EFFECT OF MIXING AND COMPACTION TEMPERATURES ON THE INDIRECT TENSILE STRENGTH AND FATIGUE BEHAVIOUR OF BITUMINOUS CONCRETE MIX PREPARED USING POLYMER MODIFIED BITUMEN

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ABSTRACT - Bituminous mixes are used in the surface layer of road and airfield pavements. The mix is composed usually of aggregate and bitumen. The design of bituminous paving mix, as with the design of other engineering materials is largely a matter of selecting and proportioning of constituent materials to obtain the desired properties in the finished pavement structure.

In the present study, an attempt is made to evaluate the effects of Mixing and Compaction temperature on the Marshall Properties, Indirect Tensile Strength and Fatigue behaviour of Bituminous Concrete Mix prepared using Polymer Modified Bitumen. The present study includes an aggregate gradation of Bituminous Concrete Mix Grading-2 as per MoRT&H specifications (4th revision), Polymer Modified Bitumen (PMB-70) as binder. The design of Bituminous Concrete Mix prepared using Polymer Modified Bitumen as per IRC SP 53-2002 specifications.

Based on the experimental work and analysis carried out in the present study, an ideal mixing temperature of 160^{o}C and compaction temperature of 140^{o}C is suggested for the preparation of Bituminous Concrete Mix prepared using Polymer Modified Bitumen.

1. INTRODUCTION

1.1 GENERAL

Bituminous materials are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties relatively at low cost. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates and coarse aggregates to produce a mix which is workable, strong, durable and economical. Significant variation in daily and seasonal temperature of pavement induces early development of distress conditions (ravelling, undulation, rutting, cracking, bleeding, and potholing) of bituminous pavement. Another major concern for distress of road surface is overloading of commercial vehicles and increased traffic density.

SBS is a styrene-butadiene-styrene made by the co-polymerization of butadiene and styrene. Butadiene and styrene block copolymer, to form a styrene (S) - butadiene (B) - benzene Ethylene (S) of the structure, as thermoplastic elastomeric. SBS has the advantages of rubber and plastic, at room temperature with a rubber elastic, like rubber, as high temperatures can melt flow, a plastic material. SBS formed within the bitumen, greatly improving the performance of bitumen.

Binder viscosity varies with temperature and different binders require different temperatures to achieve the same handling properties. Polymer modified binders, in particular, increase in viscosity at a much faster rate on cooling than normal paving grade bitumen.

1.2 OBJECTIVES OF THE PRESENT STUDY

- To assess the physical properties of aggregate as per MoRT&H requirements.
- To assess the physical properties of Polymer Modified Bitumen [PMB-70 (SBS)] as per IRC SP: 53-2002 requirements.
- To determine the optimum bitumen content of Bituminous Concrete Mix prepared using Polymer Modified Bitumen by Marshall Method of mix design.
- To assess the Marshall Properties of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at optimum bitumen content by varying mixing and compaction temperatures.
- To conduct Indirect Tensile Strength Test on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at optimum bitumen content by varying mixing and compaction temperatures.
- To conduct Indirect Tensile Fatigue Test on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at 25^{o}C keeping constant mixing temperature, varying compaction temperature and stress level.

- To carryout Linear Regression analysis for the data obtained from Indirect Tensile Fatigue Test conducted on Bituminous Concrete Mix prepared using Polymer Modified Bitumen.

2. LITERATURE REVIEW

2.1 GENERAL

The durability of asphaltic concrete is greatly influenced by the environmental changes during the year between hot and cold temperatures and between day and night. High temperatures can soften the bitumen and consequently reduce the stiffness of asphaltic concrete making the mix more susceptible to rutting. On the other hand, low temperature can increase the stiffness of bitumen and reduce the flexibility of the asphaltic concrete, hence, inducing fatigue failure. As a result, cracking of the pavement surface may develop which adversely affects the performance of the asphaltic concrete. Thus, high temperature stiffness and low temperature flexibility are important properties in bituminous mixtures respectively to avert rutting and cracking.

2.2 PRACTICAL MIX DESIGN MODEL FOR ASPHALT MIXTURE.[5]

This paper describes an "Optimisation of asphalt mixture design to ensure favourable behaviour at low and high air temperatures" is aimed to find a practical model for the optimisation of asphalt mixture composition which will be related to the target functional properties of asphalt pavement relevant for various climate and traffic conditions in the field.

2.3 DETERMINATION OF MIXING AND COMPACTING TEMPERATURES FOR HOT MIX ASPHALT.[3]

This paper gives the typical mixing and compacting temperature has been normally set as 160°C and 140°C respectively based on experience for the lab procedure purpose. With the newly revised Specification of Roadwork 2007, new bitumen grade had been introduced including grade 60-70 and some other types of modified bitumen. The objective of this study is to determine the appropriate mixing and compacting temperature for the bitumen grades by viscosity and correlation with other physical properties of bitumen. Rotational Brookfield Viscometer was used to determine the correct temperature for viscosity at 165°C and 135°C and at viscosity ranges of 0.17±0.02 and 0.28±0.03 Pa s for mixing and compacting, respectively as per ASTM D 2493

3. EXPERIMENTAL INVESTIGATIONS

3.1 GENERAL

In the present study the aggregate gradation Grading-2 adopted for Bituminous Concrete as per Table 500-18 recommended by MORT&H (IVth Revision) specifications. Basic Engineering tests on aggregates and binder were conducted in the laboratory to assess their properties.

Marshall Method of mix design was adopted to carryout mix design for Bituminous Concrete Mix prepared using Polymer Modified Bitumen. Marshall Stability and Indirect Tensile Strength tests were conducted on Bituminous Concrete Mix prepared using Polymer Modified Bitumen by varying mixing and compaction temperatures. For the selected mixing and compaction temperatures Indirect Tensile Fatigue test was conducted at 25^{o}C by varying stress level.

