INVESTIGATION OF MODIFIED BITUMEN USING GLASS FIBRE IN BITUMINOUS CONCRETE

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ABSTRACT

Study has been devoted to change the properties of BI and enhance the performance of the flexible pavements. Adopting various fibers in mixtures is known as beneficial HMA modifier. Even though applying these modifiers increases the initial cost, they may enhance pavement resistance for rutting thereby, postpone the rehabilitations and decrease maintenance cost.

Glass fiber is a type of material comprising abundant fibers of fine glass. Additive is a major factor to improve performance of Flexible Pavements. Glass Fibers have been use to enhance the performance of asphalt mixtures counteract permanent deformation and fatigue cracking because of with the asphalt and excellent automatic properties.

Bitumen source can is available in different forms and grades. For elaborating bitumen and studying the performance bituminous concrete (BC), Penetration and ductility tests are necessarily performed. The other tests like softening point, flash and fire point test are more useful to guide the paving analysts during field investigations.

In the below present analysis, attempt is made to understand or study effects of the use of natural mineral fiber called glass fiber as an additive in bituminous concrete (BC) mix. An experimental analysis should be performed on conventional bitumen and fibers using Marshall Procedure, Optimum Fiber Content (OFC) and Optimum Binder Content (OBC) for BC are to be calculated respectively.

The glass fiber at different percentages i.e. 0.5% to 2.5% is subjected to different optimum binder content specimens and performance is investigated.

Keyword: - *Marshall Stability test, optimum bitumen content, optimum fiber content, glass fiber, voids in mineral aggregates, voids filled with bitumen .*

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1. INTRODUCTION

Aggregates that are bounded the bitumen generally commonly utilized around world for the case in construction, preservation of flexible pavements. The secure, constant, fine, or thick aggregates graded which are bounded to the natural bitumen ordinarily carry out good in greatly traffic roads incase are planned and accomplished correctly as per guidelines and specifications. However, it's impossible all time to assign densely graded type of aggregates accessible at site. In those conditions, as a solution bituminous mix with several fibers can be attempted. Because of

Huge number of vehicles that are imposing constant axle loads directly on the road can cause disagreeable effects to construction and environment condition methods. These normally cause unchanged deformation, temperature cracking, fatigue and lesser, service period of the pavement layer can be depreciable. Rutting and Fatigue are most probable distresses caused inside road pavement that can consequence in decrease in pavement life and develop maintenance cost along with road user cost. So, it is necessary to identify ways to depreciating the pavement weakening and developing long life of pavement. Several research have been organized to advance road pavement performance and features which provide convenient ride , assure greater durability and longer service life opposition climate changing conditions and traffic loading.

A desired design and execution of bituminous mix accomplish the results in a mix which is acceptably strong, durable, advances skid resistance, resistive to deformation and fatigue, make less permeability, surroundings friendly and inexpensive etc.

Depending on the structural behavior, Pavements might be mainly classified into two divisions of Flexible pavements and rigid pavements. Flexible pave undule, or bend due to load. A flexible pave gets undulated for the sake of undulation of lower layer of pavement. Each layer leaves the loads to under layer by grain to grain mode by means point of connection in granular figure. The lower layers hold lesser magnitudes of stress for the sake of traffic loads. The well compacted granular structure arranges a good flexible pavement.

1.1 Objectives of the Present Investigation

In this analysis, we are examining about the quantity of Glass fiber that is added to the bituminous mix and which will come across the optimum fiber content and as an outcome predicting an increase in strength. Bituminous Concrete mix is adopted in our investigation. Fiber content differs between ranges of 0.5% - 2.5%. VG 30 bitumen is adopted as binder in the present analysis.

The entire work is executed in altered stages which are explained under.

- Concentrating on Marshall Mix Properties in Bituminous Concrete mixes adopting Rock Powder as filler with different percentages of bitumen content to conclude optimum Bitumen content.
- Concentrating on Marshall Mix Properties in Bituminous Concrete mixes with different percentages of Glass fiber to conclude Optimum Fiber Content.

1.2 Mix Design

There are three general bituminous mix design methods in use. They are Marshall Stability Method, Hveem Method and Super pave Method. Marshall Mix design is the numerously used method all over India. In this method load is acted to a cylindrical specimen of bituminous mix and the sample is checked till its failure as stated in the ASTM standard. For the present analysis, the bituminous mix is designed adopting the Marshall method and attained at the volumetric properties.

