Experimental Evaluation of Influence of Fly Ash in Bituminous Mixtures

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***Abstract*—Fly ash has been effectively used for many years to produce high-performance concrete with limited asphalt pavements. It is because of the performance benefits which fly ash provides to asphalt mixtures. The present research article demonstrates that fly ash in bitumen materials is a better option because it improves performance and reduces costs. Experimental tests have been analyzed and compared to evaluate the properties of bitumen. The results revealed that fly ash in the bitumen improves performance and increases viscosity at high temperatures. The findings indicate that fly ash may be used as a substitute for traditional filler and as acceptable material for bituminous road construction.**

Keywords: Bitumen, Fly Ash, Road Construction, Pavements

I. Introduction

With the changing lifestyle among different classes of the society, the road network has become one of the essential backbones for the movement as it provides reasonable access for the commuters to travel to their desired place. Over the last 50 years, road transportation expanded radically. Most of the roads constructed in the road network are flexible pavement consisting of soil subgrade, sub-base course, base course, and surface course. The increase of traffic on the road leads to heavy load implications on the pavement by traffic movement. To problems related to pavement distresses, namely irradiate fatigue, excessive rutting, and thermal crack, which causes shorter service life of pavement, many researchers and agencies concerned to look for various efforts that may be practiced for improving the properties of the bitumen. One of the recently received methods is modifying the bitumen with other materials, namely admixtures. The admixtures work as modifiers of bitumen if thoroughly mixed with it, increasing binder properties. These admixtures may directly add to the bitumen mixture as a bitumen modifier or added to the mixture's aggregate. Fly ash has successfully been used as filler for bitumen mixes for a long time, as it's readily available at a cheaper cost compared to other fillers. Several admixtures were utilized for the bitumen modification polymers, such as plastic polymer, fiber polymer, elastomers, ground granulated blast furnace slag, fly ash, rubber, crumb rubber, and natural rubbers. However, modified bitumen produced at higher prices leads to an increase in the economy of the modification process. The present study focuses on material characterization, i.e., evaluating the physical properties of the original binder of viscosity grading (VG 30). Marshall characteristics (such as stability, flow, air voids) of bituminous mix prepared from standard and modified bitumen have been performed.

A research study has concluded that adding fly ash to asphalt surfaces may improve the rutting resistance and stiffness of the tarmac mortar and improve the mixture's toughness. Mechanically precipitate fly-ash as filler for bituminous concrete has been adopted in several studies, which proved better results [1-6]. In traffic studies, the pavement plays a significant role [7-9]. Several studies reported fly ash as a cost-effective mineral filler in hot mix asphalt paving applications [10-13]. The basic properties of fly ash which make it useful for implantation on site are the content of lime contained, which improves the rheological properties of tarmac binder as inert filler. As an inert filler, fly ash imparts a stiffening of the asphalt mixture and enhances resistance to permanent deformation. Fly ash holds an active filler effect, which is the unique ability to reduce age-hardening characteristics of bituminous mixtures by interacting with reactive polar compounds in the binder. Fly ash is also well known and

 ISBN: 978-93-91355-11-1

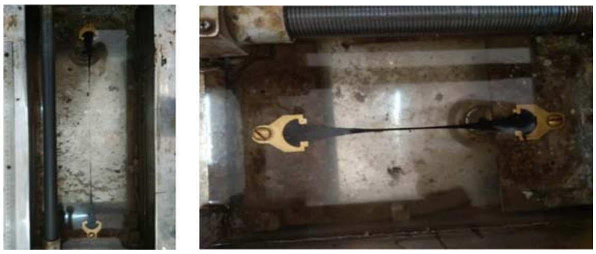
widely used in asphalt to substantially reduce the harmful effects of moisture. Moisture in asphalt promotes loss of strength and loss of aggregate.

The present paper compares the performance of modified bitumen with fly ash as an admixture with that of the original bitumen through laboratory investigation.

II. Result and Discussion

In the present study, a penetration test has been conducted, which measures the strength or hardness of the bitumen. A ductility test was conducted to measure the hardness of the asphalt. Specific gravity test and marshall stability test have been performed, as shown in Fig.1. The results of the various tests performed have been concluded in the tables. The properties of modified and unmodified bitumen have been shown in Table 1. The specific gravity of the fly ash has been tabulated in Table 2.