3.2 CONSTITUENTS OF A MIX (Aggregates, Bitumen & Cement)

Table 3.1: Physical Properties of Aggregates

Description of Aggregate Tests	Test Results	Requirements as per Table 500-17 of MoRT&H Specifications
Aggregate Impact value (%)	18.94	Max 24%
Flakiness and Elongation Index (Combined) (%)	28.97	Max 30%
Los Angeles Abrasion value (%)	19.44	Max 30%
Water Absorption (%)	0.5	Max 2%

Table 3.2: Test Results of Polymer Modified Bitumen PMB-70(SBS) and Requirements

Test	Test Results	Requirements as per IRC SP:53-2002
Penetration at 25°C, 100gm, 5 Seconds, 0.1mm	68.67	50-90
Softening Point (Ring & Ball), °C	58.5	Minimum 55
Ductility at 27°C	100+	+60
Flash point, COC, °C	252	Minimum 220
Elastic Recovery of Half Thread in Ductilometer at 15°C, %	78	Minimum 75
Separation, Difference in Softening point (Ring & Ball),°C	2	Maximum 3
Viscosity at 150°C, Poise	3.59	2-6
Thin Film Oven Test (TFOT) on Residue		
Loss in mass, %	0.64	Maximum 1
Increase in Softening point (Ring & Ball), °C	4	Maximum 6
Reduction in Penetration of Residue at 25°C, %	23.29	Maximum 35
Elastic Recovery of Half Thread in Ductilometer at 25°C, %	60	Minimum 50

Table 3.3: Specific Gravity of Materials

Description of materials	Specific Gravity
Coarse aggregate	2.67
Fine aggregate	2.72
Mineral filler (cement)	3.12
Polymer Modified Bitumen PMB-70(SBS)	1.02

Table 3.4: Aggregate Gradation for Bituminous Concrete Mix (Grading-2) as per MoRT&H Specification

IS Sieve Size, mm	% Passing (Specified)	% Passing (Mid Limit)
19	100	100
13.2	79-100	89.5
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.60	26-38	32
0.30	18-28	23
0.15	12-20	16
0.075	4-10	7

3.3 MARSHALL METHOD OF MIX DESIGN

There are two major features of Marshall Stability method of designing mixes are:

- Density Voids Analysis
- Stability Flow Test.

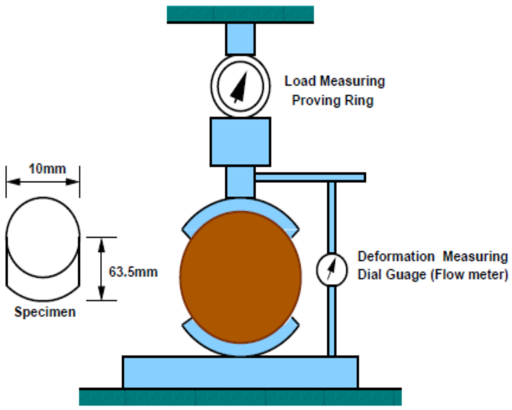


Figure 3.1: Marshall Stability Test

3.4 INDIRECT TENSILE STRENGTH TEST

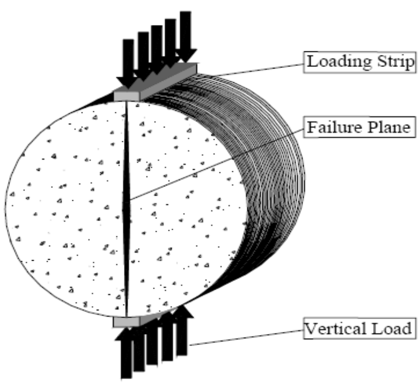


Figure 3.2: Indirect Tensile Strength Test

3.5 INDIRECT TENSILE FATIGUE TEST

Indirect Tensile Fatigue Test apparatus

Salient features of the equipment
Capacity - 2 Tons
Load type - Half Sine
Major component - LVDT (Linear Variable Differential Transducers)
- Load cell
- Loading frame
- Temperature controlled chamber
- Position controller
- Data acquisition system

