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Marshall Test Properties of Bituminous Concrete Mixes Using Fly Ash Modified Bitumen

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Abstract - Flexible pavement with bituminous surfacing is used in India. Distress symptoms, such as cracking, rutting, etc., are being increasingly caused earlier by high traffic intensity, over loading of vehicles and significant variations in daily and seasonal temperature of the pavement. Investigations have revealed that modifiers can be used to improve rheological properties of bitumen and bituminous mixes to make it more suitable for road construction. Also there are many materials that may be tried as modifiers in bitumen. This paper reports an investigation carried on Bituminous concrete mixes corresponding to grade-1, prepared at mid-point gradation using Fly Ash as modifier. The conventional Marshall Stability test was conducted on the specimens as per ASTM D 1559. The present investigation comprises of determining the Marshall test properties of Bituminous Concrete Mixes Using 60/70 penetration grade bitumen modified with Fly Ash as Modifier. The results such as stability, flow, volume of air voids, voids in mineral aggregates, voids filled with bitumen, bulk density etc was determined. The study helps to ascertain the suitability of Fly Ash as modifier.

Index Terms - Bituminous Concrete Mixes, Fly Ash, Grade-1, Midpoint gradation, Marshall Stability test

1 INTRODUCTION

Flexible pavements with bituminous surfacing are widely used in many parts of the world. The high intensity of traffic in terms of commercial vehicle and over loading of trucks and significant variation in daily and seasonal temperature of the pavement have been responsible for early development of distress symptoms like undulations, rutting, cracking and pot holing of bituminous surface. A factor which causes serious concern is varying climatic conditions at different periods of time. Under such conditions, flexible pavements tend to become soft in summer and brittle in winter.

Several investigation have revealed that properties of bitumen and bituminous mixes can be improved significantly to meet the requirements of pavement with incorporation of certain additives or blend of additives so that the early development of distress symptoms can be prevented and there by preventing pavement deterioration. The desirable properties of good bituminous mixes are stability, durability, cohesion, skid resistance and workability. If bituminous mix is poor in any of the above properties, then that mix ultimately result in pavement failure. A good mix is one which has got all the de sirable properties.

The properties of bitumen and bituminous mixes can be improved to meet the requirements of pavement with the incorporation of certain additives. These additives are called as bituminous modifiers and bitumen pre mixed with these modifiers is known as modified bitumen.

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1.1 Need for Modified Bitumen for the Pavement Construction

Bitumen which is responsible for the viscous-elastic behavior characteristic of asphalt plays a large part in determining many aspects of road performance, particularly resistance to permanent deformation and cracking. In general, the proportion of any induced strain in asphalt that is attributable to viscous flow, which is non-recoverable, increases with both loading time and temperature.

One of the prime roles of a bitumen modifier is to increase the resistance of the asphalt to permanent deformation at high road temperatures without adversely affecting the properties of the bitumen or asphalt at other temperature.

In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. But its resistance towards water is poor. Anti-stripping agents are being used. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with organic and synthetic polymers like rubber and plastics.

The use of plastic materials such as carry bags, cups, etc. is constantly increasing. The consumption of plastics have increased from 4000 tons/annum (1990) to 4 million tons/annum (2001) and it is expected to rise 8 million tons/annum during the year 2009. Nearly 50 to 60% of the total plastics are consumed for packing. Once used, these plastic materials are generally thrown as waste. They do not undergo bio-decomposition. Hence, they are either land filled or incinerated. Both are not eco-friendly processes as they pollute the land and the air. Any method that can use this plastic waste for the purpose of construction is always welcomed.