(a) Penetration Tests



(b) Ductility Tests

Fig. 1: (a & b): Laboratory Testing

Table 1. Properties of Modified and Unmodified Bitumen

Test	Modified Bitumen			Unmodified
	4% Fly Ash	6% Fly Ash	8% Fly Ash	
Penetration	45.1mm	38.4 mm	31.4 mm	63.5 mm
Ductility	48.1cm	40.04 cm	37.6 mm	100+
Specific Gravity	1.08 mm	1.10	1.10 mm	1.04

Table 2: The Specific Gravity of the Fly Ash

Sample	1	2	3
w_1	123.24	107.5	123.4
w_2	163.24	147.69	163.2
w_3	392.75	376.72	392.5
w_4	371.42	355.75	372.3

From above table

w_1= weight of the empty flask

w_2= weight of empty flask + fly ash

w_3= weight of empty flask + fly Ash + Full water

w_4= weight of empty flask + full water

$$\text{This specific gravity} = \frac{(w_2 - w_1)}{(w_4 - w_1) - (w_3 - w_2)}$$

The average specific gravity of fly ash has been calculated as 2.07. For the modified bitumen specimen, the ratio of fly ash with a quantity of 4%, 6%, and 8% to the equal weight of bitumen was used. In this preheated fly ash by oven storage at 170°C for 24 hrs has been carried out. The bitumen of grade VG 30 was heated to the temperature of 150°C before adding fly ash and which was kept for 15 minutes at a constant temperature of 150°C. Marshall mix characteristics of bituminous mixes were carried out by evaluating the cylindrical sample of 100 mm diameter. Characteristics of a marshall mix using standard bitumen have been tabulated in Table 3. The values for various marshall parameters were evaluated, and the relationship between original and modified bitumen has been concluded.

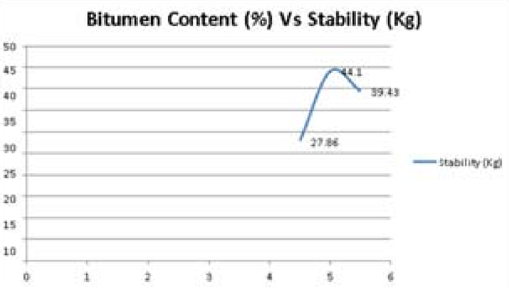
Table 3: Characteristics of a Marshall Mix using Standard Bitumen

Bitumen Content (%)	Unit Density (gm)	Air void (%) (Vv)	VFB (%)	Stability (Kg)	Flow (mm)
4.5	2.291	4.7	79.65	27.86	6
5	2.296	4.1	82.36	44.1	8.5
5.5	2.87	3.6	83.39	39.43	10.7

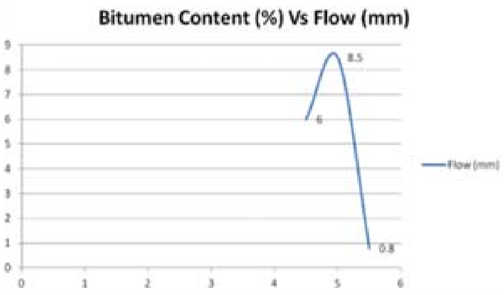
Results of the various performed tests have been illustrated in Fig. 2 (a-t), which reveals that, with the increases in fly ash content, marshall stability values become higher. The results showed that the amount of fly ash increased in a binder, resulting in a change in its properties and increasing shear resistance. With the increase in the fly ash in bitumen, the growth of the void in the mix occurs. The results revealed that with the rise in fly ash in the binder, there is a decrease in VFB.

Table 4. Characteristics of a Marshall Test Using Modified Bitumen

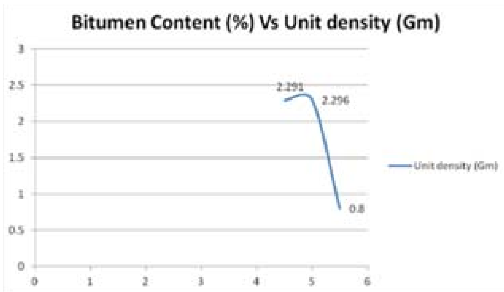
Bitumen Content (%)	Fly Ash Content (%)	Unit density (Gm)	Air void (%) (Vv)	VFB (%)	Stability (Kg)	Flow (mm)
4.5	4	2.30	11.9	58.73	55.8	6
4.5	6	2.285	12.7	55.973	69.2	6.5
4.5	8	2.264	13.4	55	76.1	7.9
5	4	2.40	7.6	68.94	60.53	4.3
5	6	2.35	8.1	68.24	70.72	5.4
5	8	2.35	9.1	64.48	74.8	6.2
5.5	4	2.35	9.2	65.05	70.73	3.24
5.5	6	2.32	9.6	63.27	75.83	4.2
5.5	8	2.295	11.3	58.90	78.1	6.1



