International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 6, Nov-Dec-2020, ISSN (Online): 2395-566X

Utilization of Fly Ash in Bitumen And In Flexible Pavements

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Abstract- **Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations of conventional bitumen performance.Early developments of distress symptoms like cracking, rutting, raveling, undulations, shoving and potholing of bituminous surfacing have been reported for flexible pavements.A bituminous mixture needs to be flexible enough at low service temperatures to prevent pavement cracking and to be stiff enough at high service temperature to prevent rutting. Bitumen modified with fly ash offers a combination of performance related benefits as the physical properties of the bitumen is improved without changing the chemical nature of it.This paper presents the experimental study carried out conventional bitumen and fly ash modified binder. It has been shown that marshal stability, flow value, ductility, rutting resistance, indirect tensile strength and resilient modulus of the bituminous concrete mix with fly ash modified bitumen is significantly improved.The advantage with fly ash is it is easily available and their cost low and it is a waste material.These additives increase the elasticity, decrease the brittle point and increase the softening point of the bitumen. This, in turn, will alter the properties of the mix in which such modified bitumen is used and these mixes will exhibit greater stiffness at higher temperature and high flexibility at low temperatures.**

Keywords- **bitumen, fly ash, pavement cracking, etc.**

I. INTRODUCTION

Bitumen is a non-crystalline, black or dark brown viscous material, which is substantially soluble in organic solvents, such as toluene and carbon disulphide, and which possesses adhesive and water-proofing qualities. It consists essentially of hydrocarbons and typically comprises at least 80% carbon and 15% hydrogen. The remainder is oxygen, sulphur, nitrogen and traces of various metals. Bitumen can be obtained from various sources. As mentioned earlier, it occurs naturally, but for most purposes it is petroleum on which the world relies for its supplies of bitumen. The bitumen content of crude petroleum oil can vary between15% and 80%, but the more normal range is 25% to 40%.Bitumen is a strong and durable adhesive that binds together very wide variety of other materials without affecting their properties.

Its durability is essential to major engineering projects such as roads and waterways where it must perform for up to 20 years or more. Bitumen is insoluble in water and can act as an effective waterproofing sealant. It also resists action by most acids, alkalis and salts and does not contaminate water, so it can be used to line watercourses. Bitumen is a thermoplastic material: it softens and becomes liquid with the application of heat and hardens as it cools.Modified bitumen'sare formulated with additives to improve their service performance by changing such properties as their durability, resistance to ageing, elasticity and/or plasticity. Over 80% of the 100 million tonnes of worldwide annual bitumen consumption is used for paving applications in the construction and maintenance of roads. The remainder is used for various purposes. The use of bitumen in road maintenance can be up to four times its use in road construction.An understanding of how roads are built is necessary for an appreciation of the importance of the role played by bitumen.

Modern road design and construction techniques are aimed at building flexible road layers or courses so that the tensile and compressive stresses imposed by passing traffic are distributed evenly through these layers, according to their relative strengths. This ensures that neither the ground supporting the road nor the individual layers are permanently deformed by these concentrated stresses. The mixing of aggregates and bitumen to produce asphalt may take place at a purpose-built plant located away from the road construction site, or it may be done at the site itself.Controlled amounts of various size aggregates, which have been carefully blended and graded to meet the required specification, are dried and heated before being mixed with a measured quantity of hot bitumen. All this takes place in a purpose-built plant. The hot mixture, or hot mix, at a temperature of up to 160°C, is carried to the construction site and laid while still hot.

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1. Fly Ash

Fly ash, a coal ignition mineral by-product in the thermal energy plan, usually dumped land nearby presents a risk to the atmosphere and to human health. In India, the number of the annual production of fly ash is so high (approximately 170 million tons) that it is successfulIt has become a national interest to recycle this waste. Even though fly ash was used in there has been only little usage of asphalt pavement for specific research for years.Most of the fly ash was correlated with the presence of spherical particles with a smooth surface made up of an organic state of alumino silicate. They used the X-ray emission technique caused by protons, which also suggested the existence ofAlong with opaque porous carbonaceous particles and metallic particles with a spherical smooth form, several irregular glass particles. SEM studies by Mamane et al revealed that predominantly smooth mineral spheres with no detectable perforated hollow spheres were both fine and coarse fractions of fly ash. In the mineral centre, sulphur emerged as a surface layer and almost 90 percent of the mass was concentrated in the coarse fraction.

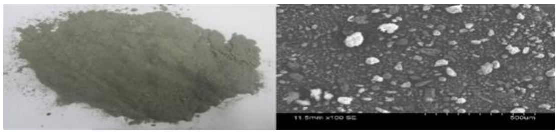

Fig. 1 (a) Physical appearance and (b) SEM image of fly ash used.