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Some of the properties of bituminous mixes that can be improved using polymers are: increased resistance to stripping[1]; reduce the effect of bleeding of binder during peak summer[1], Aging[1] and skid-resistance characteristics are improved; improvement in toughness[2]; increase in tenacity[3,4]; resistance to creep deformation[5, 6]; increase in indirect tensile strength[7] and compressive strength[7]; decrease the rutting rate [8, 9]; increase the fatigue resistance[10, 11, 12]; improve the temperature susceptibility; increase in Marshall stability[13, 14, 15], reduces the porosity, absorption of moisture and improves soundness; improvement in skid resistance characteristics[16]; increases the melting point[17]; improves the viscosity and elasticity of the materials tested[18]; improve the resistance to abrasion at low and high temperature; decrease the brittleness[19].

Polymer Modified Bitumen is used due to its better performance. But in the case of higher percentage of polymer bitumen blend, polymer dispersion in bitumen, get separated on cooling. This may affect the properties and quality of the blend and also the road laid using such blend.

1.2 Desirable Properties of Modifiers-Rubber and Polymer

Polymer and rubber modified bitumen, often abbreviated as modified bitumen is obtained with the incorporation of selected thermoplastics and powdered rubber from discarded truck tires, natural rubber or any other suitable elastomers in bitumen. When used as bitumen modifier, selected polymers/rubber or blend should have few properties such as, it should be compatible with bitumen; resist degrading of bitumen at mixing temperature; be capable of being processed by conventional mixing and laying machinery; produce coating viscosity at application temperature; maintain premium properties during storage, application and in service; be cost effective on a life cycle cost basis.

Polymers are being increasingly used to modify bitumen and to enhance the properties of bituminous mixes. The polymer modified binders are highly suitable for special applications, where traffic is extremely high. However climatic and mixing temperature play important role in the preparation of polymer modifier binder.

1.3 Object of the Present Study

The objective of the present study is to determine the Marshall Test properties of Bituminous concrete mixes using 60/70 penetration bitumen modified using Fly Ash.

1) To identify some waste materials as potential bitumen modifiers, so as to address the disposal issues to environment and world oil crisis.
2) To study the effect of fly ash as modifier in various proportions in bituminous mixes.

2. EXPERIMENTAL METHODOLOGY

2.1 Selection of Materials

2.1.1 Aggregates

The required quantity of aggregates consisting of assorted sizes was collected from a nearby quarry. The quarry is situated just 2km away from south-west of Bidadi and its longitude and latitude is 12° 47′ 24″ N and 77° 21′ 49″ E respectively. The aggregates have been crushed from the rock which is medium grained, mesocratic (grayish black) showing granitic structure. The essential minerals are Quartz, Feldspar and Biotite Mica and minor mineral is Hornblende. It is also contains accessory minerals like magnetite. It is a oversaturated acid plutonic igneous rock. It has low specific gravity and very hard. Based on the above observation, the rock is identified as granite.

2.1.2 Bitumen

The Bitumen of 60/70 penetration grade which was supplied by Mangalore Refinery and Petrochemicals Limited (MRPL) was used.

2.1.3 Modifier

Fly Ash, from thermal power plant situated at Tornagul, Bellary District was selected. It is used as filler in most of the bituminous road construction and cement is substituting by fly ash by some percentage in most cement concrete road. It is cheaper and obtained by combustion of powered coal as end product. So here effort is made to minimize the cost of bituminous road upto some extent by using Fly ash as a modifier along with bitumen.

2.2 Determination of Aggregate Shape Factors

Flakiness and Elongation index was determined as per the procedure laid down by IS: 2386 part-I. The aggregates were sieved into fractions such as 26.5-19, 19-13.2 and 13.2-9.5mm using a gyratory coarse aggregate mechanical sieve shaker. The weight of aggregate in each fraction was found. Using the thickness gauge, each aggregate in the first fraction was passed along its thickness through the respective opening. The flaky aggregate passing through the respective openings were separated and weighed. Using the length gauge, each aggregate retained on thickness gauge was passed along its length through the respective opening. The elongated aggregate retained in the respective openings were separated. Similarly the elongated aggregates in the other fractions were separated.

