.09.

Table 1. Grain size analysis (used hydrometer)

Sieve (μ)	72.3	53.2	41.6	11.2	6.9
% finer	19.35	17.2	15.01	13.8	12.4

Table 2. Chemical Composition of Fly ash

Compounds	SiO_2	Al_2O_3	K_2O	Fe_2O_3	CaO	O_2
% in mass	37.76	36.66	1.2	3.6	4.78	16

2.2 Aggregates

Basic physical tests were performed on the aggregates which have been used in preparation of mix to check their suitability.

Table 3. Physical Properties of Aggregates

Parameters	Test Method	Result	Specification
Water absorption	IS 2386-part 3	0.7%	Max 2%
Aggregate Impact value	IS 2386-part 4	12%	Max 24%
Aggregate Crushing Value	IS 2386-part 4	14%	Max 30%
Flakiness and Elongation Index	IS 2386-part 1	27%	Max 40%
Specific gravity	IS 2386-part 1	2.7	……..
Los Angeles Abrasion value	IS 2386 part 4	12.5%	Max 30%
Stripping value	ASTM D3635-96	2-3%	Max 5%

2.3 Binding Material

Viscosity graded binder VG 40 was selected for the present study. Different physical and consistency properties of the selected binder were determined as per relevant Indian standards.

Table 4. Test results on binder (VG 40)

Parameters	Test Method (BIS	VG 40	
		Result	Spec.
Absolute viscosity at 60^0C, poise	1206 (part 2)	3600	Min 3200
Kinematic viscosity @ 135^0C	206 (part 3)	697	Min 400
Penetration at 25^0C, 100g,5sec,0.1mm	1203 (1978)	38	30-40
Softening point (R & B),^{0}C	1205 (1978)	57	Min 50

2.4 Marshall Mix Design

Mixing and compaction temperatures play an important role in the mix design of bituminous mixes. BC-I gradation was selected for present study.

Table 5. Mixing and Compaction temperature

Binder	Mixing Temperature (^{0}C)	Compaction Temperature (^{0}C)
VG 40	177	167

3. RESULTS AND DISCUSSION

3.1 Marshall Mixes parameters

Table 6. Values of OBC, Stability and Flow

Type of mix	Fly sh (%)	OBC (%)	Stability (KN)	Flow (mm)
BC	VG 40 +0%	6.0	17.82	4.561
BC	VG 40 +50%	5.9	22.39	3.354
BC	VG 40+100%	5.85	21.42	3.647

3.2 Indirect Tensile Strength

Bituminous mixes were prepared by using VG 40 binder with different proportions of fly ash as filler at 6% constant binder content for all mixes. The indirect strength test was done in static mode.

Table 7. Indirect Tensile Strength at 25^0C

Type of mix	Fly ash %	ITS (kPa) after 30 min.
BC	VG 40 + 0%	1584
	VG 40 + 50%	1245
	VG 40 + 100%	1230

3.3 Moisture Susceptibility of Mixes

MoRTH (2001) prescribes Retained indirect Tensile strength test for determining the moisture susceptibility of Marshall mixes.

Table 8. Indirect Tensile strength (kPa) @ 60^0C

Type of mix	Fly ash %	ITS (kPa) after 30 min.	ITS (kPa) after 30 24 hrs.	Retained ITS (%)
BC	VG 40 + 0%	864.2	734.4	84.9
	VG 40 + 50%	804.6	674	83.7
	VG 40 + 100%	786.09	638.2	81.1

3.4 Rut testing of Bituminous Mixes

The permanent deformation of bituminous mixes was evaluated by static indentation test [5]. All the samples used for this test was made of 6% binder content and was compacted using Marshall Compactor. The test was performed after conditioning the sample in water bath at 60^0C for 90 minutes. An indentation pressure (creep) of 0.7MPa was applied using circular contact areas of 38 mm for 30 minutes and the sample was allowed to recover for the 1 hour after loading. The strains in the sample were measured using a dial gauge, which was having a least count of 0.01mm

Table 9. Static Indentation Results

Type of mix	D_{max}	D_r	(D_r / D_{max}) x 100
VG 40 mix	36	2	5.0
VG 40 + 50 % fly ash filler	32	7	21.8
VG 40 + 100% fly ash filler	20	6	30.0

Figure 1 shows the relation between deformation and time of unmodified and modified bituminous concrete mixes.

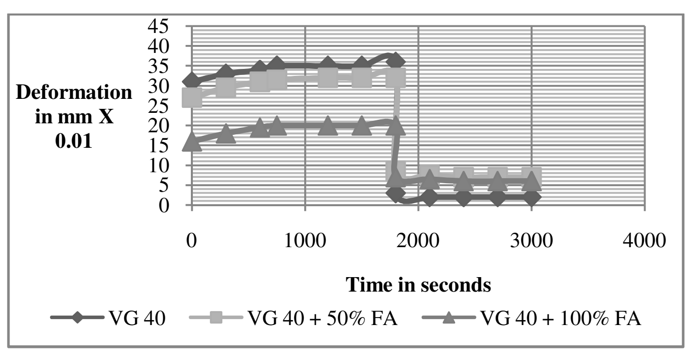

Fig. 1. Plot of deformation with time

3.5 Result of Dynamic Shear Rheometer Test for extracted binder

DSR tests were carried out after extraction of binder (VG 40) from different mixes. Test was carried out on different temperature with constant frequency of 10 rad/sec.

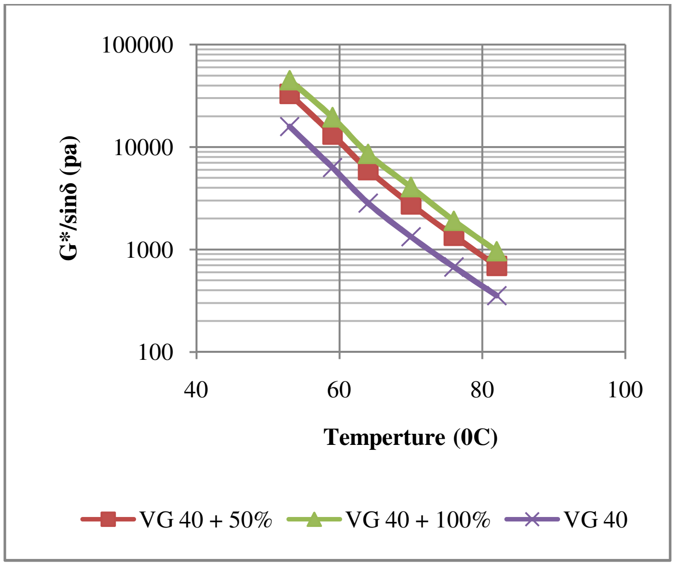

Fig. 2. Variation of $G^*/\sin\delta$ (Pa) versus Temperature

4. CONCLUSIONS

a) From volumetric analysis, it was found that optimum binder content decreases with increase in fly ash content. This tendency might be due to better coating or holding property of binder – filler matrix with coarse aggregates.

b) From Marshall Stability test, the stability value is also found to increase when stone dust filler was replaced the fly ash. The flow values tended to decrease. This indicates improvements in the resistance to permanent deformation of mixes with addition of fly ash.

c) The retained Marshall stability of the mix was found to decrease in mixes prepared using fly ash compared to that of unmodified mix.

d) Dynamic shear and static indentation test conducted on bituminous concrete specimen indicated improved rutting resistance due to addition of fly ash.

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