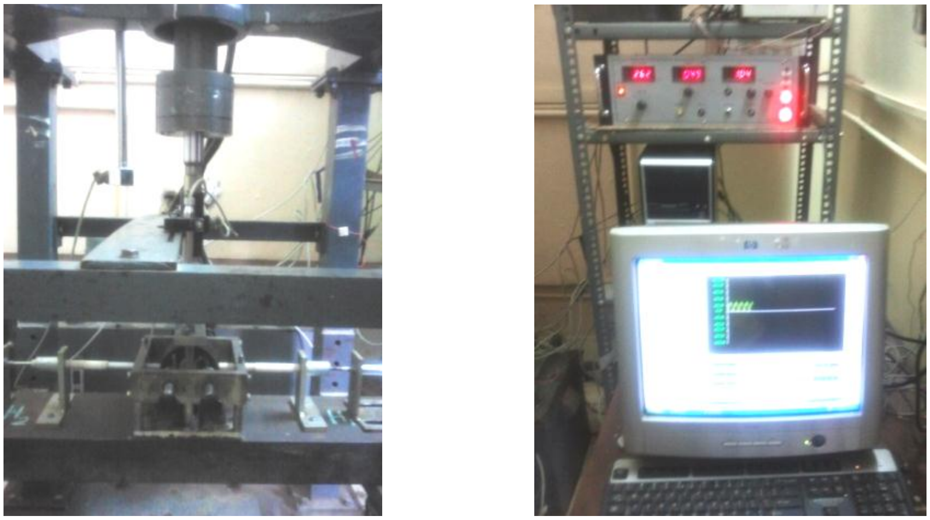


Figure 3.3: Indirect Tensile Fatigue Test

4. ANALYSIS OF DATA

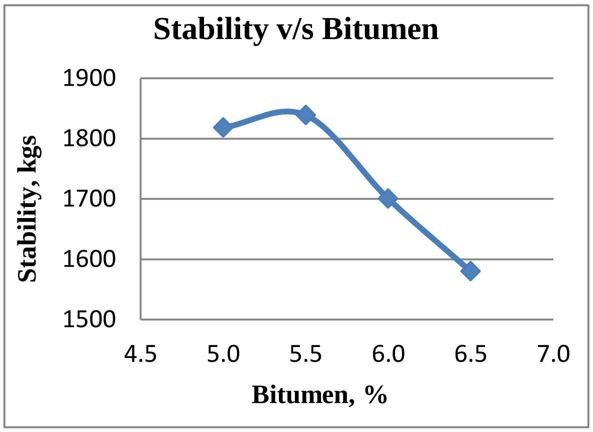
4.1 GENERAL

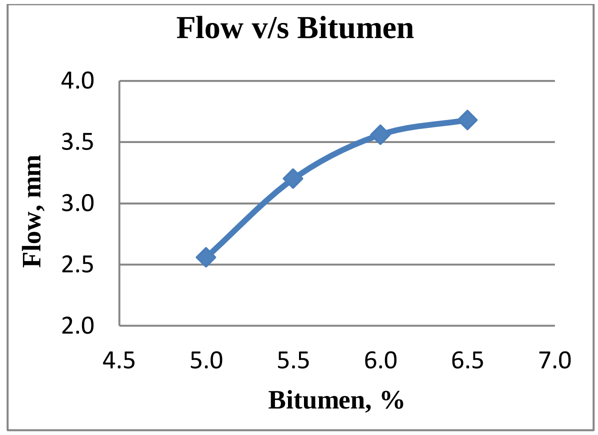
Marshall Stability test was carried out on Bituminous Concrete Mix specimens prepared using Polymer Modified Bitumen to determine the optimum bitumen content, Marshall Stability and volumetric properties of the mix.

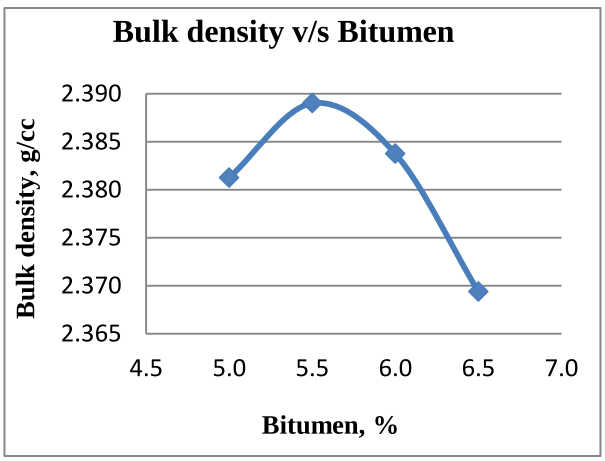
The Marshall properties and Indirect Tensile Strength values of Bituminous Concrete Mix prepared using Polymer Modified Bitumen were calculated by varying mixing and compaction temperatures. Indirect Tensile Fatigue Test was carried out on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at 25°C keeping constant mixing temperature, varying compaction temperature and stress level.

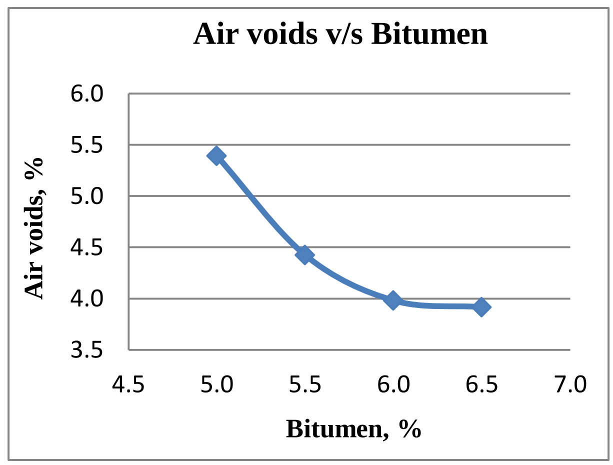
Table 4.1: Marshall Properties of Bituminous Concrete Mix prepared using Polymer Modified Bitumen

Bitumen content, %	Marshall stability, kgs	Flow, mm	Bulk density, g/cc	Total air voids, %	Voids Filled with Bitumen, %	Voids in Mineral Aggregates, %
5.0	1818.14	2.56	2.38	5.39	68.41	17.06
5.5	1838.93	3.20	2.39	4.42	74.45	17.31
6.0	1700.51	3.56	2.38	3.98	77.90	18.00
6.5	1579.84	3.68	2.37	3.92	79.41	19.02









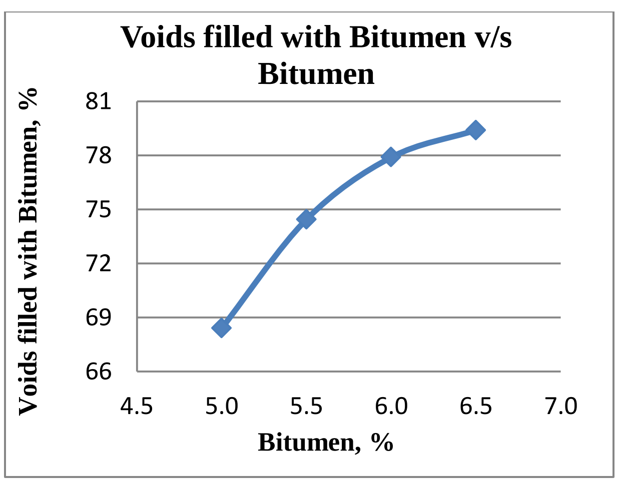


Figure 4.1: Marshall Properties of Bituminous Concrete Mix prepared using Polymer Modified Bitumen to determine the optimum bitumen content

4.2 DETERMINATION OF OPTIMUM BITUMEN CONTENT

The optimum bitumen content for mix is determined by taking the average values of three bitumen content corresponding to Maximum Stability, Maximum Bulk Density and 4% Air Voids in Total Mix. From the graphs shown in figure 4.1, Bitumen content corresponding To Maximum Stability, Maximum Bulk Density and 4% Air Voids in Total Mix is 5.4%, 5.5% and 6% respectively.

