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Laboratory Investigation of Conventional Asphalt Mix Using Shell Thiopave for Indian Roads

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ABSTRACT
The characteristic performance of asphalt pavement always depends on the properties of bitumen, volumetric properties of asphalt mixtures. Bitumen is visco– elastic material where the temperature and rate of load application have a great influence on its behavior. There are different solutions to reduce the pavement distress such as using Thiopave (binder extender and asphalt mixture modifier) in the mix design. Thiopave can significantly alter the performance properties of the mix and it is helpful to extend the life span of pavement. In this study, investigating use of thiopave and the change in the performance properties is dependent both on the percentage of virgin binder using VG-30 bitumen that is substituted with thiopave with different percentages. The study indicated that 10%, 20%, 30% and 40% replacement of binder was done with thiopave. The most notable impact of the addition of thiopave to a bituminous mixture is an increase in the stiffness of the mixture for better resistance to fatigue cracking and rutting. Thiopave materials can have a positive impact on laboratory mixture performance. The addition of thiopave has been shown to significantly increase Marshall Stability. From this study it is observed that thiopave can be utilized up to 30% to 40% as replacement to bitumen.
Keywords **-** Aggregates; Filler; Bitumen; Shell Thiopave

I. INTRODUCTION

The surface layer is made of bituminous combination with aggregate and filler material. The material for the base coarse is typically base course of wet mix macadam, crusher run macadam aggregates or unbound granular layers. The aggregate base could also be bound layer mixed with Bitumen. The sub-base is mostly a local aggregate material. Also, the top of the sub grade is sometimes stabilized with lime.

In India, the bitumen grading is provided on basis of viscosity test, which is conducted to know the viscosity of bitumen by measuring the time required for a fixed quantity of material to flow at a temperature of 135°C temperature. A huge amount of money is invested in highway construction to reach excellent pavement performance. But the pavement shows distress due to change in climatic condition and high traffic loads, which are directly affect the durability and pavement performance. The most common problem associated with the performance of bituminous pavements is fatigue cracking during cold climate and rutting during hot summer.

Therefore, pavement distress needs urgent solutions which is very necessary and does not accept any delay. The typical road surface temperature on a hot summer day is 60°C to 70°C. At this temperature the bitumen becomes soft and starts to penetrate and shove under loaded truck tyres which lead to rutting and corrugations under the wheel tracks of the highway pavement. But when temperature falls or in the cold climate, bituminous pavements become too brittle and fatigue cracks occur when excessively loaded. Fatigue is the process of cumulative damage resulting from repeated traffic loading. There are several ways to minimize the distress of asphalt pavements, which could improve the service and extent the pavement life such as:

- By producing new asphalt additives in the conventional mix which improved physical, chemical and mechanical properties.
- By improving pavements and mix design.
- By improving the construction methods and maintenance techniques.

The most important solutions for pavement distress are to develop a new binder with the help of additives. Has also been used a common method to extend bitumen (conventional mix) properties and is found to have wide range of application and potential for use.

A. Advantages of Thiopave into Conventional Asphalt Mix

1. It replaced up to 30 to 40 % of the bitumen in a conventional bituminous mixture with all equivalent volume of Thiopave as well as an asphalt mixture modifier, which can lower the compaction temperatures of paving mixtures.

2. Thiopave pallet contains up to 3% carbon black which acts as a plasticizer for improved dispersion in the mixture and mixture workability.
3. Thiopave reduces emissions of Hydrogen sulphide (H_2S) entrained in the sulphur. Workability additive allows the asphalt mixture to be mixed at lower temperature than conventional asphalt, which limits H_2S generation and saves energy in asphalt production.
4. Thiopave dispersed in the bitumen eventually precipitates to form sulphur crystals and lattices, which stiffens the asphalt paving mixture at high service temperature and under slow or stationary loads.

B. Aim of the Study

The aims of present study are

1. The Study of this work is to explore use of thiopave into conventional mix Grade-I (dense bituminous macadam) to improve the performance of flexible pavements.
2. To study the marshall properties of dense bituminous macadam Grade –I mixes using VG- 30 and thiopave.
3. To study the marshall stability retained in saturated condition.
4. To study the aggregate coating with VG-30 and thiopave material.
5. To study the effects of thiopave on dense bituminous macadam mix with VG-30 in terms of flow.
6. To study the Retained stability in saturated condition.
7. To compare the experimental tests results of dense bituminous macadam mix with that of thiopave for 10, 20, 30 and 40 different percentages.