The mixes are performed according to Marshal Process particularized in A.S.T.M. The course aggregate, finer aggregate, and the filler material must be proportioned so as to fulfill the specifications of the relevant standards.

The fundamental amount of the blend is taken to deliver compacted bituminous blend examples of size 63.5 mm roughly around 1200 grams of aggregates and filer are necessary to get the coveted thickness. The aggregates are roasted at a temp of 175 degrees to 190 degrees other than the compaction mould get together and rammer are cleaned and put pre-roasted to a specific temp of 100 degrees to 145 degrees. The bitumen is warmed to a specified temp of 121 degrees to 138 degrees and the important measure of first trail of bitumen is blended to the roasted aggregates and altogether blended. The blend is put in a form and compacted with no of blows as to required particulars; i.e.75 blows on either side, the example is removed out of the shape following couple of minutes utilizing test extractor.

The sample mould is then tested as per the specific guidelines provided in the design procedure.

2. EXPERIMENTAL INVESTIGATION

Division elaborates the investigational works executed out in analysis. This division has been isolated into 2 divisions. To begin with division come across with analysis performed on the materials (bitumen, coarse aggregates, fine aggregates, and filer), second division come across with the tests performed on bituminous mixes.

2.1 Tests on Materials Used

Analysis on Aggregates: For making of bituminous mixes, aggregates are sieved as per MORTH grading as illustrated in Table below 2.1 , a appropriate sort of bitumen and fiber in necessary quantities were mixed as per Marshal Procedure.

Sieve Size mm	Grade II
	30-45MM
26.5	-
19	100
13.2	79-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	42-58
0.60	26-38
0.30	18-28
0.15	12-20
0.075	4-10
BITUMEN portion	5.0-7.0

Table -2.1 Approved aggregate gradations for bituminous concrete

Coarse Aggregates: Coarse aggregates containing of stone pieces collected from a neighboring provenance source, to 4.75 millimeter IS sieve size. Its specific gravity was achieved as 2.602. Standard tests were prearranged to resolve physical properties as summarized in Table below 2.2

Fine Aggregates: Fine aggregates, containing of stone crush dusts were collected from a neighborhood provenance crusher with portions passing 4.75 millimeter and stopped on 0.075 millimeter IS sieve. Its specific gravity was achieved as 2.63.

Property	Test result	Provisions as per Table 500-14 of MORTH (IV revision) Specifications
1. Crush value (%)	18.47%	Max 35%
2. Impact value (%)	24.07%	Max 24%
5. Water adsorption (%)	0.6%	Max 2%
6. Specific gravity of course aggregates	2.64	2.5-3.0

Table -2.2 physical properties of course aggregates

Filer: Aggregate passing within 0.075 millimeters IS sieve is called as filer. Present rock powder dust filler used as filler whose specific gravity is achieved as 2.58.

Bitumen: Here 60-70 penetration grade (also called VG30) bitumen is adopted as binder for preparation of Mixes, whose specific gravity was achieved as 0.95. It's important property is given in table - 2.3 for examine the binder quality, we have checked by the following two trails:

Property	Grade of bitumen	Result	Test methods
Penetration at 250 C	60/70	68	IS:1203-1978
Soften point 0C		47.25	IS:1205-1978
Ductility @270C, cm		52.8	IS:1208-1979
Specific gravity of bitumen		0.95	IS:1202-1980

Table -2.3 Describes properties of binder

Fiber

Glass fiber was adopted as additive which has measures about several millimeters, 10 cm or above. And thickness differed from 0.3 to 0.6 mm. The glass fibers were slice to small pieces of 1 to 2 cm in measurement lengthwise to assure suitable blending with the aggregates and bitumen at the time of blending.

2.2 Computation of specific gravity of material used

Specific gravity is the proportion of the density of substance to the mass of a reference substance; equivalently, it is proportion of weight of a substance to the mass of a referred substance for the same given volume. Apparent specific gravity is the proportion between weights of an amount of the material to the mass of an identical quantity of the referred material.