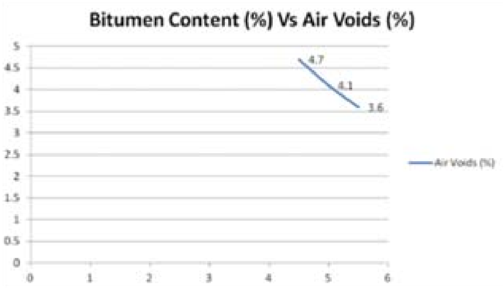
(a) Marshall Stability Value



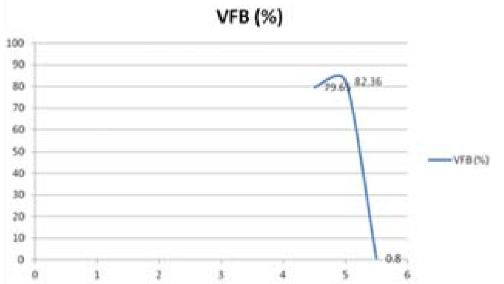
(b) Marshall Flow Value



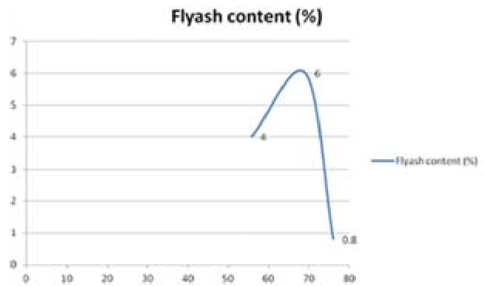
(c) Unit Density of the Bituminous Mix



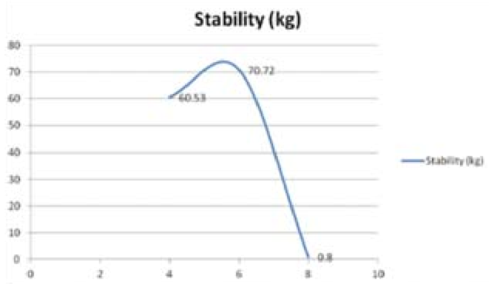
(d) Percentage Air Voids in Bituminous Mix



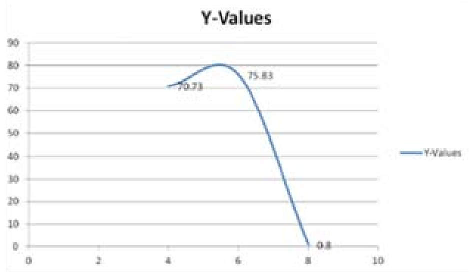
(e) Percent Voids Filled with Bitumen in the Mix