2.3 Preparation of Marshall Dry Mix

Table 2.1: Composition of Bituminous Concrete Pavement Layers (MoRTH-2001)

Grading	1	2
Nominal aggregate size	19mm	13mm
Layer thickness	50-65mm	30-45mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
45	-	-
37.5	-	-
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix	5.0-6.0	5.0-7.0
Bitumen grade (pen.)	65	65

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2.3.1 Calculation of Weight of Aggregates of Different Fractions

Table 2.2: Percentage of Aggregates Retained on each Sieve

IS Sieve (mm)	Percentage passing	Mid-point of percentage passing	Percentage retained
26.5	100	-	-
19	79-100	89.5	10.5
13.2	59-79	69	20.5
9.5	52-72	62	7
4.75	35-55	45	17
2.36	28-44	36	9
1.18	20-34	27	9
0.6	15-27	21	6
0.3	10-20	15	6
0.15	5-13	9	6
0.075	2-8	5	4

Table 2.3: Quantity of Aggregates for Dry Mix Preparation

IS Sieve (mm)	Weight of (FA) g	Weight of (EA) g	Weight of NF-NE g	Total weight aggregates g
26.5-19	18.90	18.90	88.20	126.00
19-13.2	36.90	36.90	172.20	246.00
13.2-9.5	12.60	12.60	58.80	84.00
9.5-4.75	-	-	-	204.00
4.75-2.36	-	-	-	108.00
2.36-1.18	-	-	-	108.00
1.18-0.6	-	-	-	72.00
0.6-0.3	-	-	-	72.00
0.3-0.15	-	-	-	72.00
0.15-0.075	-	-	-	48.00
0.075-pan	-	-	-	60.00
Weight of Marshall Mix, g				1200.00

The dry mix was prepared based on mid-point gradation for combined index of 30%, using aggregates of different sizes from 26.5, 19, 13.2, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15, 0.075 mm and Marshall powder (passing on IS 0.075 mm and retained on Pan) confirming to grade-1 as per MoRTH-2001 shown in table 3.4. Required quantity of aggregates consisting Flaky Aggregates (FA), Elongated Aggregates (EA) and Non Flaky-Non Elongated Aggregates (NF-NE) was mixed to prepare dry mix weighing 1200g each, shown in table 3.6. Shape test is not applicable for aggregates size less 6.5mm.

2.4 Preparation of Marshall Test Specimens

Approximately 1200g of the aggregate consisting of different aggregate fractions, as worked out earlier, was preheated to 175-190°C. The bitumen (plain/modified) was heated to 121-138°C and the first trial bitumen content was added to a preheated steel bowl. The mix was thoroughly mixed at mixing temperature about 154°C. The mix was compacted in a preheated Marshall mould by applying 75 blows on each face of the specimen.

Specimens were prepared at bitumen content 4.5%, 5%, 5.5%, 6% and 6.5% weight of dry mix modified using Fly ash at 2%, 4%, 6%, 8% and 10% weight of bitumen respectively.

3. RESULTS AND ANALYSIS

The Marshall Stability test was conducted on the prepared specimens as per as per ASTM D 1559 to determine the stability and flow values. The Marshall Test properties such as bulk density, Volume of air voids, volume of bitumen, voids in Mineral aggregates, etc were determined.

Table 3.1: Marshall Test Properties of Modified Bituminous Concrete Mixes Using Fly Ash