Data Analysis: Manipulation the specific gravity of materials using the following formula:

$$\text{Specific Gravity}, G_S = \frac{W_0}{W_0 + (W_A - W_B)}$$

Material	Aggregate	Bitumen	Rock powder	Filler
Pycnometer bottle number	1	2	3	4
WP = Mass of empty, clean pycnometer (grams)	629	29.5	677	29.5
WPS = Mass of empty pycnometer + dry material (grams)	1129	49.5	1177	51.5
WB = Mass of pycnometer + dry material + water (grams)	1837	78.5	1857.5	93
WA = Mass of pycnometer + water (grams)	1527	79.5	1551	79.5
Specific Gravity (GS)	2.63	0.95	2.58	2.58

Table -2.4 Represents specific gravity of materials

3. ANALYSIS RESULTS AND DISCUSSION

In the phase Outcome and examination of test executed out before chapter was analyzed & discussed. This phase is alienated into five sections. First sector is dealing with formulae and calculations adopted for examination. Second sector manages the commutating Optimum binder Content of Bituminous Concrete where rock powder is adopted like filler. Third sector manages the computation of Optimum binder Content & Optimum Fiber content, Marshall Properties in Bituminous Concrete with/without adopting fiber.

3.1 Formulae and calculations

a. Theoretical specific gravity in mixes (G_t): Theoretical specifics gravity (G_t) is specifics gravity excluding air voids, & is given as:

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}}$$

Where,

W_1 is weigh of course aggregate in entire portion,

W_2 is weigh of fines aggregate in entire portion,

W_3 is weigh of filer in entire portion,

W_b is weigh of bitumen in entire portion,

G_1 is apparent specific gravity of course aggregate,

G_2 is apparent specific gravity of fines aggregate,

G_3 is apparent specific gravity of filer &

G_b is apparent specific gravity of bitumen,

b. Bulk specific gravity of mixes (G_m): The bulk specific gravity of mixes G_m is specific gravity which is taking air gaps & achieved by the formulae:

$$G_m = \frac{W_m}{W_m - W_w}$$

Where, W_m is weigh of mixes in space,

W_w is weigh of mixes in water,

Note: $W_m - W_w$ gives quantity of mixes. Now and then for getting precise bulk specific gravity, specimen applied with light film of paraffin wax, when load is seized in water. It is still necessary for taking weight & volume of wax in calculations.

c. Percent Air voids (V_v): Air voids V_v is portion of air voids to the content in specimen and is formulated by:

$$V_v = \frac{(G_t - G_m)100}{G_t}$$

Where Gt is theoretical specific gravity of mixes, &

G_m is bulk specific gravity of mixes.

d. Percent volume of bitumen (V_b): The volume of bitumen V_b is portion of amount of bitumen to entire amount& formulate by:

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}}$$

Where, W_1 is weigh of course aggregate in entire mixes,

W_2 is weigh of fine aggregate in entire mixes,

W_3 is weigh of filer in entire mixes,

W_b is weigh of bitumen in entire mixes,

G_b is apparent specifics gravity of bitumen, &

G_m is bulk specifics gravity of mixes

e. Voids in mineral aggregate: Voids in mineral aggregate are amount of voids in aggregates, & is total of air gaps &amount of bitumen, and is computed as

$$VMA = V_v + V_b$$

Where, V_v is % air voids in mixes

V_b is % bitumen portion in mixes

f. Voids filled with bitumen (VFB): Voids filled with bitumen (VFB) are voids in mineral aggregate permeated with bitumen, and is determined by:

$$VFB = \frac{V_b \times 100}{VMA}$$

Where, V_b is % bitumen portion in mixes&

VMA is % voids in mineral aggregate

4. COMPUTATIONS OF OPTIMUM BINDER CONTENT AND OPTIMUM FIBER CONTENT

4.1 Computation of Optimum Binder Content

Various percentages of binder adopting rock powder are studied and the difference of Marshall Properties of bituminous concrete (BC) is explained below

Computations of optimum binder content (OBC) using rock powder:

W_1 is weigh of course aggregate in entire mixes, = 510gms

W_2 is weigh of finer aggregate in entire mixes, = 460gms

W_3 is weigh of filer in entire mixes, = 170gms

W_b is weigh of bitumen in entire mixes,

Percent	5%	5.5%	6%	6.5%	7%
W_b (gms)	63.15	69.84	76.59	83.42	90.32

G_1 is apparent specifics gravity of coarse aggregate, = 2.602

G_2 is apparent specifics gravity of fine aggregate, = 2.630

G_3 is apparent specifics gravity of filer& = 2.58

G_b is apparent specifics gravity of bitumen, = 0.95

Binder %	$W_1 \div G_1$	$W_2 \div G_2$	$W_3 \div G_3$	$W_b \div G_b$	G_T	G_M
5%	196	174.9	65.89	66.47	2.39	2.243
5.5%				69.84	2.37	2.255
6%				76.59	2.35	2.261
6.5%				83.42	2.33	2.253
7%				90.32	2.31	2.237

Table -4.1: Describes OBC density calculation

Bitumen %	G_T	G_M	V_v	V_b	VMA	VFB	STABILITY	FLOW VALUE
5%	2.39	2.243	6.15	12.39	18.54	66.82	721.95	2.2
5.5%	2.37	2.255	4.85	13.70	18.55	73.85	941.19	2.6
6%	2.35	2.261	3.78	14.98	18.76	79.85	727.05	4.5
6.5%	2.33	2.253	3.30	16.17	19.47	83.05	638.34	2.9
7%	2.31	2.237	3.16	17.28	20.44	84.54	779.06	3.9

Table -4.2: Describes optimum binder content calculations

Marshall Stability: It can be noticed that the stability rate increased with increment in bitumen portion up to particular percentage; after that stability value will be decreased. Fluctuation of Marshall's Stability value towards varying binder portion is given beneath in chart -4.1.

Flow Value: It can be notified an increment in bitumen portion flow value will be increased. For bituminous concrete flow value have to be at intervals 2-4 mm. Fluctuations of flow-value by varying binder portion is given beneath in chart -4.2.

Unit Weight: It can be noticed that unit-weight increase by increment in bitumen portion up for definite binder percentage; then the unit weight decreases. Fluctuation of unit-weight rate with varying bitumen portion is given beneath in chart -4.3.

Air Void: It can be noticed an increment bitumen portion void gap decreases. MORTH recommended the air voids should be lies at intervals 3 to 6%.Fluctuation of air gaps with varying binder portion is given beneath in chart -4.4.

Voids in Mineral Aggregate (VMA): It can be noticed that primary it is decreased& is increment at pointed pace. Fluctuation of V.M.A to varying binder portion was given beneath in chart -4.5

Void filled with Bitumen (VFB): V.F.B increased with increment of binding portion. Fluctuation to V.F.B by varying binding content is given beneath in chart -4.6.