The Optimum Bitumen Content (OBC) for mix is the average of three values

OBC = (5.4+5.5+6) / 3 = 5.63 %

4.3 MARSHALL PROPERTIES OF BITUMINOUS CONCRETE MIX PREPARED USING POLYMER MODIFIED BITUMEN AT OPTIMUM BITUMEN CONTENT

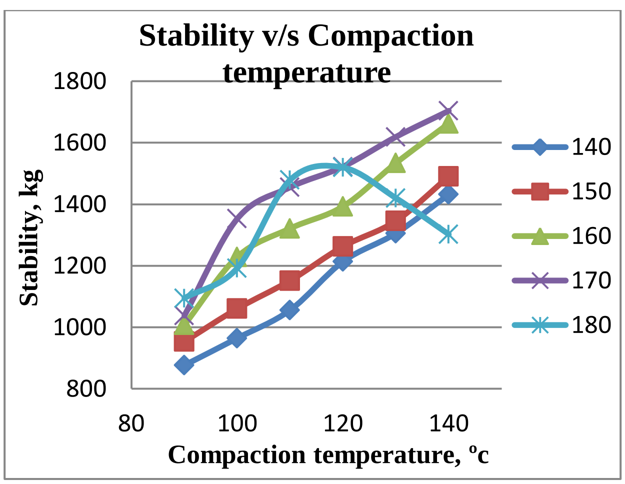
The Bituminous Concrete Mix specimens prepared using Polymer Modified Bitumen was subjected to Marshall Stability test at optimum bitumen content. Marshall Properties at optimum binder content and test results are presented in table 4.2.

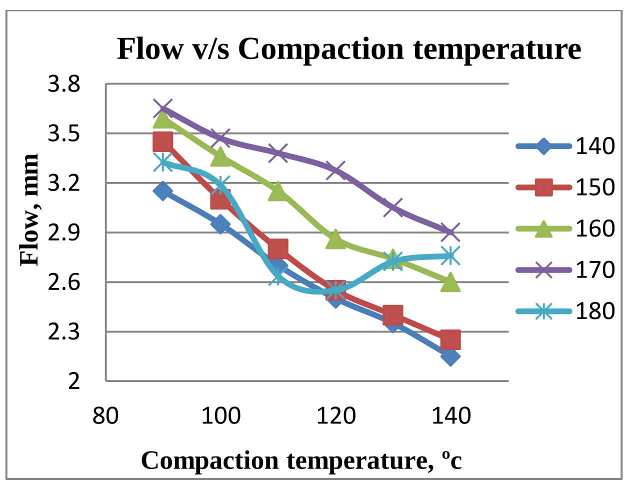
Table 4.2: Marshall Properties of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at Optimum Bitumen Content

SL. No.	Marshall Properties	Test Results	Requirements as per IRC SP 53 2002
1	Optimum Bitumen Content, %	5.63	-----
2	Marshall Stability, kgs	1776.83	1200
3	Marshall Flow, mm	3.60	2.5 - 4.0%
4	Marshall Quotient, kg/mm	493.56	250-500
5	Air voids(Vv), %	4.43	3.0 - 5.0%
6	Bulk density, g/cc	2.38	-----
7	Voids in Mineral Aggregates (VMA), %	17.59	-----
8	Voids filled with Bitumen (VFB), %	74.82	-----

4.4 COMPARISON OF MARSHALL PROPERTIES BY VARYING MIXING AND COMPACTION TEMPERATURES

Comparison of Marshall Properties V/S Compaction Temperature of Bituminous Concrete Mix prepared using Polymer Modified Bitumen for Mixing Temperature 140°C, 150°C, 160°C, 170°C and 180°C are shown in figure 4.2.