Fly Ash Content %	Bulk Density (Gb) g/cc	Theoretical Density (Gt) g/cc	Volume of Air Voids (Vv) %	Volume of Bitumen (Vb) %	Voids in Mineral Aggregates (VMA) %	Voids Filled with Bitumen (VFB) %	Marshall Stability (S) Kn	Flow (F) mm
Bitumen Content 4.5%								
0	2.38	2.48	3.17	10.29	14	77.27	15.64	2.00
2	2.37	2.49	4.63	11.77	11.96	72.69	25.26	2.03
4	2.38	2.51	4.46	10.70	11.24	67.69	27.05	2.27
6	2.38	2.51	4.84	10.64	11.29	55.28	27.34	2.10
8	2.35	2.51	5.36	10.6	11.78	52.80	23.01	1.95
10	2.39	2.52	4.31	10.3	11.31	69.17	26.20	2.00
Bitumen Content 5.0%								
0	2.40	2.46	2.84	10.78	13.68	79.19	18.91	2.60
2	2.39	2.47	3.05	12.95	11.75	77.87	28.77	2.50
4	2.39	2.49	3.48	11.95	10.67	76.15	28.71	2.27
6	2.45	2.49	2.92	12.29	10.93	72.96	29.49	2.15
8	2.37	2.49	2.96	12.15	10.41	70.99	25.09	2.00
10	2.41	2.50	2.77	11.47	10.81	76.36	27.31	2.90
Bitumen Content 5.5%								
0	2.42	2.44	2.33	10.87	13.26	79.50	22.76	3.20
2	2.41	2.45	2.61	13.9	10.51	81.93	24.71	3.90
4	2.41	2.47	3.18	13.24	10.47	83.76	27.31	3.07
6	2.44	2.47	2.69	13.44	10.83	82.72	27.25	2.20
8	2.38	2.47	2.81	13.17	9.93	79.88	31.38	2.79
10	2.40	2.49	2.14	12.56	10.36	78.90	22.14	3.15
Bitumen Content 6.0%								
0	2.41	2.43	2.09	10.87	13.21	79.91	21.71	3.40
2	2.41	2.43	1	15.68	10.11	90.52	20.77	4.50
4	2.40	2.46	3.07	14.39	10.31	86.53	20.37	3.63
6	2.41	2.46	2.6	14.45	10.80	90.24	21.57	3.35
8	2.42	2.46	2.14	14.68	8.88	80.21	22.78	3.80
10	2.39	2.47	2.05	13.66	10.01	80.99	21.30	4.80
Bitumen Content 6.5%								
0	2.40	2.41	2.00	10.89	13.14	80.03	14.28	4.40
2	2.39	2.41	0.87	16.95	9.59	95.07	19.26	4.80
4	2.38	2.44	2.54	15.76	8.81	87.93	20.27	4.10
6	2.40	2.44	2.43	15.58	9.76	95.41	20.13	3.55
8	2.39	2.44	2.21	15.66	8.67	80.54	20.97	3.80
10	2.37	2.46	1.93	14.86	9.94	86.88	19.45	4.90

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Graphs are plotted taking Marshall test properties along Y-axis and bitumen content along X-axis for various Fly

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Ash content which is as shown in the figure 3.1- 3.8