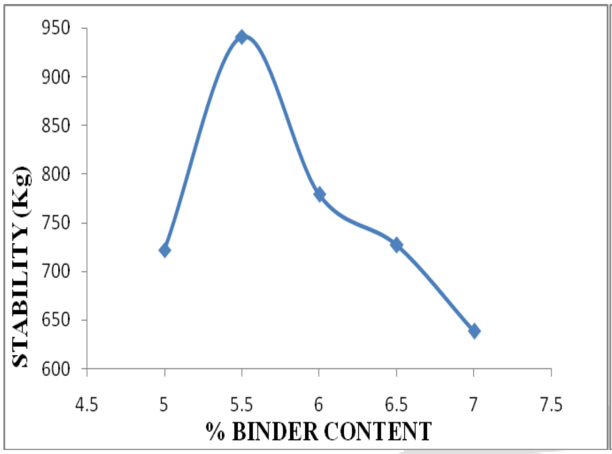


Chart -4.1: Describes % Binder Vs Stability

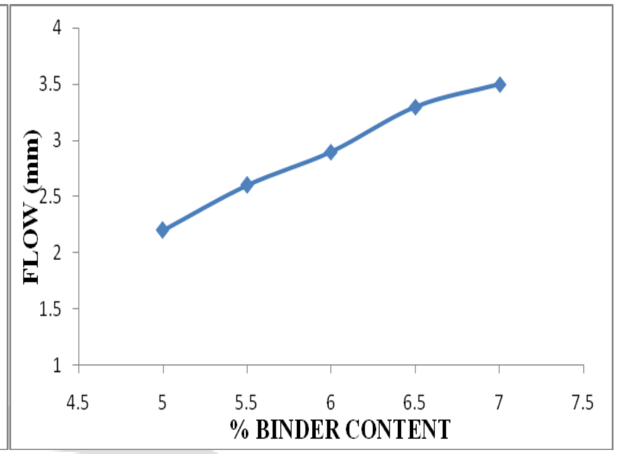


chart -4.2: Describes % Binder Vs Flow

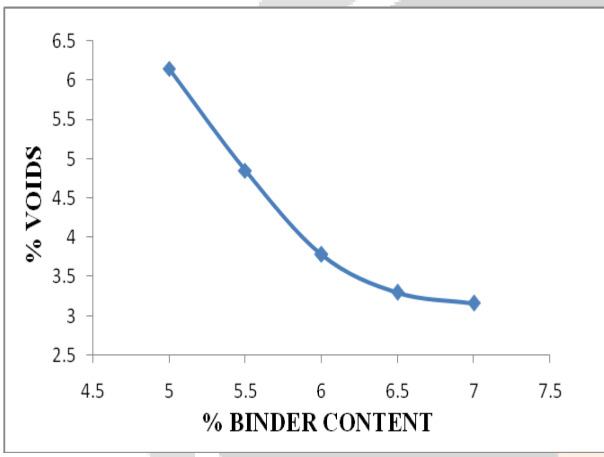


Chart -4.3: Describes % Binder Vs Unit weight

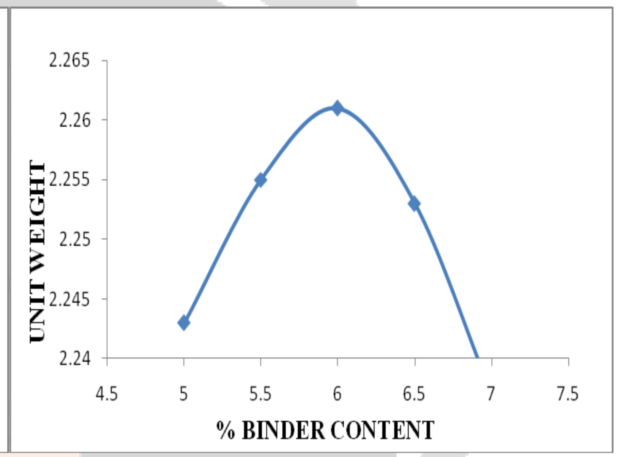


chart -4.4: Describes % Binder Vs Air voids

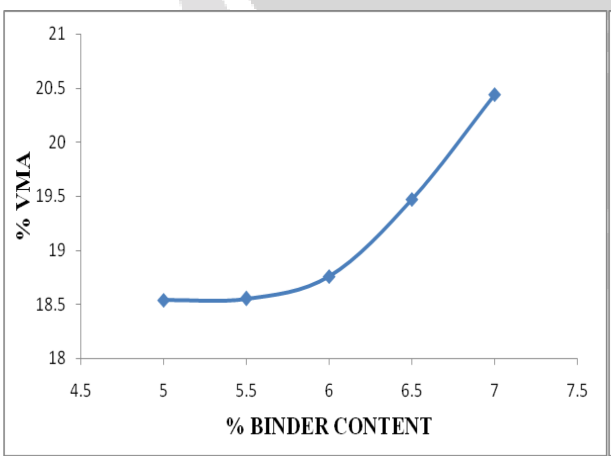


Chart -4.5: Describes % Binder Vs % VMA

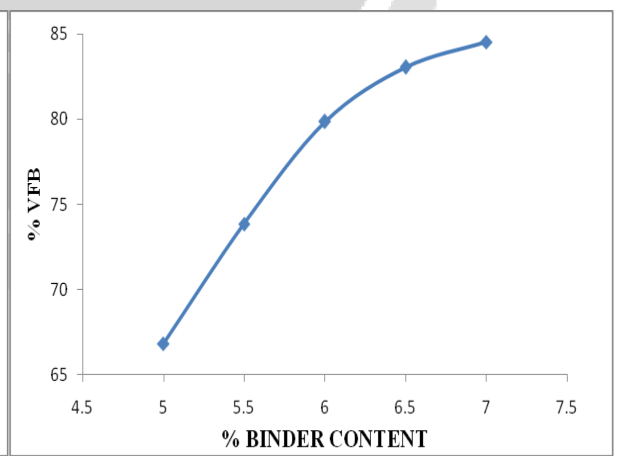


chart -4.6: Describes % Binder Vs % VFB

4.2 Optimum Binder Content Result

"Optimum Binder Content" computed is taken by middling rate of sequential three binder portion achieved by above graphs i.e.