II. MATERIALS AND THIER PHYSICAL PROPERTIES

A. Bitumen

The Bitumen used was VG-30(50 -70 Grade) bitumen with supplied by Mangalore Refineries Petroleum Limited, Karnataka. Paving bitumen conforming to IS:73:2006. The various properties of Bitumen were in accordance with results are tabulated in Table 1.

Table 1: Properties of Bitumen – VG-30

SL. No	Test	Results	IS: 73-2006 (III Revision) requirement
1	Specific Gravity (gms/cc)	1.02	0.99 min
2	Thin Film Oven test (%)	0.928	2% max
3	Ductility test (cm)	46.5	40 min
4	Softening Point test (^oC)	48.8	47 min
5	Penetration test (mm)	57	50 -70
6	Flash Point test (^oC)	246	220 min
7	Kinematic Viscosity test	378.13	350 min

B. Aggregate (Coarse and Fine Aggregate)

In this investigation, the Aggregate locally available stone were used as coarse aggregates and fine aggregate. The aggregates were collected from the Vastrad Crushers near Hire Bagewadi village, Belgaum, Karnataka. The aggregates were tested as per relevant IS specification IS: 2386-1963.

Table 2: Individual Sieve Analysis of 40mm, 20 mm, 10 mm, 5mm Aggregate and filler for dense bituminous macadam:

Sieve Size in mm	% Weight passing			
	40 mm	20 mm	10 mm	5 mm
45	100	100	100	100
37.5	98.28	100	100	100
26.5	59.88	100	100	100
13.2	0.50	22.70	95.26	100
4.75	0.00	3.22	12.13	96.59
2.36	0.00	2.57	4.05	75.78
0.300	0.00	0.00	1.47	30.79
0.075	0.00	0.00	0.00	11.68

Table 3: Aggregate blending gradation for dense bituminous macadam

Sieve Size in mm	Aggregate blending gradation adopted (25: 16: 20:39)	Specified gradation Limits As per MoRT&H	Mid Limit
45	100	100	100
37.5	99.57	95 – 100	97.5
26.5	89.97	63 – 93	78
13.2	61.81	55 – 75	65

4.75	40.61	38 – 54	46
2.36	30.78	28 - 42	35
0.300	12.30	7 – 21	14
0.075	4.56	2 - 8	5

Table 4: Permissible Variation Limits for Job Mix

Sieve Size mm	% of Passing	Permissible Variation Limits As per MoRT&H	JMF Lower Limit	JMF Upper Limit
45	100	(+/-) 8	100	100
37.5	99.57	(+/-) 8	95	100
26.5	89.97	(+/-) 8	82	93
13.2	61.81	(+/-) 7	55	69
4.75	40.61	(+/-) 6	38	47
2.36	30.78	(+/-) 5	28	36
0.300	12.30	(+/-) 4	8	16
0.075	4.56	(+/-) 2	3	7

Table 5: Blending Dry Gradation for Dense bituminous macadam of ratios 25:16:20:39 of total weight = 20000kg (40 mm = 5000 kg, 20 mm = 3200 kg, 10 mm= 4000 kg and 5 mm = 7800 kg)

Sieve Size mm	Weight Retained (gms)	Weight of Cumulative Retained (gms)	% of Weight Retained	% of Passing
45	0	0	0	100
37.5	132	132	0.66	99.34
26.5	2062	2194	10.97	89.03
13.2	5379	7573	37.87	62.14
4.75	4013	11586	57.93	42.07
2.36	2014	13600	68.00	32.00
0.300	3834	17434	87.17	12.83
0.075	1667	19101	95.51	4.50

Graph -1: Shows Blending Dry Gradation Limits for Dense bituminous macadam of ratios 25:16:20:39