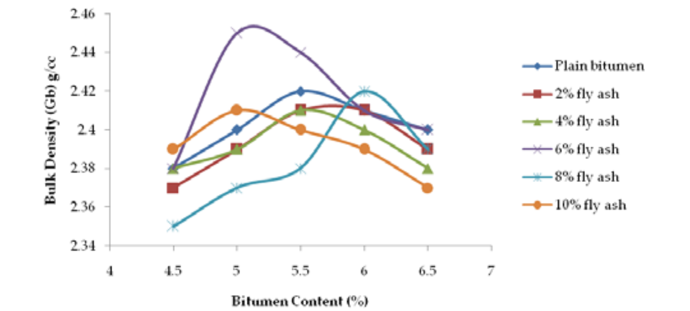

Fig 3.1: Bulk Density Vs Bitumen Content

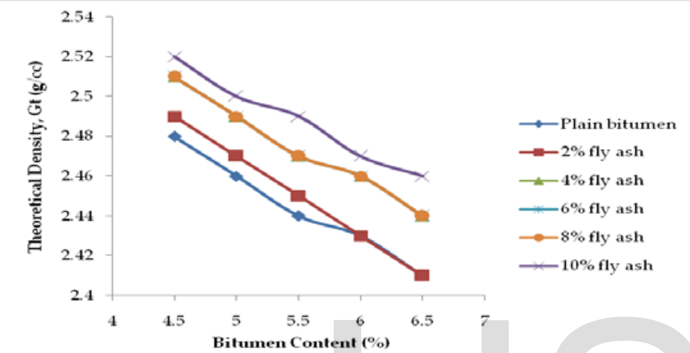

Fig. 3.2: Theoretical Density Vs Bitumen Content

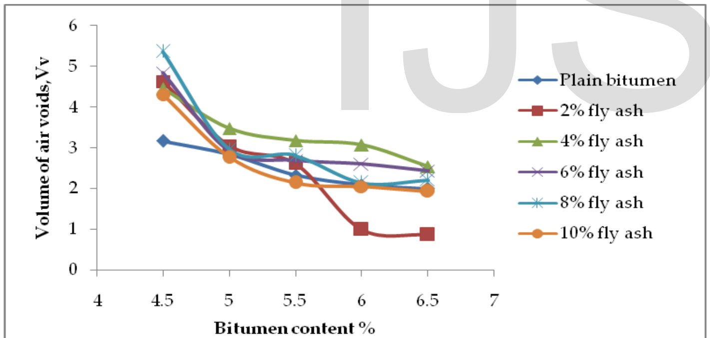

Fig. 3.3: Volume of air voids Vs Bitumen Content

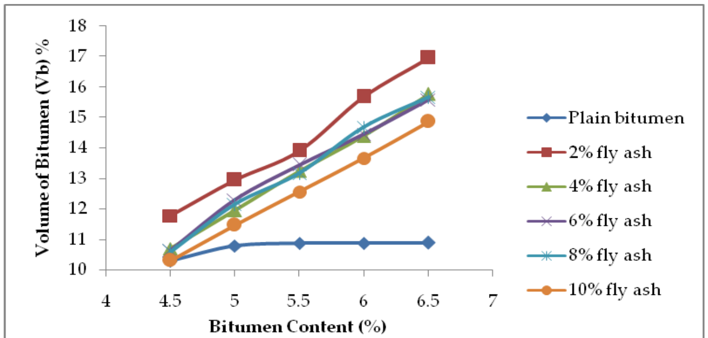

Fig. 3.4: Volume of Bitumen Vs Bitumen Content

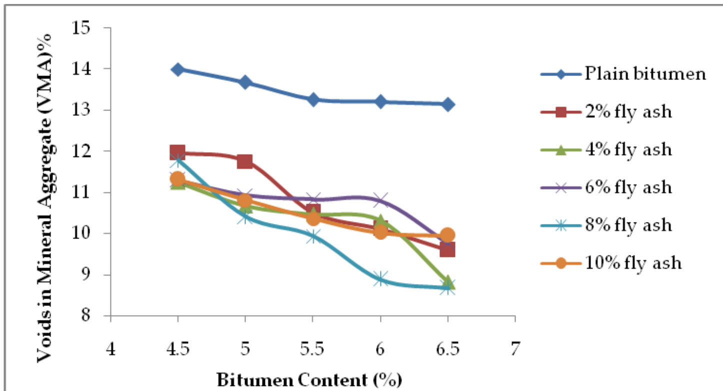

Fig. 3.5: Voids in Mineral Aggregate Vs Bitumen Content

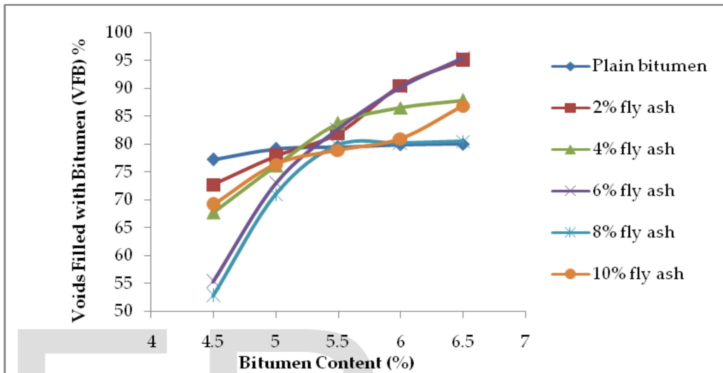

Fig. 3.6: Voids Filled with Bitumen Vs Bitumen Content

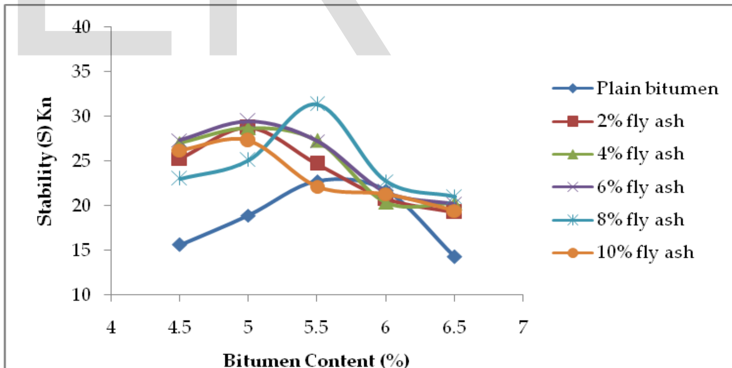

Fig. 3.7: Stability Vs Bitumen Content

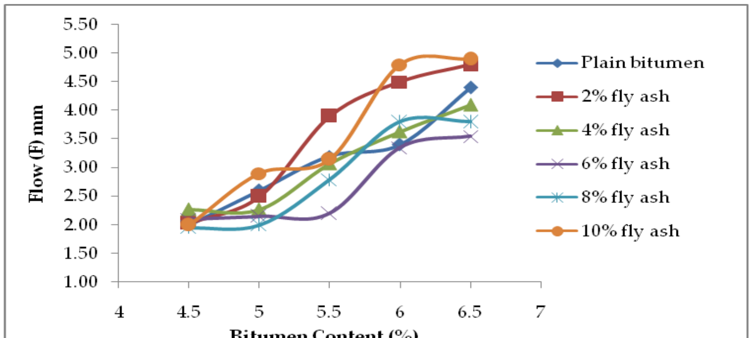

Fig. 3.8: Flow Vs Bitumen Content

4. DISCUSSION

In this section the properties such as bulk density, Theoretical density, volume of air voids, volume of bitumen, VMA, VFB,, Marshall Stability value and flow value were analysed for fly ash modified bitumen in varying proportion 2%, 4%, 6%, 8% and 10% for 4.5%, 5%, 5.5%, 6% and 6.5% bitumen content, are presented in table 3.1 and shown in figs 3.1 to 3.8. All these properties are indicators of the performance of bituminous concrete mix in the field. In the sight of the usefulness of the addition of modifiers, the following discussions are presented.

From the above results it is observed when the percentage of fly ash (modifier) increases the Marshall stability values and bulk density values are increased and decreases, where stability is found maximum at 31.38Kn for 8% fly ash at 5.5% bitumen content and density of 2.45 g/cc for 6% fly at 5% bitumen content respectively.

It is also observed that theoretical density, volume of air voids, VMA, VMA decreases where as Volume of bitumen, VFB decreases.

5. CONCLUSIONS

On the basis of observation and analysis of Marshall Test properties using Fly Ash, the flowing conclusions are drawn.

- The Marshall Stability value is found maximum of 31.38Kn for 8% fly ash at 5.5% bitumen content which is more than plain bitumen.
- The bulk density is also found maximum having 2.45 g/cc for 6% addition of fly ash at 5% bitumen content.
- It is also observed that air voids decrease, which is required for better strength and service life of the pavement and the VFB is increased by addition of bitumen.
- As per MoRTH, Optimum Binder and modifier content is found to be 5.03% and 8% respectively.
- Modification of Bituminous concrete mix has resulted in maximum stability with less bitumen content, which solves the world oil crisis.

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