1.2 Properties of fly ash

Table 1 properties of fly ash

Fillers	Chemical compositions								Physical properties	
	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	K_2O	SO_3	LOI*	SSA** (m^2/kg)	Specific gravity
Fly ash	49.4	12.1	25.2	4.6	1.3	2.2	0.8	3.09	308.4	2.32

II. LITERATURE REVIEW

Fly ash, a coal ignition mineral by-product in the thermal energy plan, usually dumped land nearby presents a risk to the atmosphere and to human health. In India, the number of the annual production of fly ash is so high (approximately 170 million tons) that it is successfulIt has become a national interest to recycle this waste. Even though fly ash was used in there has been only little usage of asphalt pavement for specific research for years. Investigations have revealed that properties of bitumen and bituminous mixes can be improved to meet the growing requirements of pavement with incorporation of certain additive like fly ash. The advantage with fly ash is it is easily available and their cost low and it is a waste material.These additives increase the elasticity, decrease the brittle point and increase the softening point of the bitumen. This, in turn, will alter the properties of the mix in which such modified bitumen is used and these mixes will exhibit greater stiffness at higher temperature and high flexibility at low temperatures. Owing to the decline of natural resources, the rise of road building activities, the decline in energy use, and environmental concerns, the use of waste materials has become an important topic in recent years.

Many researchers have therefore attempted to investigate the possibility of using waste material in pavement design.Filler is a very fine powder used in bituminous mixes that has a significant influence on the efficiency of in-service of HMA. It plays a dual function in the mix, filling the gaps between mineral aggregates and mineral aggregates. due to its fineness it is blended with bitumen producing a high-consistency bituminous latex caulk. This, this, the resulting latex caulk is able to control the mixture's physical and mechanical properties to a vast degree. They are three main factors for enhancing the effect of fillers in physicochemical interactions in bituminous mix. (Clopotel, Velasquez, & Bahia, 2012,

Kim & Buttlar, 2010, Underwood & Kim, 2011) The asphalt can be used with various forms of fillers, including crushed stone, cement and lime blends.(ASTM D242, 2009; MORT&H, 2013) Many studies on the use of waste materials are now underway, such as recycled fine aggregate powder, brick dust, glass powder, sewage sludge ash, marble dust, lime waste and coal waste powder. (Al-sayed, Mandy, & Bauli, 1995; Chandra,Kumar, & Feyissa, 2002; Chen, Lin, & Wu, 2011; Chen, Lin, Wu, & Liu, 2011; Do, Mun, &Keun, 2008; Modarres & Rahamanzadeh, 2014; Sobolev, Vivian, Saha, Wasiuddin, & Saltibus,2014; Tremblay, Vaillancourt, & Perraton, 2015).

In the early 1950s, FA was first introduced as mineral filler in the bituminous mixture (Carpenter, 1952). The positive impact of FA on the moisture resistance, fatigue life, rut resistance and tensile strength of the bituminous mix has since been discussed by many researchers.Because both volume filling and particle structuralism are mechanical reinforcement methods, filler particles begin to form an integrated system, lead to a sudden rise in the hardening rate with increasing volume fraction. (Underwood & Kim, 2011)

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III. METHODOLOGY

1. Softening Point (R&B) Test

Softening point (ring and ball) test is a method for the determination of the softening point of bitumen and bituminous binders, in the range 30 °C to 150 °C. Two horizontal discs of bituminous binder, cast in shouldered brass rings, are heated at a controlled rate in a liquid bath while each supports a steel ball. The softening point is reported as mean of the temperatures at which the two discs soften enough to allow each ball, enveloped in bituminous binder, to fall a distance of (25,0 ± 0,4) mm.

2. Penetration test

Penetration value is the measure of hardness or consistency of bitumen sample. It involves penetration by the point of a standard needle under specific conditions of load, time and temperature. This test is used for evaluating consistency of bitumen.Penetration test is a commonly adopted test on bitumen to grade the material in terms of its hardness. Here we have tested the samples on a two day scenario.

3. Marshal stability test

Marshal stability test is most commonly used for design of bituminous concrete. This test is extensively used for paving work. For a standard temperature of 60˚c the bituminous mix the load carried by compacted sample is termed as stability of bituminous mix.This test is done to determine the Marshall stability of bituminous mixture as per ASTM D 1559. The principle of this test is that Marshall stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 60oC and is measured in kg. The apparatus needed to determine Marshall Stability of bituminous mixture is

- Marshall stability apparatus
- Balance and water bath

The sample needed is From Marshall stability graph, select proportions of coarse aggregates, fine aggregates and filler in such a way, so as to fulfil the required specification. The total weight of the mix should be 1200g.