(f) Stability of Bituminous Mix With 4.5% Bitumen

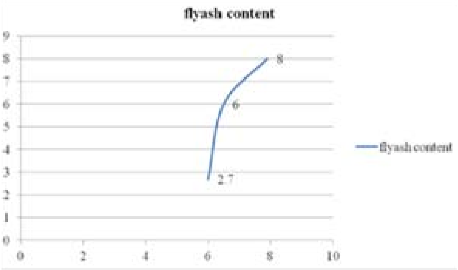


(g) Stability of Bituminous Mix With 5% Bitumen

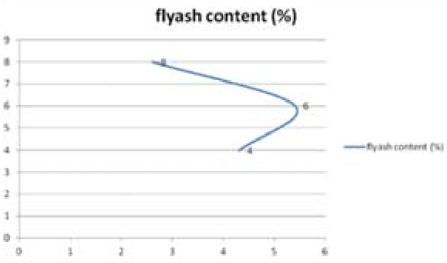


(h) Stability of Bituminous Mix With 5.5% Bitumen

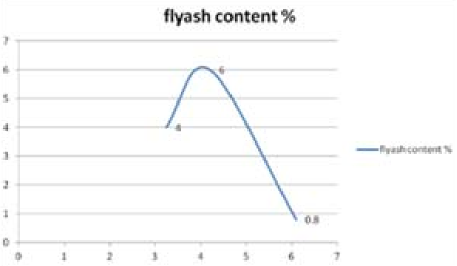
ISBN: 978-93-91355-11-1



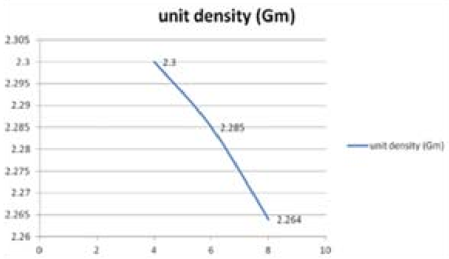
(i) Flow Bituminous Mix With 4.5% Bitumen



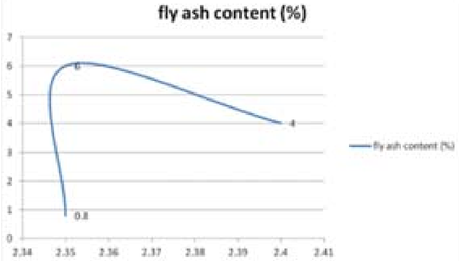
(j) Flow Bituminous Mix with 5% Bitumen



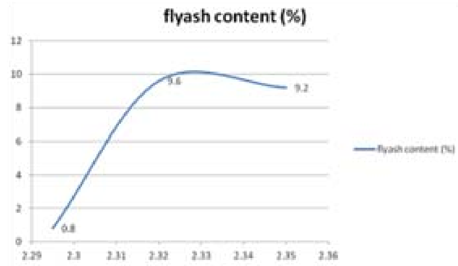
(k) Flow Bituminous Mix in 5.5% Bitumen



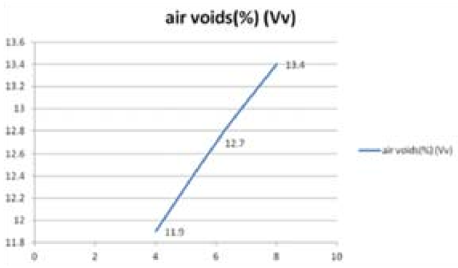
(l) Unit Density of Bituminous Mix With 4.5% Bitumen



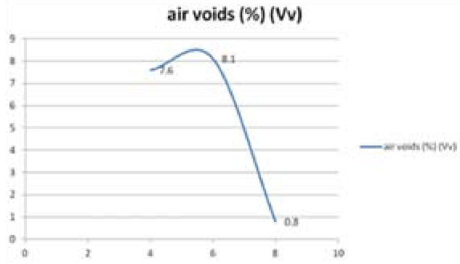
(m) Unit Density of Bituminous Mix With 5% Bitumen



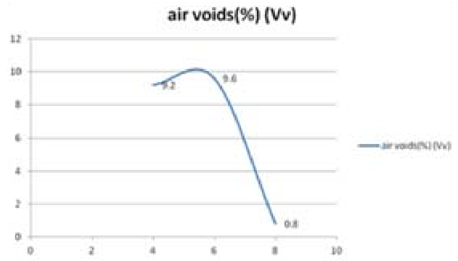
(n) Unit Density of Bituminous Mix With 5.5% Bitumen



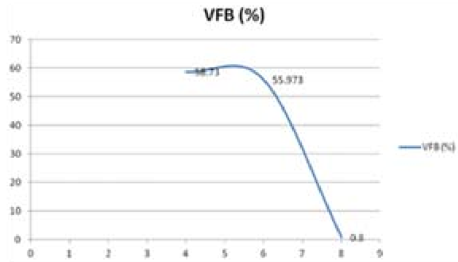
(o) Percent Air Voids of Bitumen Mix With 4.5% Bitumen



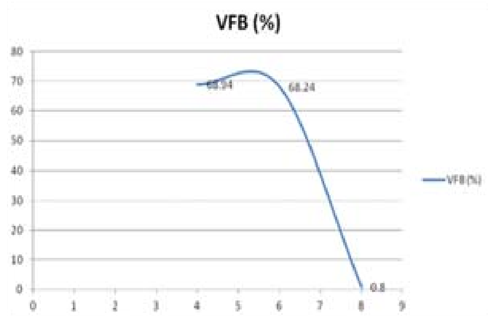
(p) Percent Air Voids of Bituminous Mix With 5%



