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Research Article

Influence of Fly Ash as Mineral Filler in Bituminous Mix Design

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Abstract

This study is about the effect of fly ash as filler on bituminous mix design under various condition. The main purposes of this project is to study the possibility of using fly ash as mineral filler in bituminous paving mixes where in general stone dust are used. Fly ash from Barapukuria Coal Power Plant has been used in the present experimental work. Suitable aggregate grading is selected for bituminous mixes. Standard Marshall Mix design procedure is followed in the design by using standard filler stone dust and testing of those mixes to determine the density, stability, flow, voids in mixes and optimum bitumen content. By this optimum bitumen content, mixes are prepared by replacing standard filler stone dust with fly ash at levels 25%, 50%, 75% and 100% by weight of total filler. The mixes are tested to obtain optimum fly ash content. By fixing optimum bitumen content and fly ash content mixes are prepared to observe the effect of water submergence on compacted mixes where compacted mixes are submerged in water for 5, 10, 15 and 20 days. In this study, it is found that 25% fly ash and 75% stone dust by total weight of filler satisfy the mix design criteria for medium traffic condition. So 25% fly ash by total weight of filler can be used as optimum. Again, compacted mixes, prepared using optimum fly ash content and optimum bitumen content, can be submerged in water for 10 days at room temperature. So compacted mixes, prepared using 25% fly ash by total weight of filler and 5.56% OBC, are suitable for flood plain areas where roads are submerged in water for 10 days.

Keywords: Optimum Bitumen Content; Optimum Fly Ash content; Stone Dust; Water Effect

Abbreviations: AASHTO: American Association of State Highway and Transportation Officials; BS: British Standard; CA: Coarse Aggregate; FA: Fine Aggregate; MF: Mineral Filler; OBC: Optimum Bitumen Content; Va: Voids in total Mix; VMA: Voids in Mineral Aggregate; VFB: Voids Filled with Bitumen

Introduction

The surface coarse of flexible pavement normally comprises of coarse aggregate, fine aggregate and filler heated to suitable temperature, mixed thoroughly with heated bitumen at required viscosity and then compacted [1]. One of the major concerns of mix design of bituminous mix is the type and amount of filler used which may affect the performance of the mix. Various studies have been conducted to study properties of mineral filler, generally the material passing 0.075mm IS sieve, to evaluate its effect on performance of asphalt paving mix in terms of consistency, void filling, Marshall Stability and mix strength. Fly ash is one of the major wastes by products of coal based thermal power station [2-5]. This waste is mostly disposed by coal-based thermal power plant in the form of refuse in piles and behind embankment type retaining structures. At present, with the expectation of small scales underground waste disposal operations in abandoned coal mines, most of this waste is disposed at the surface which inevitably requires excessive planning and control of minimize the environmental impact of mining. It also results in non-productive use of land, air and water pollution, possible failure of waste embankments and loss of aesthetic value of the land.

In recent years various research studies on fly ash have been conducted to analyze the possibility of utilization of these ashes. Hence, in this study, an attempt has been made to explore the use of fly ash passing 0.075mm sieve and has been considered to be filler in bituminous paving mixes by studying various fundamental engineering properties [6]. In recent years various researches have been conducted to use fly ash as mineral filler in bituminous mix design. Sankaran and Rao [7] made a comparison of fly ash with other fillers. They pointed out that fly ash at 2% filler content provided the highest stability among the other filler. Henning

[8] investigated the effect of a class C fly ash on asphalt mixture properties and concluded that the addition of 4% fly ash resulted in the higher stability and flow but ended up with low air voids. Rosner et al. [9] used fly ash as mineral filler and anti-stripping agent for asphalt concrete mixtures and showed that retained strengths of samples increased as additional fly ash was used in the prepared mixtures.