I. Binder portion equal to max stability

II. Binder portion equal to max unit weight

III. Binder portion equivalent to median of calculated limit of %air gaps in entire mixes

Binder percent %	Stability value, kg	Flow, mm
5%	721.95	2.2
5.5%	941.19	2.6
6%	727.05	4.5
6.5%	638.34	2.9
7%	779.06	3.9

Hence the optimum binder content for the present analysis is taken as **5.8%.**

By taking the optimum binder content value the fiber is combined to the binder by percentage weights and altering the binder content and computation of optimum fiber content are examined to conclude the percentage fiber where stability and flow increases and decreases

4.3 Computation of Optimum Fibre Content

Various percentages of glass fiber adopting 5.8% as optimum binder content are studied and the differences of Marshall Properties of bituminous concrete (BC) is explained below

Computations of optimum fiber content (OBC) using rock powder:

W_1 is weight of course aggregate in entire mixes, = 510gms

W_2 is weight of fine aggregate in entire mixes, = 460gms

W_3 is weight of filer in entire mixes, = 170gms

W_b is weight of bitumen in entire mixes, = 73.88gms

G_1 is apparent specific gravity of course aggregate, = 2.602

G_2 is apparent specific gravity of fine aggregate, = 2.630

G_3 is apparent specific gravity of filer& = 2.58

G_b is apparent specific gravity of bitumen, = 0.95

G_G is apparent specific gravity of glass fiber, = 1.7

Fiber %	$W_1 \div G_1$	$W_2 \div G_2$	$W_3 \div G_3$	$W_G \div G_G$	$W_b \div G_b$	G_T	G_M
0.5%				0.37	73.51	2.359	2.235
1%				0.74	73.14	2.360	2.255
1.5%	196	174.9	65.89	1.12	72.76	2.361	2.260
2%				1.50	72.38	2.362	2.281
2.5%				1.89	71.99	2.363	2.275

Table -4.3: Describes OFC density calculation

Fiber %	G_T	G_M	V_v	V_b	VMA	VFB	STABILITY	FLOW VALUE
0.5%	2.359	2.235	5.25	14.24	19.49	73.06	1347.04	3.70
1%	2.360	2.255	4.44	14.30	18.74	76.30	1438.81	4.30
1.5%	2.361	2.260	4.27	14.25	18.52	76.94	1473.48	4.36
2%	2.362	2.281	3.42	14.31	17.73	80.71	1350.10	5.07
2.5%	2.363	2.275	3.72	14.20	17.90	79.32	1324.61	6.53

Table -4.4: Describes optimum fiber content calculations

Marshall Stability: It can be noticed that the stability rate is increased with increment in fiber content up to certain%; then stability rate will be decreased. Fluctuation of Marshall's Stability rate by varying fiber portion& given beneath in chart 4.8.

Flow Value: It's noticed that increment in fiber portion will increase flow value. For bituminous concrete the flow value is at intervals 2 to 4 mm. Fluctuation for flow value to varying fiber-portion is given beneath in chart 4.9.

Unit Weight: It can noticed that unit-weight is increased with increment fiber-portion up to particular fiber%; so the unit weight decreases. Fluctuation of unit-weight rate by varying fiber-portion is given beneath in chart 4.10.

Air Void: It's noticed that by increase in fiber-portion air-void is decreased. MORTH recommended the air-voids should be lies at intervals 3 to 6%. Fluctuation of air void with varying fiber-portion is given beneath in chart 4.11.

Void in Mineral Aggregate: It can be noticed that first it is decreased & then it increment by pointed rate. Fluctuation of V.M.A with varying fiber-portion is given beneath in chart 4.12

Void filled with Bitumen" (VFB): Void filled with Bitumen increase with increment fiber portion. Fluctuation of Void filled with Bitumen by varying fiber-portion is given beneath in chart 4.13.