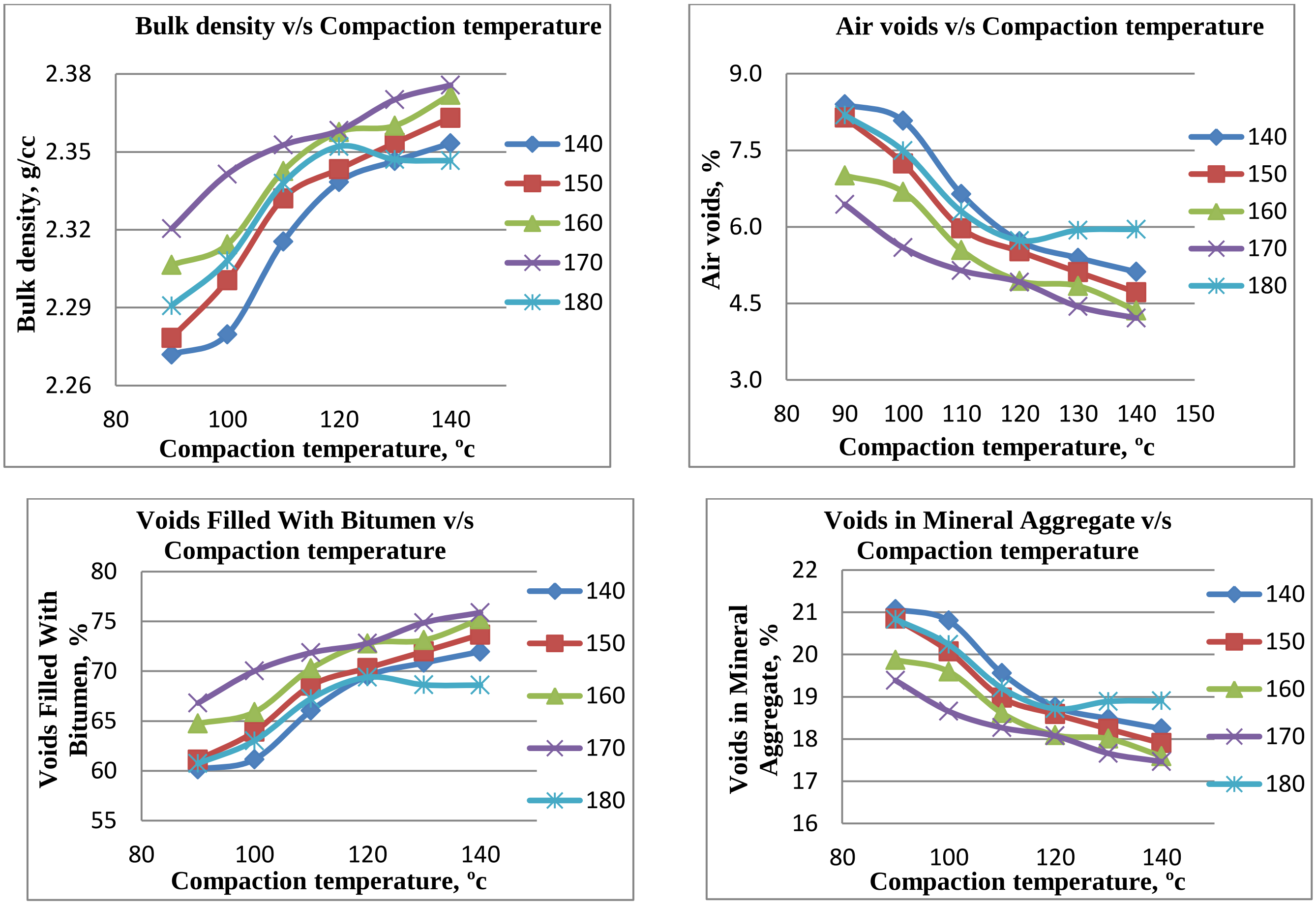


Figure 4.2: Comparison of Marshall Properties V/S Compaction Temperature of Bituminous Concrete Mix prepared using Polymer Modified Bitumen for Mixing Temperature 140°C, 150°C, 160°C, 170°C and 180°C

4.5 COMPARISON OF INDIRECT TENSILE STRENGTH BY VARYING MIXING AND COMPACTION TEMPERATURES

4.6

Comparison of Indirect Tensile Strength v/s Compaction Temperature of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at mixing temperature 140°C, 150°C, 160°C, and 170°C is shown in figure 4.3.

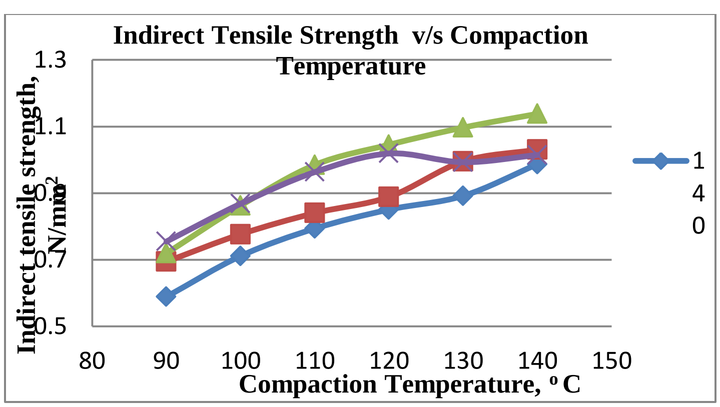


Figure 4.3: Comparison of Indirect Tensile Strength v/s Compaction Temperature of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at mixing temperature 140°C, 150°C, 160°C, and 170°C

4.7 INDIRECT TENSILE FATIGUE TEST ON BITUMINOUS CONCRETE MIX PREPARED USING POLYMER MODIFIED BITUMEN AT 25°C KEEPING CONSTANT MIXING TEMPERATURE, VARYING COMPACTION TEMPERATURE AND STRESS LEVEL

Indirect Tensile Fatigue Tests were conducted on cylindrical specimens of Bituminous Concrete Mix. Indirect Tensile Fatigue Test was conducted at 25°C test temperature on Bituminous Concrete Mix prepared using Polymer Modified Bitumen keeping constant mixing temperature (160°C), varying compaction temperature (110°C, 120°C, 130°C and 140°C) and stress levels (10%, 20%, 30% and 40%). The test results are presented in table 4.3, 4.4, 4.5, 4.6.

Table 4.3: Indirect Tensile Fatigue test on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and compaction temperature 110°C by varying Stress Level at 25°C test temperature

Stress Level, %	Load, N	Height of specimen, mm	Stress, Mpa	Resilient Horizontal Deformation, mm	Resilient Modulus, Mpa	Initial Tensile Strain, Micro	Fatigue Life, No. of cycles
10	1152	66.25	0.11069	0.03082	349.80	648.66	6156
10	1152	66.5	0.11027	0.03122	344.02	657.08	5854
20	2304	67	0.21889	0.06256	340.80	1316.69	1588
20	2304	66.5	0.22054	0.06408	335.22	1348.68	1392
30	3456	67.75	0.32470	0.09532	331.80	2006.18	480
30	3456	67.5	0.32591	0.09612	330.25	2023.02	446
40	4608	67.75	0.43294	0.12864	327.81	2707.46	208
40	4608	67.75	0.43294	0.12925	326.26	2720.30	188

Table 4.4: Indirect Tensile Fatigue test on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and compaction temperature 120°C by varying Stress Level at 25°C test temperature

Stress Level, %	Load, N	Height of specimen, mm	Stress, Mpa	Resilient Horizontal Deformation, mm	Resilient Modulus, Mpa	Initial Tensile Strain, Micro	Fatigue Life, No. of cycles
10	1255	65.5	0.12196	0.02533	468.98	533.12	6472
10	1255	66.25	0.12058	0.02595	452.60	546.16	6198
20	2511	66.5	0.24035	0.05856	399.78	1232.50	2326
20	2511	66.75	0.23945	0.05943	392.45	1250.81	2282
30	3767	67	0.35789	0.09232	377.59	1943.04	542
30	3767	67.5	0.35523	0.09286	372.61	1954.41	524
40	5022	67.75	0.47184	0.12456	368.96	2621.59	224
40	5022	67.5	0.47358	0.12694	363.38	2671.68	188

Table 4.5: Indirect Tensile Fatigue test on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and compaction temperature 130°C by varying Stress Level at 25°C test temperature

Stress Level, %	Load, N	Height of specimen, mm	Stress, Mpa	Resilient Horizontal Deformation, mm	Resilient Modulus, Mpa	Initial Tensile Strain, Micro	Fatigue Life, No. of cycles
10	1290	66	0.12441	0.02167	559.21	456.08	7124
10	1290	66	0.12441	0.02233	542.69	469.97	6878
20	2580	66.5	0.24696	0.05315	452.57	1118.64	2952
20	2580	66	0.24883	0.05422	447.00	1141.16	2796
30	3870	67.25	0.36630	0.08331	428.27	1753.41	590
30	3870	67.5	0.36495	0.08362	425.10	1759.93	558
40	5160	67	0.49023	0.11505	415.03	2421.43	262
40	5160	66.75	0.49206	0.11693	409.89	2461.00	234