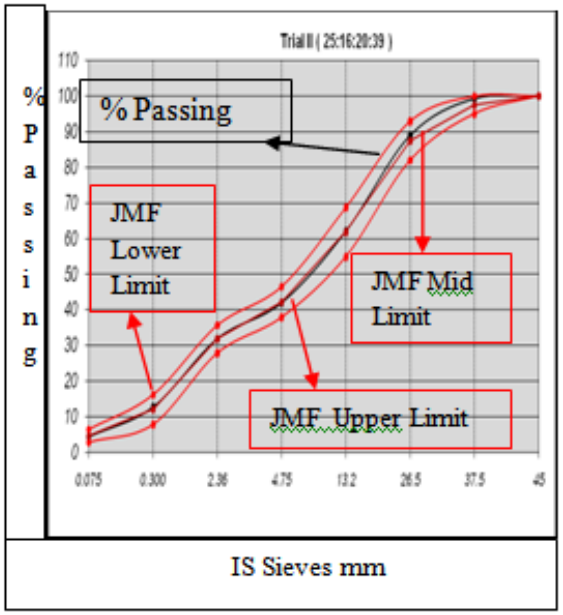


Table 6: Physical Properties of Aggregate

SL. No.	Tests	Results	Specification
1	Specific gravity (gm/cc)	40 mm = 2.849 20 mm = 2.904 10 mm = 2.916 Fine(Dust) = 2.775	2% (maximum)
2	Water absorption test (%)	40 mm = 1.45 20 mm = 1.55 10 mm = 1.60 Fine(Dust) = 1.90	27% (maximum)
3	Impact value test (%)	10.19	35% (maximum)
4	Los angeles abrasion test (%)	3.71	30% (maximum)
5	FI and EI test combined (%)	40 mm = 25.75 20 mm = 27.55 10 mm = 28.06	95% (minimum) IS:6241
6	Stripping value test (%)	96.33	

III. Methodology

A. Introduction

The present investigation the use of thiopave, the change in the performance properties is dependent both on the % of virgin binder using VG-30 bitumen that is substituted with thiopave with different percentages. The standard tests of all materials have been carried out in the laboratory as per the relevant codes.

B. Equipment Used

The following apparatus are used in the present investigation.

1. Marshall Testing machine.
2. Compaction Pedestal.
3. Oven and hot plates.
4. Water bath with thermostatically controlled.
5. Compaction mold, Compaction Hammer, paper disks, steel specimen extractor.
6. Containers, Flat bottom metal pans, Round metal pans, trowels, spatula, weighing balance, thermometers etc.
7. Glass flask, vacuum pump,

C. Determination of design asphalt content

After getting the results of stability, flow values and void data:

1) Measured stability values for specimens that depart from the standard 95.2 mm (3.75 Inch) value by means of a conversion factor. Applicable correlation ratio to convert the measured values as per 5.16 from (MS-2). Note that the conversion may be made on the basis of either measured volume.

2) Average the flow values and the final converted stability values for all specimens of given asphalt content.

3) Prepare a separate graphical plot for these values and connect plotted points with a smooth curve that obtains the best fit to determine the design asphalt content of the mix.

D. Selection of final mix design –

The design asphalt content should be a compromise selected to balance all of the mix properties. The mix design criteria will produce a narrow range of acceptable asphalt contents that pass all of the guidelines and selection of asphalt can be adjusted within the narrow range to achieve a mix property that will satisfy a requirement of a specific project.

E. Retain stability -

Marshall Stability of compacted specimens was determined after conditioning them by keeping in water bath maintained at 60°C for 24 hours prior to testing.

Table 7: Batch Weight of Mix With 100% Aggregates Of Ratios 25:16:20:39 and Bitumen 3.0, 3.5, 4.0, 4.5 and 5.0 Percentages.

IS Sieve (mm)	Percentage Weight Retained P in (%)	BITUMEN CONTENT (VG-30)				
		3.0%	3.5%	4.0%	4.5%	5.0%
P-45 and R -37.5	0.43	17.52	17.43	17.34	17.25	17.16
P -37.5 and R -26.5	9.60	391.10	389.09	387.07	385.06	383.04
P-26.5 and R-1 3.2	28.16	1147.24	1141.32	1135.41	1129.50	1123.58
P-13.2 and R-4.75	21.20	863.69	859.24	854.78	850.33	845.88
P-4.75 and R -2.36	9.83	400.47	398.41	396.35	394.28	392.22
P-2.36 and R- 0.300	18.48	752.88	748.99	745.11	741.23	737.35
P- 0.300 and R -0.075	7.74	315.33	313.70	312.08	310.45	308.83
P -0.075 and R - Pan	4.56	185.77	184.82	183.86	182.90	181.94
Bitumen (VG-30)		126.0	147.0	168.0	189.0	210.0
Total Weight of Aggregate		4074.0	4053.0	4032.0	4011.0	3990.0
Total Weight of Mix		4200	4200	4200	4200	4200