Tapkin. showed that fly ash can be used effectively in a densed-graded wearing course as a filler replacement. Konstantin et al. studied on feasibility of fillers in asphalt concrete using two different binders. These binders were fully blended with filler materials i.e. fly ash, lime and cement [10]. The study result demonstrated that rheological properties of the asphalt were greatly improved with the addition of these fillers. Fly ash also appears in improving the aging resistance of mastics. With the addition of fillers, compatibility of mixtures was not affected Kar et al. represented the influence of fly ash as a filler as a filler in bituminous mixes that the mixes with fly ash as filler exhibits marginally inferior properties compared to control mixes and satisfy desired criteria specified by a much higher margin. They recommended to utilize fly ash wherever available, not only reducing the cost of execution, but also partly solve the fly ash utilization and disposal problem. Uddin and Supriya studied the influence of fillers on paving grade bitumen and observed that fly ash being a waste product can be effectively used as filler to improve the properties of bituminous mix and fly ash also being cost effective as compared to cement and lime.

Materials & Methodology

Materials Used

Table 1: Aggregate Gradation.

Sieve Mm	% Passing by Weight	
	Specification	Blend
25.0	100	100
19	80-100	90
9.5	60-80	70
4.75	48-65	56
2.36	35-50	42
0.60	19-30	25
0.30	13-23	18
0.15	15-Jul	11
0.075	0-8	4

Aggregate: In the laboratory test program, black stone chips which are smaller than 25mm and larger than 2.36mm in size were regarded as coarse aggregate. The black stone used in this investigation was collected from construction site of architecture building of RUET. Aggregate gradation and physical properties of coarse aggregate are shown in Tables 1 & 2 respectively. The coarser sand smaller than 2.36mm and larger than 0.075mm in size were used as fine aggregate combination of domar sand and Padma river sand were used as the main source of fine aggregate. Specific gravity of fine aggregate was found to be 2.65. Two types of filler, stone dust and fly ash which is finer than 0.075mm in size a used in this investigation. Stone dust is used as standard filler for this project. Fly ash used for main purpose were collected from Barapukuria Coal Power Plant, Dinajpur. Here specific gravity of fly ash and stone dust were found to be 2.44 and 2.13 respectively [11].

Table 2: Properties of Coarse Aggregate.

Properties	Method	Coarse Aggregate
Specific gravity	T85	2.73
Water absorption	T85	0.74
Aggregate impact value	BS812	7%
Aggregate crushing value	BS812	16.90%
Unit weight (kg/m^3)	T19	1530
Loss angles abrasion value	T96	18%

Bitumen: Grade of 80/100 bitumen has been used as bitumen for preparation of bituminous mixture. The important physical properties are tabulated in Table 3.

Table 3: Properties of Bitumen.

Properties	Method (AASHTO)	Test Values
Specific gravity (at25°C)	T229	1.01
Penetration (at 25°C, 100 gm and 5 sec)	T49	86
Loss on heating(at163°C, 5 hours), %	T47	0.45
Ductility (at25°C), cm	T51	100+
Flash point, °C	T48	276
Fire point, °C	T48	283
Softening point, °C	T53	49.5

Methodology

At first the test procedure introduced by Bruce Marshall and developed by the U.S Corps of Engineers was applied to find optimum bitumen content using stone dust as standard filler for medium traffic condition. This test has been fundamentally used in this study to evaluate the different mixture at different bitumen contents and the parameters considered are stability, flow value, unit weight, air voids, voids in mineral aggregates, voids filled with bitumen. Now by fixing this optimum bitumen content specimens were prepared. Specimens prepared by replacing stone dust with fly ash gradually such as 0% fly ash and 100% stone dust, 25% fly ash and 75% stone dust, 50% fly ash and 50% stone dust, 75% fly ash and 25% stone dust and 100% fly ash and 0% stone dust by total weight of filler. Bruce Marshall test was applied to determine optimum fly ash content by Marshall Mix design criteria for medium traffic condition [12]. Now using these optimum bitumen content and optimum fly ash content specimens were prepared to observe the effect of water submergence on compacted specimen. To observe the effect of water submergence on compacted specimen, compacted specimens were submerged in water for 0, 5, 10, 15 and 20 days. After each selected days Marshall Test was applied on these specimens.