Table 4.6: Indirect Tensile Fatigue test on Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and compaction temperature 140°C by varying Stress Level at 25°C test temperature

Stress Level, %	Load, N	Height of specimen, mm	Stress, Mpa	Resilient Horizontal Deformation, mm	Resilient Modulus, Mpa	Initial Tensile Strain, Micro	Fatigue Life, No. of cycles
10	1331	66.25	0.12788	0.01763	706.53	371.06	8158
10	1331	66.25	0.12788	0.01801	691.62	379.05	7856
20	2662	66.5	0.25481	0.03782	656.23	795.99	3952
20	2662	66.25	0.25577	0.03987	624.84	839.14	3788
30	3993	66.5	0.38221	0.06439	578.16	1355.20	906
30	3993	66.75	0.38078	0.06836	542.55	1438.76	792
40	5324	67	0.50581	0.10376	474.82	2183.82	456
40	5324	67.25	0.50393	0.10498	467.55	2209.49	374

4.8 LINEAR REGRESSION ANALYSIS

Linear regression analysis was carried out for data obtained from Indirect Tensile Fatigue Tests conducted at 25°C test temperature on Bituminous Concrete Mix prepared using Polymer Modified Bitumen and the details are presented in table 4.7 and graphs are shown in figure 4.4, 4.5, 4.6, 4.7.

Table 4.7: Linear regression analysis for the data obtained from Indirect Tensile Fatigue Test

Compaction Temperature	Relationship		R^2 value	Equations
110°C	Fatigue Life	Stress Level	0.7757	y = -184.48x + 6651
120°C			0.8537	y = -201.58x + 7384
130°C			0.875	y = -225.59x + 8314
140°C			0.9031	y = -257.97x + 9734.5
110°C	Fatigue Life	Tensile Stress	0.7797	y = -17236x + 6729.2
120°C			0.8569	y = -17246x + 7477.2
130°C			0.8724	y = -18493x + 8356.5
140°C			0.9073	y = -20567x + 9812.8
110°C	Fatigue Life	Resilient Modulus	0.8404	y = 274.1x – 89987
120°C			0.9858	y = 64.91x – 23590
130°C			0.9713	y = 48.86x – 19800
140°C			0.8349	y = 31.995x – 15681
110°C	Fatigue Life	Initial Tensile Strain	0.8125	y = -4.0105x + 8084.1
120°C			0.8545	y = -2.8692x + 6918.5
130°C			0.8709	y = -3.4292x + 7638.7
140°C			0.8125	y = -4.0105x + 8084.1

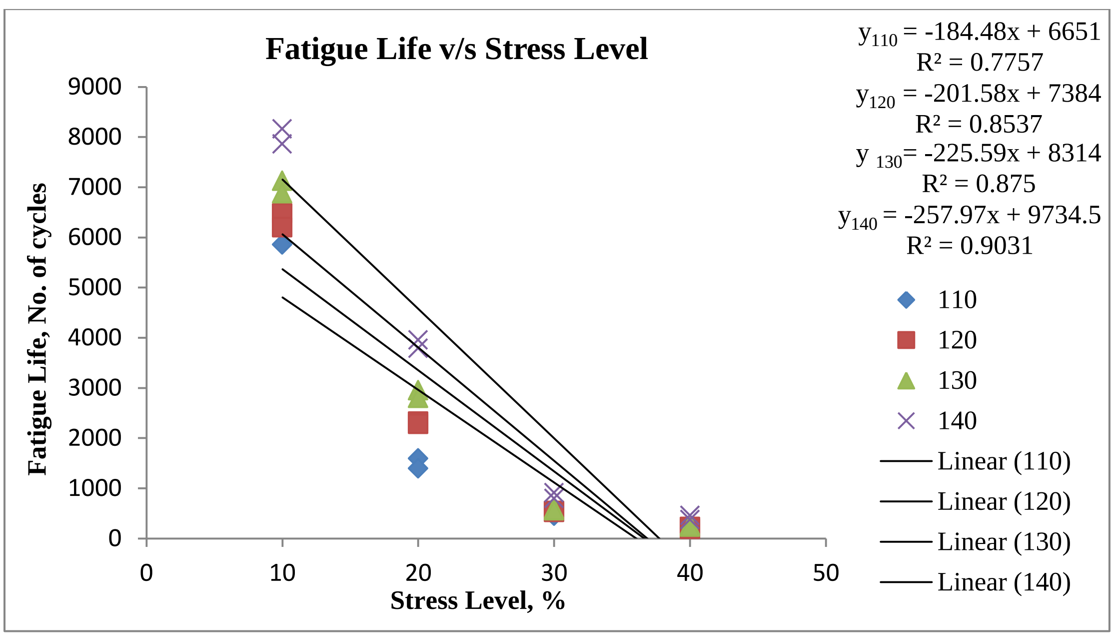


Figure 4.4: Fatigue Life v/s Stress Level of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and by varying compaction temperature (110°C, 120°C, 130°C and 140°C) and Stress Level at 25 °C