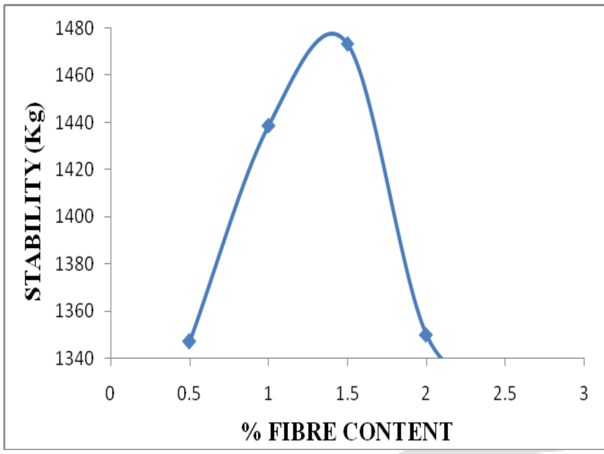


Chart -4.8: Describes % fiber Vs Stability

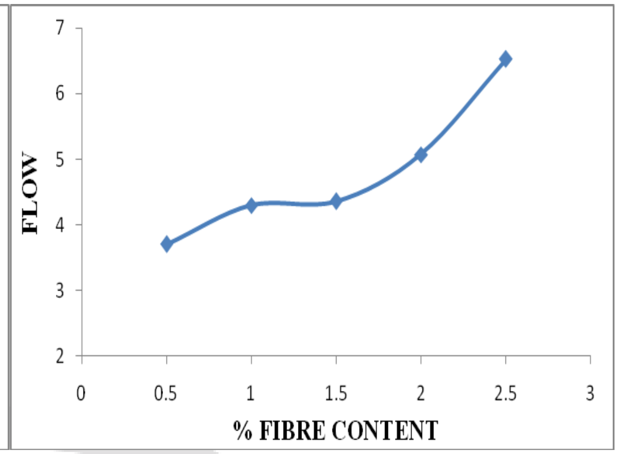


chart -4.9: Describes % fiber Vs Flow

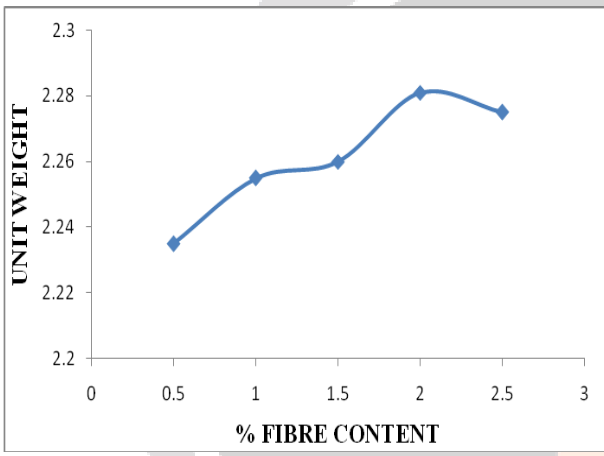


Chart -4.10: Describes % fiber Vs Unit weight

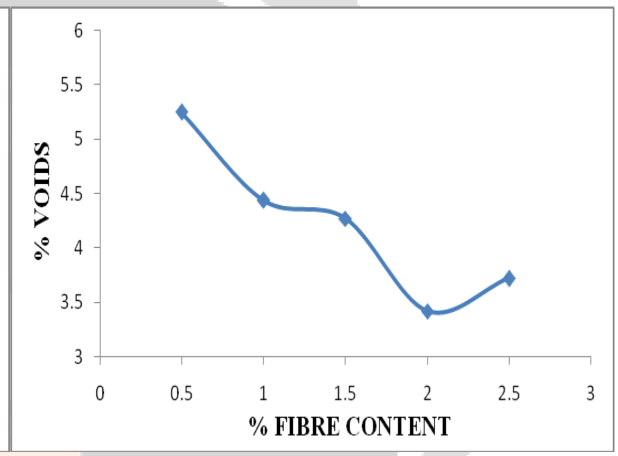
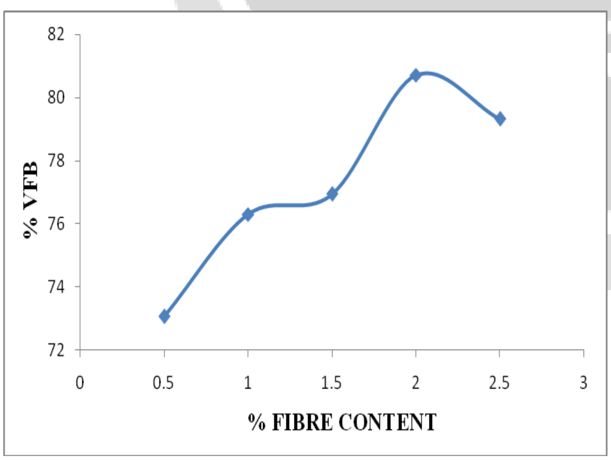