Result and Discussion

Marshall Test of Specimens Using Stone Dust as Filler

For Bituminous mixes using standard filler stone dust and various bitumen content following six curves showing the relationships of unit weight, Marshall stability, flow, percentage of voids in total mix, percentage of voids in mineral aggregates, percentage of voids filled with bitumen with percentage of bitumen content were drown to determine optimum bitumen content. Curves were drown with data from Table 4. Curves are shown in Figures 1-6. Here, Optimum bitumen content from above figure calculated as 5.56%. Value of Stability, flow, %Va, %VMA and %VFB for optimum bitumen content satisfy the Marshall Mix Design Criteria.

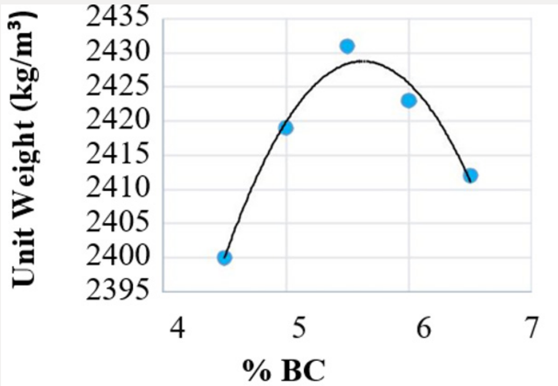

Figure 1: Relationship between unit weight and bitumen content.

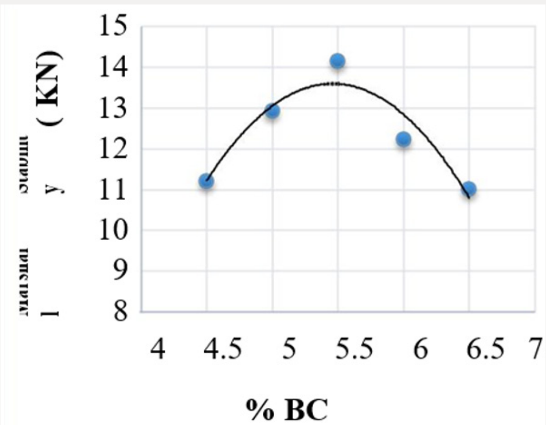

Figure 2: Relationship between Marshall Stability and bitumen content.

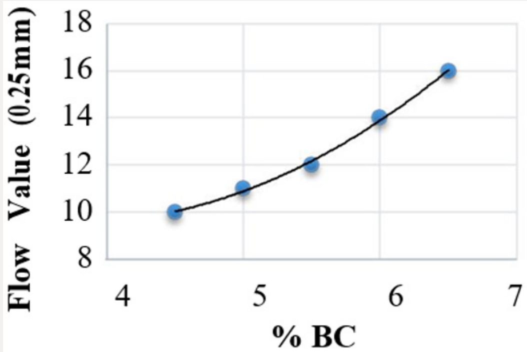

Figure 3: Relationship between flow value and bitumen content.

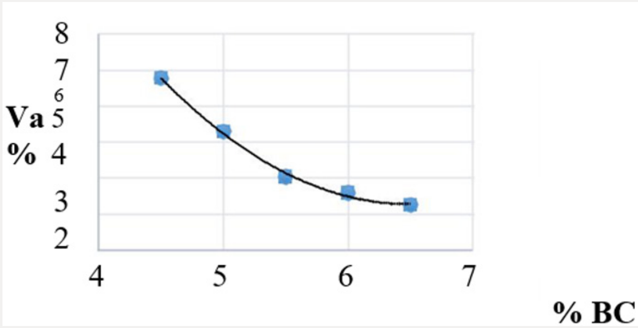

Figure 4: Relationship between air voids in mineral total mix and bitumen content.