Note: P- Passing and R- Retained

Table 7: Maximum Specific Gravity Of Mix Of Ratios 25:16:20:39 and Bitumen 3.0, 3.5, 4.0, 4.5 And 5.0 Percentages.

Sl. No	Bitumen Content (%)	Maximum Specific Gravity of Paving Mix
1	3.0	2.732

2	3.5	2.709
3	4.0	2.686
4	4.5	2.663
5	5.0	2.641

Table 8: Marshall Properties For Determining The Optimum Binder Content For Dense Bituminous Macadam Grade-I.

Sl.No.	Bitumen Content (%)	Avg Bulk Density (g/cc)	Avg Stability (KN)	Air Voids (%)	Avg Flow (mm)	Voids in Mineral Aggregate (%)	Voids Filled by bitumen (%)
1	3.0	2.540	21.37	7.02	2.40	13.26	47.06
2	3.5	2.551	23.66	5.84	2.97	13.36	56.31
3	4.0	2.572	25.95	4.25	3.73	13.10	67.58
4	4.5	2.565	24.87	3.67	3.83	13.76	73.32
5	5.0	2.555	23.12	3.25	4.53	14.56	77.68

From the above table results we know the optimum binder content is 4.3%. (From graph and Narrow range of acceptable)

Table 9: Batch Weight of Mix for Marshall Stability and Maximum Specific Gravity With 100% Aggregates Of Ratios 25:16:20:39 and Bitumen 4.3%.

IS Sieve (mm)	Percentage Weight Retained P in (%)	Bitumen Content (VG-30)	
		4.3% Mould	4.3% Gmm
P -45 and R -37.5	0.43	17.28	20.58
P -37.5 and R -26.5	9.60	385.86	459.36
P -26.5 and R-1 3.2	28.16	1131.86	1347.46
P -13.2 and R- 4.75	21.20	852.11	1014.42
P -4.75 and R -2.36	9.83	395.51	470.84
P- 2.36 and R -0.300	18.48	742.79	884.27
P -0.30 and R -0.075	7.74	311.10	370.36
P- 0.075 and R -Pan	4.56	183.28	218.20
Bitumen (VG-30)		180.60	215
Total Weight of Aggregate		4019.40	4785
Total Weight of Mix		4200	5000

Note: P- Passing and R- Retained
Maximum Specific gravity for 4.3% Bitumen = 2.677

Table 10: Marshall Properties and Retained Stability for Binder Content 4.3% for Dense Bituminous Macadam Grade-I.

Sl.No.	Bitumen Content (%)	Avg Bulk Density (g/cc)	Avg Stability (KN)	Air Voids (%)	Avg Flow (mm)	Voids in Mineral Aggregate (%)	Voids Filled by bitumen (%)
1	4.3	2.569	25.74	4.05	3.88	13.48	69.94
2	4.3 (30 minutes Soaking at 60°C)	2.568	26.35	4.08	4.00	13.50	69.79
3	4.3 (24 Hours in. Soaking at 60°C)	2.566	22.85	4.16	-	13.58	69.36

Retained stability = (22.85/ 26.35) X100 = 86.73 % minimum required 80 % as per MoRT&H

III: Thiopave as a Additive Used In The Dense Bituminous Mix

Thiopave is patented product developed by shell sulphur solutions for use in bituminous paving mixture as an additive. The thiopave is an odorless pellet containing sulphur, plasticizer and compaction additives to improve workability of bituminous mixture during paving operation. Melting point of thiopave is approximately 130°C. The thiopave is added directly into the aggregates and bitumen mixture during the mixing process. The thiopave helps in replacing the bitumen by 10 to 40% in the bituminous mixture (Bituminous macadam and Dense bituminous macadam).