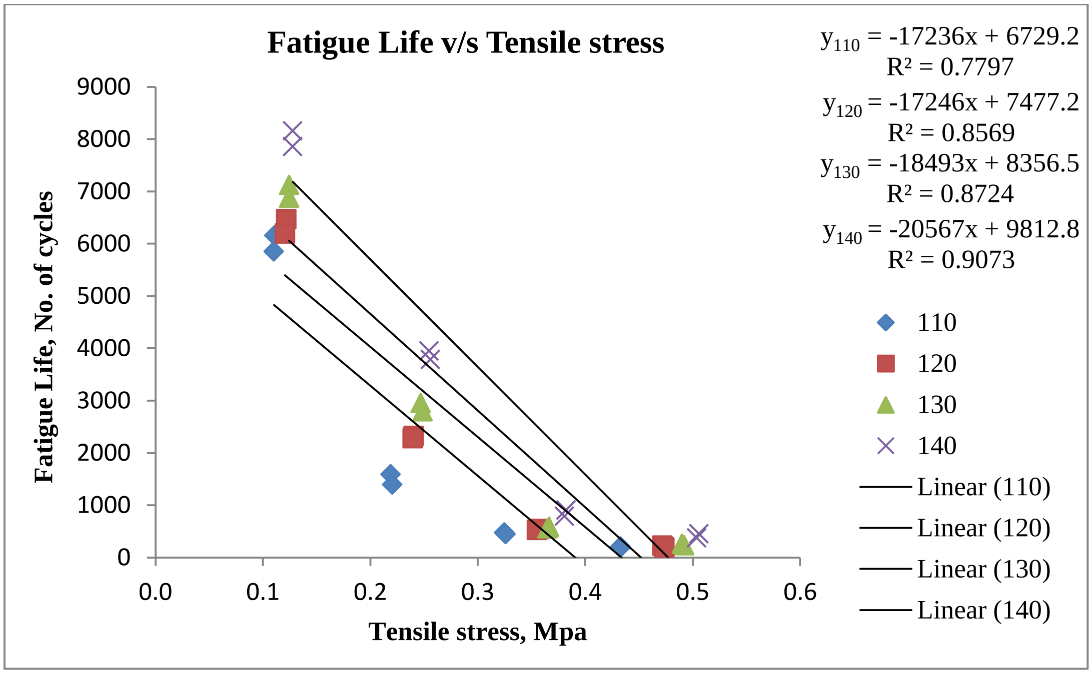


Figure 4.5: Fatigue Life v/s Tensile Stress of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and by varying compaction temperature (110°C, 120°C, 130°C and 140°C) and Stress Level at 25°C

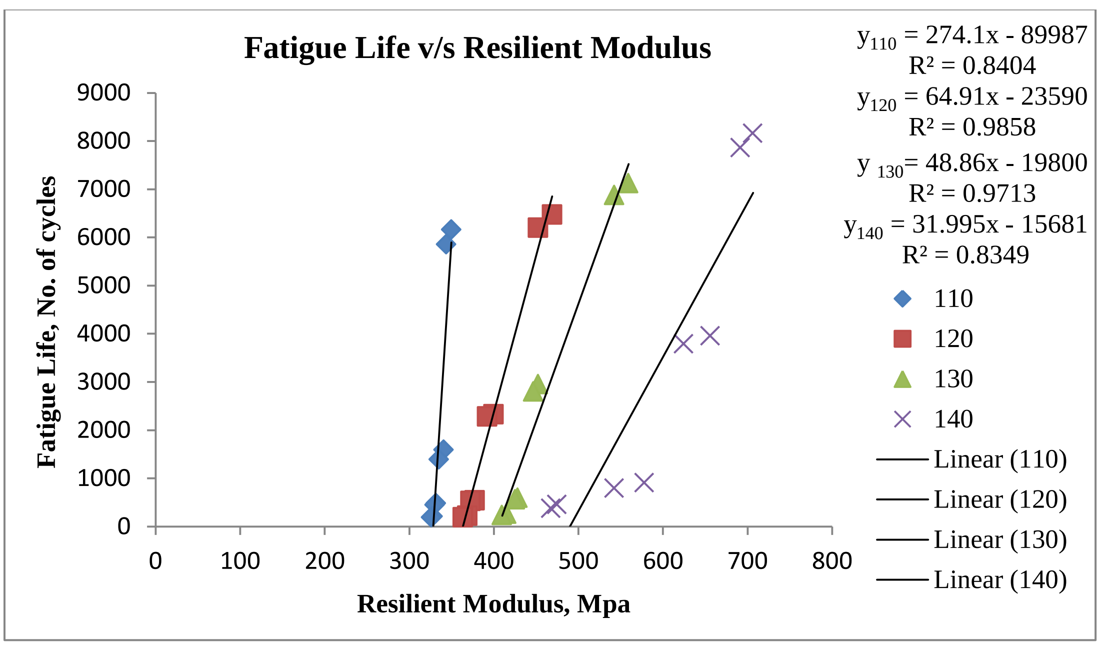


Figure 4.6: Fatigue Life v/s Resilient Modulus of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and by varying compaction temperature (110°C, 120°C, 130°C and 140°C) and Stress Level at 25°C

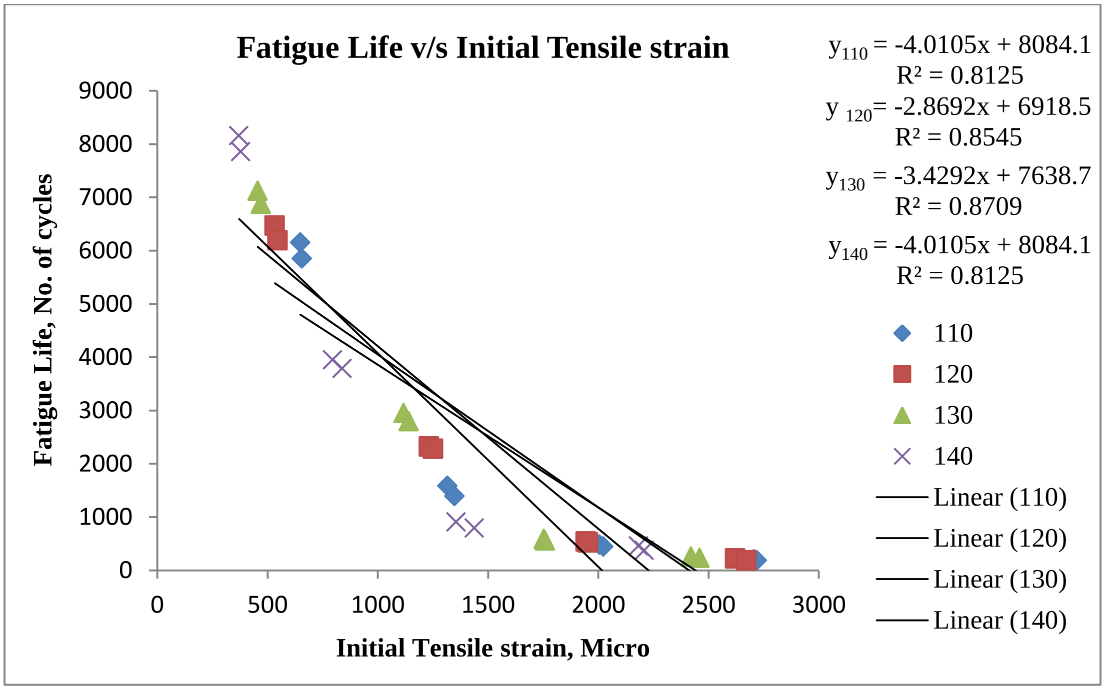


Figure 4.7: Fatigue Life v/s Initial Tensile Strain of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at constant mixing temperature 160°C and by varying compaction temperature (110°C, 120°C, 130°C and 140°C) and Stress Level at 25°C