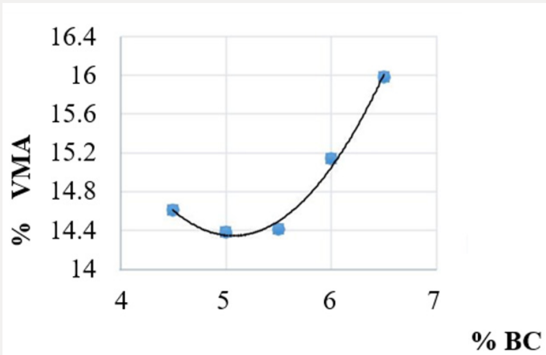

Figure 5: Relationship between voids in mineral aggregate and bitumen content.

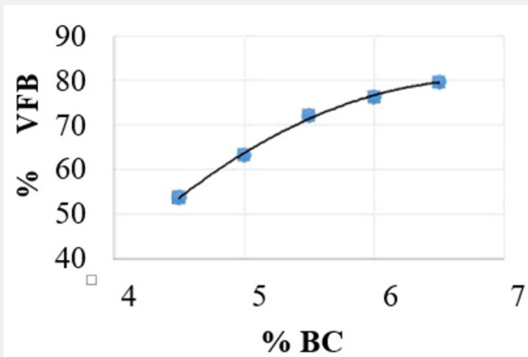

Figure 6: Relationship between voids filled with bitumen and bitumen content.

Table 4: Results of Marshall Test.

SL NO.	1	2	3	4	5
%BC	4.5	5	5.5	6	6.5
Unit weight (kg/m^3)	2400	2419	243 1	242 3	241 2
Marshall Stability (KN)	11.2	12.9	14.2	12.2	11
Flow value, 0.25mm	10	11	12	14	16
% Va	6.8	5.3	4	3.6	3.2
% VMA	14.6	14.4	14.4	15.1	15.9
% VFB	53.7	63.2	72	76.3	79.7

Marshall Test of Specimens Using Fly Ash and Stone Dust as Filler

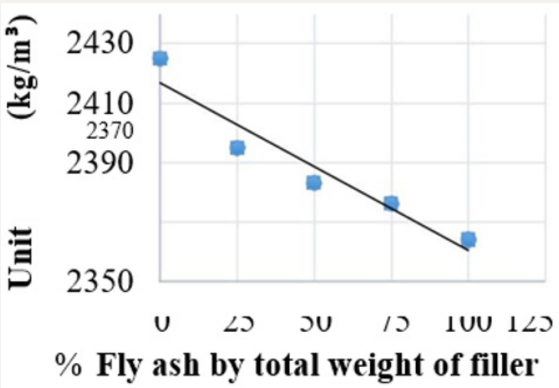

Figure 7: Relationship between unit weight and fly ash by total weight of filler.

For bituminous mixes six curves are drown showing the relationships of unit weight, Marshall stability, flow, percentage of voids in total mix, percentage of voids in mineral aggregates, percentage of voids filled with bitumen with percentage of fly ash by total weight of filler. Curves were drowning with data from Table 5. Curves are shown in Figures 7-12. In Figure 7, unit weight decreases with the increase in percentage of fly ash by total weight of filler. Here standard filler stone dust is gradually replaced by fly ash by fixing constant bitumen content. But unit weight of fly ash is smaller than the unit weight of stone dust. That's why unit weight of compacted mixes decreases with the increase in percentage fly ash by total weight of filler. In Figure 8, Marshall Stability decreases with increase in percentage of fly ash by total weight of filler. Here adding 50% fly ash and 50% stone dust by total weight of filler gives the stability of 8.75 KN which satisfies the Marshall Mix design criteria for medium traffic condition. Again for adding 25% fly ash and 75% stone dust by total weight of filler, value of flow (0.25mm), %Va, %VMA, %VFB were found 15, 4.81%, 15.60%, and 69.18% respectively which satisfy the Marshall Mix design criteria. So, 25% fly ash by total weight of filler can be used as optimum.