A: Method for Calculation of Thiopave and Bitumen for Dense Bituminous Macadam Mixture

Marshall Mix design method was adopted for design of both conventional and Thiopave dense bituminous macadam mixtures. The optimum bitumen content obtained for conventional dense bituminous macadam mixture with VG-30 grade bitumen was 4.3% .In this section the Thiopave to bitumen ratio considered was 10:90, 20: 80, 30:70, and 40:60 respective ratios. The specific gravity of Thiopave (2.0) is higher than the specific gravity of bitumen, the total quantity of binder, the mixture of thiopave + bitumen required was calculated using equation,

Thiopave +
Bitumen weight % = A X [100 R / 100 R – Ps (R – G bitumen)]

Where,

A = Percent bitumen by mass (optimum binder content) in conventional mixture design.

Ps = Mass % Thiopave in binder

G = Specific gravity of bitumen

R = Thiopave to bitumen substitution ratio for equivalent binder volume.

R = G Thiopave / G bitumen = G Th / G Bit

Consider A = 4.3%

Ps = 40 % (i.e. 40 % Thiopave and 60% Bitumen blend by mass)

G Thiopave = 2.0

Gbit = 1.02

= 100 **[**(40 / 2) + 60/1.02)]

GB = 1.269 **(Combined specific gravity)**

= 2.0/1.02 = 1.96

Thiopave + Bitumen weight %

= 4.3 x [100 x 1.96 / 100(1.96) – (40) (1.96 – 1.02)]

= 4.3 x 196 / 196-37.6

= 4.3 x 1.23

Bitumen Content (VG-30 + Thiopave) = 5.32%

Therefore, P_{TH} = 2.12% and P_{Bit} = 3.2%

Table 11: Batch Weight of Thiopave and bitumen ratios 10:90, 20: 80, 30:70, and 40:60 respectively

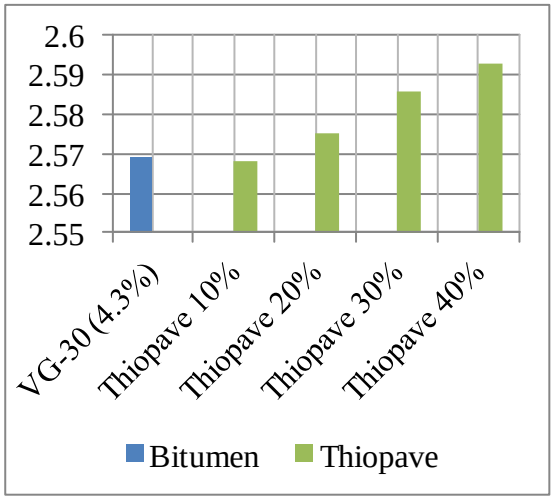
IS Sieve (mm)	Weight Retained P in (%)	Thiopave : Bitumen			
		10:90	**20:80**	**30:70**	**40:60**
P- 45 & R -37.5	0.43	17.20	17.20	17.20	17.20
P-37.5 & R -26.5	9.60	384.00	384.00	384.00	384.00
P-26.5 & R-1 3.2	28.16	1126.40	1126.40	1126.40	1126.40
P-13.2 & R-4.75	21.20	848.00	848.00	848.00	848.00
P-4.75 & R-2.36	9.83	393.60	393.60	393.60	393.60
P-2.36 & R- 0.300	18.48	739.20	739.20	739.20	739.20
P-0.300 &R-0.075	7.74	309.60	309.60	309.60	309.60
P-0.075 & R - Pan	4.56	182.40	182.40	182.40	182.40
Bitumen (VG-30) in %		171.73 (4.10%)	159.66 (3.80%)	147.37 (3.5%)	135.16 (3.2%)
Total Weight of Aggregate		4000	4000	4000	4000
Weight of Thiopave in %		18.85 (0.45%)	40.34 (0.96%)	63.16 (1.5%)	89.55 (2.12%)
Weight of Compaction Additive in %		0.84 (0.02%)	0.84 (0.02%)	0.84 (0.02%)	0.84 (0.02%)
Total Weight of Mix		4191.42	4200.84	4211.37	4225.55

B: Comparison of Marshall Properties with Bitumen VG-30 and different % of Thiopave + Bitumen.