4. Procedure to Determine Marshall Stability of Bituminous Mixture

- Heat the weighed aggregates and the bitumen separately up to 170^{o}C and 163^{o}C respectively.
- Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.
- Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.
- Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
- A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (3 specimens) or bitumen content.
- Before testing of the mould, keeps the mould in the water bath having a temperature of 60^{o}C for half an hour.
- Check the stability of the mould on the Marshall Stability apparatus.

Table 3 Aggregate gradation

Sieve size (mm)	Specification (%)	Designed gradation (%)
25	100	100
19	90-100	95
9.5	56-80	75
7.75	35-65	60
2.36	23-49	41
0.3	5-19	11
0.075	2-8	7

Table 3 Aggregate gradation

5. Fillers

Fly ash is used as replacement of filler in hot mix asphalt at the range of 4 to 8 percentage. Sample is prepared at different percentage of filler and according to it gradation of mix is done by MORTH specification.

IV. OBSERVATION & CALCULATION

1. Softening point test

Softening point (ºC) = the temperature at which the ball touches the bottom

= 68.5ºC, 70ºC

Average reading (ºC) = 69.25ºC

2. Penetration test

Here we have tested the samples on a two day scenario.
Freshly prepared sample.

Table 4 Penetration value

bitumen(fly ash added)		
No.	Dial gauge reading	Penetration value (0.1 mm)
1	160 to 226	120
2	120 to 215	95
3	100 to 201	101

Final penetration value = average of the three readings= 105.3.

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3. Ductility test

Table 5 Ductility value

Bitumen (fly ash added)	
No.	Ductility (cm)
1	58.9
2	63.6

Ductility (cm) = average of the two readings = 61.25.

IV. MARSHAL STABILITY TEST

1. Marshall stability, flow and Marshall Quotient tests:

The primary objective of the design of the Marshall mix is to assess the optimal bitumen content (OBC) relative to the different proportions of the mix. For this reason, the Marshall Stability and Flow Test must be carried out on each sample at a loading rate of 50.5 mm / min at 60 ° C on the basis of ASTM: D6927. The Marshall quotient, which is a kind of pseudo-stiffness, can be calculated as the stability to flow ratio.The Other Marshall properties like voids filled with bitumen (VFB), voids in mineral aggregate (VMA), stability, flow and Marshall Quotient (MQ) were then checked to be within the specified limits of MORTH at that bitumen content.

Table 6 Marshal Test result.

% filler	OBC (%)	VMA (%)	VFB (%)	Stability (kg)	Flow (mm)	Marshal quotient (KN/mm)
4	5	15.05	74.25	15.34	3.67	4.17
6	4.9	14.65	73.55	19.35	3.39	5.70
8	5.3	16.06	74.75	17.48	3.75	4.61

V. RESULT

1. Softening point test

Softening point of fly ash added bitumen and virgin bitumen is compared.

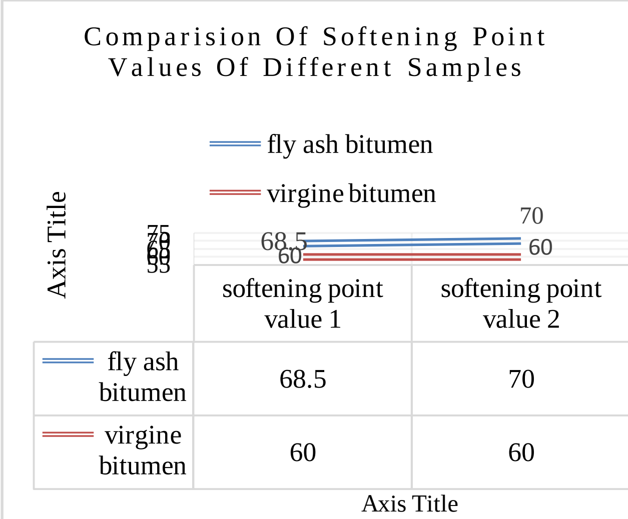

Figure 3comparison of softening point value.