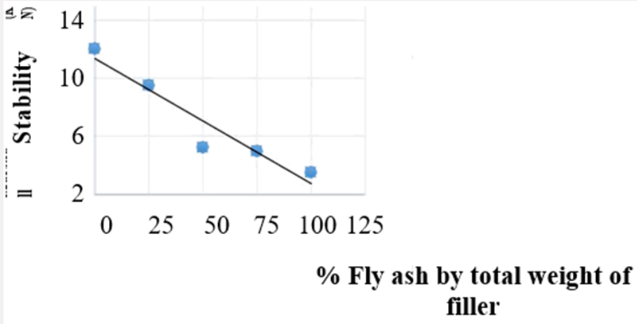

Figure 8: Relationship between Marshall Stability and fly ash by total weight of filler.

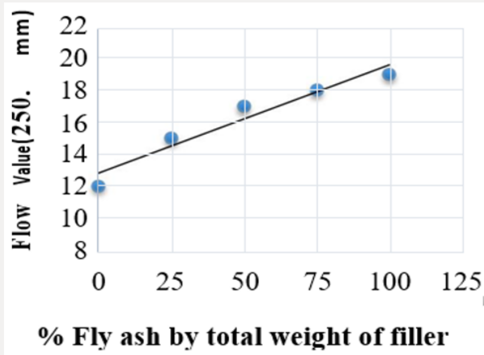

Figure 9: Relationship between flow value and fly ash by total weight of filler.

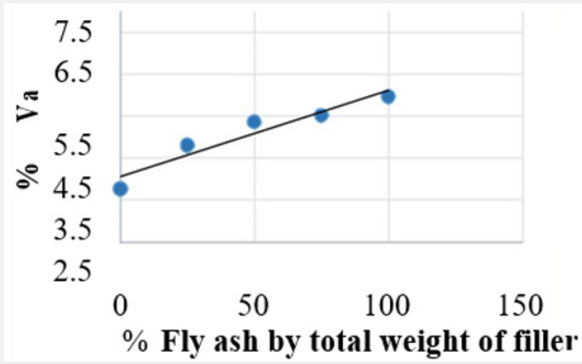

Figure 10: Relationship between air voids in total mix and fly ash by total weight of filler.

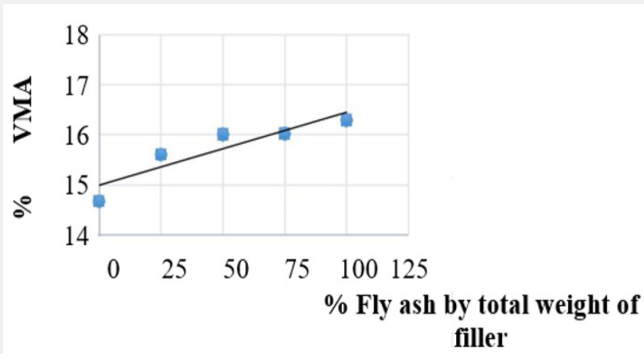

Figure 11: Relationship between voids in aggregates and fly ash by total weight of filler.

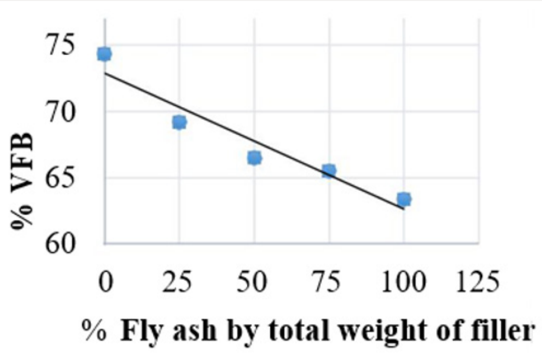

Figure 12: Relationship between voids filled with bitumen and fly ash by total weight of filler.

Table 5: Marshall Test Results.