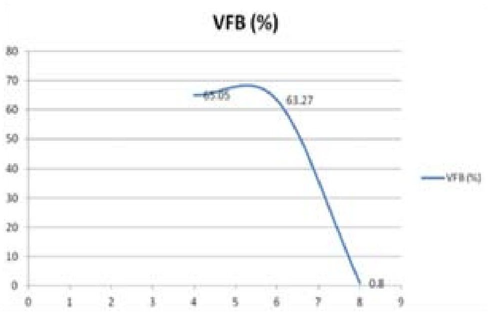
(q) Percent Air Void of Bituminous Mix With 5.5%



(r) VFB of Bituminous Mix With 4.5% Bitumen



(s) VFB of Bituminous Mix With 5% Bitumen



(t) VFB of Bituminous Mix With 5.5% of Bitumen

Fig. 2: (a-t) Results of Tests

III. Conclusions

The study was conducted on standard and the modified bitumen using fly ash in different quantities. The study results revealed that with the increase in fly ash, the ductility value decreases, due to which the bitumen becomes stiffer. The tests were performed by adding varying percentages of fly ash, which gives less penetration value, revealing that the lower grade bitumen may be modified to tackle the higher loads. The marshall stability test showed that as fly ash content increased, the stability values constantly increases. Fly ash has been used to fill voids between the aggregates grains, outcomes of which revealed that the mix continuously gained strength, leading to an increase in the bituminous mix's stability. In the modified binder, the density of final bituminous mixtures decreased as the fly ash content in bitumen increases. Also, the trend of the graphs revealed the marshall flow value increases as per the percentage of fly ash in the binder, resulting in the improvement in the resistance to permanent deformation of bituminous mixes with the addition of fly ash.

References

[01] Sobolev, K., Vivian, I. F., Saha, R., Wasiuddin, N. M., Saltibus, N. E.: The effect of fly ash on the rheological properties of bituminous materials. Fuel, 116, 471─477 (2014).

[02] Mistry, R., Roy, T. K.: Effect of using fly ash as alternative filler in hot mix asphalt. Perspectives in Science, 8, 307─309 (2016)

[03] Yan, K., Li, L., Ge, D.: Research on properties of bitumen mortar containing municipal solid waste incineration fly ash. Construction and Building Materials, 218, 657─666 (2019)

[04] Sharma, V., Chandra, S., Choudhary, R.: Characterization of fly ash bituminous concrete mixes. Journal of Materials in Civil Engineering, 22(12), 1209─1216 (2010)

[05] Sobolev, K., Flores, I., Bohler, J. D., Faheem, A., Covi, A.: Application of fly ash in ASHphalt concrete: from challenges to opportunities. In Proceedings of the World of Coal Ash Conference, Session: Cement and Concrete VI. (2013)

[06] Mistry, R., Roy, T. K.: Performance evaluation of bituminous mix and mastic containing rice husk ash and fly ash as filler. Construction and Building Materials, 268, 121187 (2021)

[07] Poddar, A., Kumar A.: Public Transportation System Reliability and Safety (Challenges and Opportunities in Public Transportation), Lambert Academic Publishing (2021)

[08] Kumar, A.: Traffic Characteristics and Junction Improvement (Relationship Between Traffic Conflicts and Accidents), Lambert Academic Publishing (2021)

[09] Kumar, A.: Traffic Studies for Junction Improvement of Major Roads in Jalandhar City. Engineering Research and Applications, 1, 245─248 (2016)

[10] Woszuk, A.: Application of fly ash derived zeolites in warm-mix asphalt technology. Materials, 11(9), 1542 (2018)

[11] Saride, S., Avirneni, D., Javvadi, S. C. P., Puppala, A. J., Hoyos, L. R.: Evaluation of fly ash treated reclaimed asphalt pavement for base/subbase applications. Indian Geotechnical Journal, 45(4), 401─411 (2015)

[12] Choi, M. J., Kim, Y. J., Kim, H. J., Lee, J. J.: Performance evaluation of the use of tire-derived fuel fly ash as mineral filler in hot mix asphalt concrete. Journal of Traffic and Transportation Engineering (English Edition), 7(2), 249─258 (2020)

[13] Woszuk, A., Bandura, L., Franus, W.: Fly ash as low cost and environmentally friendly filler and its effect on the properties of mix asphalt. Journal of Cleaner Production, 235, 493─502 (2019)

ISBN: 978-93-91355-11-1