2. Penetration Test

Penetration value is compared in this table

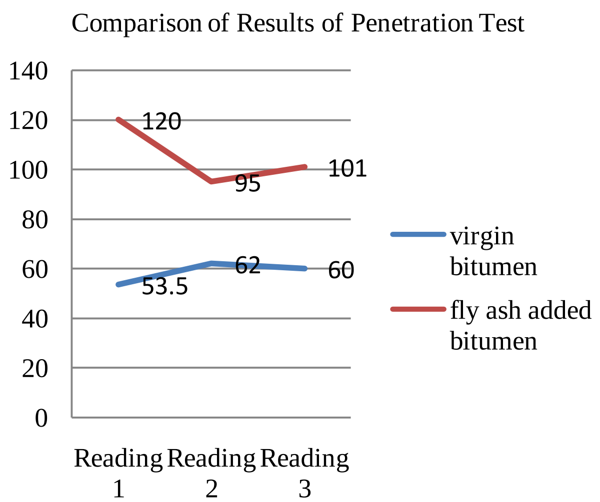

Figure 4. Comparison of penetration value

3. Marshal stability test result

In this section the at different percentage of fly ash as a filler is taken and marshal stability test is carried out finding of that testy is discussed by the graph shown below

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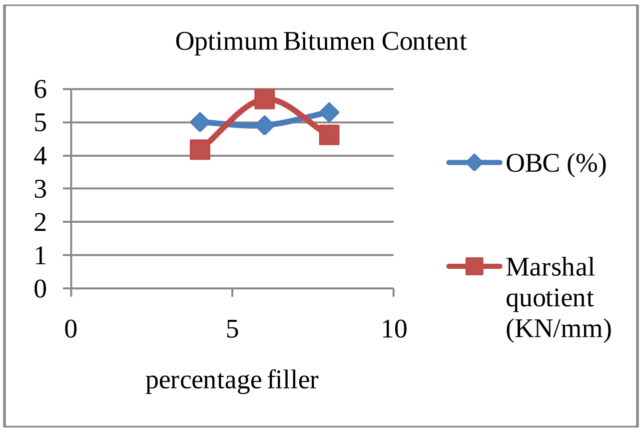

Figure 5Optimum bitumen content.

4. Void mineral aggregate and marshal stability

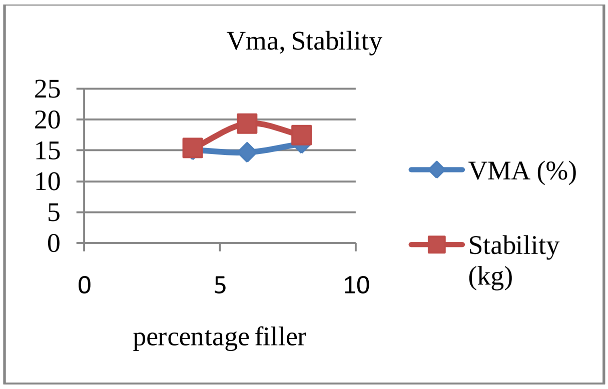

Figure 6 VMA and Stability value.

IV. SUMMARY AND CONCLUSION

1. Conclusions

Through the Marshall Mix design, the possible use of fly ash obtained from local thermal power plants in hot mix asphalt was studied. The following assumptions can be made from the study of laboratory test results

- According to the Marshall parameters obtained, incorporating up to 4 percent FA in the mix by removing traditional mineral filler provides a substantial bitumen economy in the resulting mixture.
- Experimental findings also show that FA filler adjustment provides better strength compared to that of the standard mix with less deformation.
- As a result, it may be used as a substitute for popular fillers to promote global sustainability, especially in areas where fly ash is generally dumped.

2. Summary

As mentioned earlier, the Marshall Mix design method was used to determine the optimum bitumen content (OBC) of mixes relative filler ratio in comparison with control mix. The OBC was calculated and selected at 4% airvoids.The Other Marshall properties like voids filled with bitumen (VFB), voids in mineral aggregate (VMA), stability, flow and Marshall Quotient (MQ) were then checked to be within the specified limits of MORTH at that bitumencontent. It shows the Marshall properties of the mixes corresponding to the obtaining of OBC values for both control mix and adjusted mix with FA at the studied filler material.

The OBC of the control mix is 5.21%, as shown in Table 6. The OBC values are 5.07 percent, 4.9 percent, 4.8 percent and 5.4 percent, with the addition of FA at4 percent, 6 percent and 8 percent. With the rises, the OBC values decreasein filler content up to 6%. However, a further increase in the content of the filler raises the OBC value for the control mix. In addition, Marshall Stability (MS) control mix values of 13.56 kN are given in Table 6. Whereas, 15.34, 19.35 17.68kN respectively are the MSs of mixes containing 4, 6 and 8 percent of FA. The flow values of all OBC-related mixes remained within the defined 2-4 mm range (Table 6). In addition, as the filler content increases and after a 4 percent filler ratio, the rise in MQ values is noticeable.

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