SL NO	1	2	3	4	5
%Fly Ash by total wt. of filler	0	25	50	75	100
Unit weight (kg/m^3)	2420	2397	2388	2376	2364
Marshall Stability (KN)	12	9.5	5.3	4.9	3.5
Flow value, 0.25mm	12	15	17	18	19
% Va	3.8	4.8	5.4	5.5	5.9
% VMA	14.7	15.6	16	16	16.3
% VFB	74.3	69.2	66.5	65.5	63.4

Marshall Test of specimens for water effect

Behavior of compacted mixes prepared using optimum bitumen content (5.56%) and optimum fly ash content (25% by total weight of filler), is shown in Figures 13 & 14. Curves were drawn with data from Table 6. Here in Figure 13, Marshall Stability decreases with increase the time of water submergence and flow value increases with increase the time of water submergence. For 15 days of water submergence of compacted mixes, stability was found 5.65 KN which satisfy the Marshall mix design criteria. Again For 10 days of water submergence of compacted mixes flow value was found 16 (0.25mm) which also satisfy the Marshall Mix design criteria. So compacted mixes (prepared using optimum bitumen content and fly ash content) may submerge in water for 10 days at room temperature.

Table 6: Marshall Test Results for Effect of Water Submergence.

SL NO.	Time of the Water Submergence (days)	Marshall Stability (KN)	Flow Value, 0.25mm
1	0	9.02	14
2	5	7.2	15
3	10	6.5	16
4	15	5.65	18
5	20	3.88	19

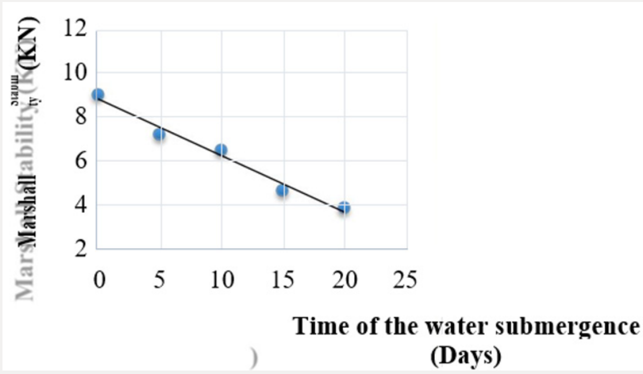

Figure 13: Relationship between Marshall Stability and time of water submergence.

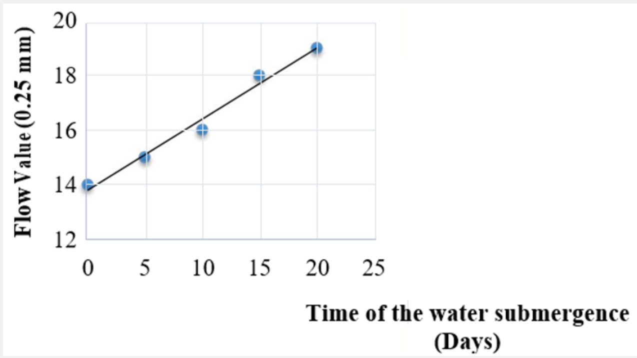

Figure 14: Relationship between flow value and time of water submergence.

Conclusion

From the above study we can reach in the following decisions:

a. Optimum bitumen content was found 5.56% using stone dust as standard filler. At this optimum bitumen content, Marshall mix properties of bituminous mix such as unit weight, stability, flow value, % Va, % VMA, and % VFB were found 2428.5 kg/m^3, 13.56 KN, 12 (0.25 mm), 4.05%, 14.53% and 72.25% respectively which satisfy the Marshall Mix design criteria.

b. Fly ash can be used as mineral filler in bituminous mixes. 25% fly ash and 75% stone dust by total weight of filler can be used as filler in bituminous mixes which satisfy the Marshall Mix design criteria.

c. Compacted mixes (prepared using optimum bitumen content and optimum fly ash content) can be submerged in water for 10 days. So, this mix are suitable for flood plain areas for medium traffic condition.

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