chart -4.11: Describes % fiber Vs Air voids



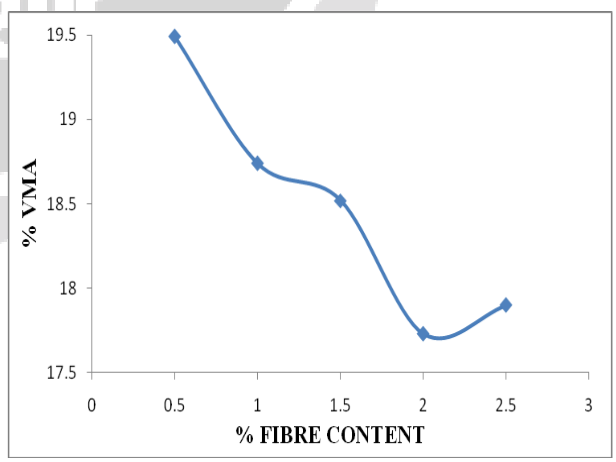


Chart -4.12: Describes % fiber Vs % VMA

chart -4.13: Describes % fiber Vs % VFB

4.4 Optimum Fibre Content Result

Optimum Fiber Content is computed by the middling number of sequential above graphs i.e.

I. Fiber-portion equivalent to max stabilities

II. Fiber-portion equivalent to max unit weight

III. Fiber-portion equivalent to midpoint of the intended limits of %air-voids in total blend

fiber percent %	Stabilities value, kg	Flow, mm
0.5%	1347.04	3.70
1%	1438.81	4.30
1.5%	1473.48	4.36
2%	1350.10	5.07
2.5%	1324.61	6.53

Hence, the optimum fiber content for the above analysis is taken as 1.5%.

As mixing of 1.5% of glass fiber the stability-value and flow-value is increased but after further mix about 2% of glass-fiber the stabilities value decreases but flow value decreases. Therefore the optimum fiber content is taken as 1.5%.

5. CONCLUSIONS

Depending upon the results and discussion of trial, analysis is conceded out on Bituminous Concrete mixes successive conclusion was drawn. This analysis focuses at the significant effect of binder content and amount of fiber adopted in the mix

According to the MORTH Specification mixes design necessity is necessary to the bitumen mix is given in the below table

Property	Value
Marshall-stability (K.N at 60℃)	>9 K.N
Flow-Value (mm)	2to4
Air-Void (%)	3to6
Voids Filled with Bitumen (%)	65to75
Optimum Bitumen Content (%)	5to6

- In the present analysis the optimum-binder-content is achieved as 5.8%,
- Utilizing optimum binder content the optimum fiber content (OFC) is achieved to be 1.5%

- By proportioning glass-fiber up to 1.5% Marshall Stability value is increased &beyond adding glass fiber will be decreased.
- By proportioning glass-fiber, flow value also decreased as correlated to mixes without fiber, but adding 1.5% fiber again flow-value is increased.

From the above results on the Marshall properties it was noticed that the addition of 1.5% glass fiber gives the superior results of bituminous mixes.

Future Scope:

Lots of properties of bitumen concrete mix such as Marshalls Properties have been premeditated in this exploration.

- VG30 Viscosity grade binder is used in the present investigation. Some other grades of bitumen like VG20 VG40 can also be further investigated.
- Further research can be done on Dense Bituminous Macadam and other wearing courses with other grades.
- Glass fiber as modifier can be done for Stone Matrix Asphalt or other modifiers.
- Few properties like moisture susceptibility, fatigue, resistance to abrasion can be further investigated.
- Some other natural fibers can be studied, investigated and compared.
- Glass-fiber-filler is used in present investigation other than that Fillers like cement, Fly ash and other industrial wastes also can be investigated.
- Glass-fiber is utilized in present assessment is low cost material therefore cost analysis can be done to determine its effect on construction cost.

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