DISCUSSIONS AND CONCLUSIONS

5.1 DISCUSSIONS

- It is observed from Table 4.1, the Optimum Bitumen Content obtained for Bituminous Concrete Mix prepared using Polymer Modified Bitumen is 5.63%.
- It is observed from Table 4.2, the Marshall Stability, Marshall Flow, Marshall Quotient, Bulk Density, Air Voids, VMA and VFB of Bituminous Concrete Mix prepared using Polymer Modified Bitumen at optimum bitumen content were 1776.83 kg, 3.6 mm, 493.56 kg/mm, 2.38 g/cc, 4.43%, 17.59% and 74.82% respectively.

Marshall Stability

- The Marshall Stability of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually increases with increase in compaction temperature by 38% from 90°C to 140°C.
- The Marshall Stability of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in mixing temperature by 14% from 140°C to 160°C and substantial increase by 2.4% from 160°C to 170°C as further increase in mixing temperature of 180°C there is sudden reduction in the stability by 23%.

Marshall Flow

- The Flow of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually decreases with increase in compaction temperature by 31.8% from 90°C to 140°C.
- The Flow of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in mixing temperature by 25.9% from 140°C to 170°C as further increase in mixing temperature of 180°C there is sudden reduction in the Flow by 4.8%.

Bulk Density

- The Bulk Density of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually increases with increase in compaction temperature by 3.5% from 90°C to 140°C.
- The Bulk Density of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in mixing temperature by 0.9% from 140°C to 170°C as further increase in mixing temperature of 180°C there is sudden reduction in the Bulk Density by 1.2%.

Air Voids

- The Air Voids of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually decreases with increase in compaction temperature by 39.1% from 90°C to 140°C.
- The Air Voids of Bituminous Concrete Mix prepared using Polymer Modified Bitumen decreases with increase in mixing temperature by 17.7% from 140°C to 170°C as further increase in mixing temperature of 180°C there is sudden increase in the Air Voids by 29.2%.

Voids in Mineral Aggregate

- The Voids in Mineral Aggregate of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually decreases with increase in compaction temperature by 13.4% from 90°C to 140°C.
- The Voids in Mineral Aggregate of Bituminous Concrete Mix prepared using Polymer Modified Bitumen decreases with increase in mixing temperature by 4.3% from 140°C to 170°C as further increase in mixing temperature of 180°C there is sudden increase in the Voids in Mineral Aggregate by 7.6%.

Voids filled with Bitumen

- The Voids filled with bitumen of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually increases with increase in compaction temperature by 16.4% from 90°C to 140°C.
- The Voids filled with bitumen of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in mixing temperature by 5.2% from 140°C to 170°C as further increase in mixing temperature of 180°C there is sudden reduction in the Voids filled with bitumen by 9.6%.

Indirect Tensile Strength Test

- The Indirect Tensile Strength of Bituminous Concrete Mix prepared using Polymer Modified Bitumen gradually increases with increase in compaction temperature by 36% from 90°C to 140°C.
- The Indirect Tensile Strength of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in mixing temperature by 13% from 140°C to 160°C as further increase in mixing temperature of 170°C there is sudden reduction in the Indirect Tensile Strength by 10%.

Indirect Tensile Fatigue Test

- The Fatigue Life of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in compaction temperature from 110°C to 140°C by 25.01% at 10% stress level, 61.54% at 20% stress level, 45.35% at 30% stress level and 52.06% at 40% stress level.
- The Resilient Modulus of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases with increase in compaction temperature from 110°C to 140°C by 50.37% at 10% stress level, 47.21% at 20% stress level, 40.87% at 30% stress level and 30.59% at 40% stress level.
- The Initial Tensile Strain of Bituminous Concrete Mix prepared using Polymer Modified Bitumen decreases with increase in compaction temperature from 110°C to 140°C by 42.55% at 10% stress level, 38.66% at 20% stress level, 30.66% at 30% stress level and 19.06% at 40% stress level.

5.2 CONCLUSIONS

- The Physical Properties of Aggregate satisfy the requirements as per Table 500-17 of MoRT&H specification.
- The Physical Properties of Polymer Modified Bitumen PMB-70 (SBS) satisfy the requirements as per IRC SP 53-2002.
- The Optimum Bitumen Content obtained for Polymer Modified Bituminous Concrete is 5.63%.
- There is considerable increase in the Marshall Stability as the mixing and compaction temperature increases and there is substantial reduction in the Marshall Stability with further increase in the mixing and compaction temperature.

- There is considerable increase in the Indirect Tensile Strength as the mixing and compaction temperature increases and there is substantial reduction in the Indirect Tensile Strength with further increase in the mixing and compaction temperature.
- Fatigue Life of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases as compaction temperature increases.
- Resilient Modulus of Bituminous Concrete Mix prepared using Polymer Modified Bitumen increases as compaction temperature increases.
- Initial Tensile Strain of Bituminous Concrete Mix prepared using Polymer Modified Bitumen decreases as compaction temperature increases.
- Based on the experimental work and analysis carried out in the present study, an ideal mixing temperature of 160^{o}C and compaction temperature of 140^{o}C is suggested for the preparation of Bituminous Concrete Mix prepared using Polymer Modified Bitumen-(70).

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