Table 12: Marshall Density of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG-30 %	Bitumen + Thiopave %			
Percentage	4.3%	10% + 90%	20% + 80%	30% + 70%	40% + 60%
Density (g/cc)	2.569	2.568	2.575	2.586	2.593

Fig-1: Variation of Marshall Density of Asphalt with VG-30 and Different % of Thiopave + Bitumen

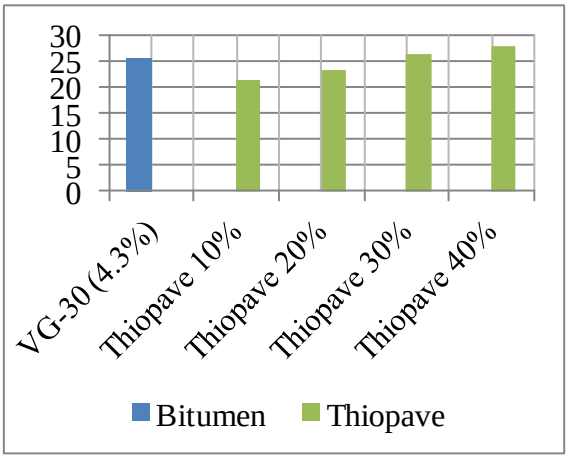


It shows that a higher density value is with 60% Bitumen + 40% Thiopave i.e. 2.593 g/cc and lower density value is with 90% Bitumen + 10% Thiopave.

Table 13: Stability of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG - 30 %	Bitumen + Thiopave %			
Percentage	4.3%	10% + 90%	20% + 80%	30% + 70%	40% + 60%
Stability (KN)	25.74	21.48	23.78	26.47	28.60

Fig-2: Variation of Stability of Asphalt with VG-30 and Different % of Thiopave + Bitumen

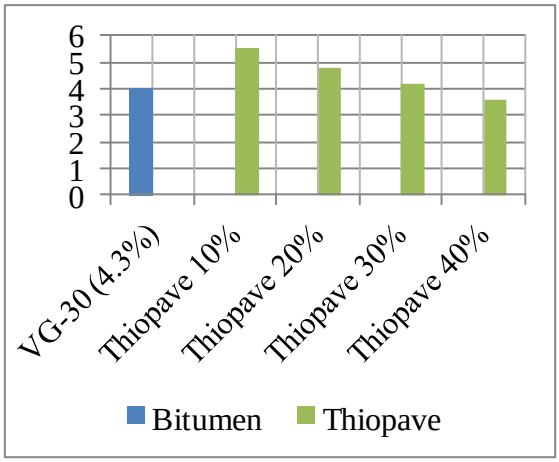


It shows that a higher stability value is with 60% Bitumen + 40% Thiopave i.e. 28.60 KN and lower stability value is with 90% Bitumen + 10% Thiopave.

Table 14: Air Voids of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG - 30 %	Bitumen + Thiopave %			
Percentage	4.3%	10% + 90%	20% + 80%	30% + 70%	40% + 60%
Air Voids (%)	4.05	5.55	4.79	4.2	3.6

Fig-3: Variation of Air Voids of Asphalt with VG-30 and Different % of Thiopave + Bitumen

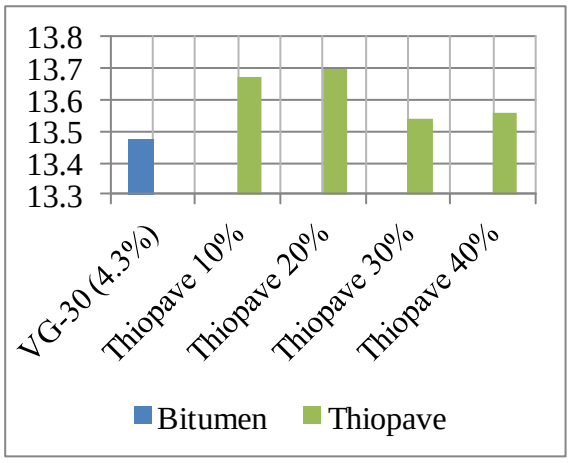


It shows that a high percentage of air voids is with 90% Bitumen + 10% Thiopave i.e. 5.55% and less percentage of air voids is with 60% Bitumen + 40% Thiopave.

Table 15: Voids in Mineral Aggregate of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG - 30 %	Bitumen + Thiopave %			
Percentage	4.3%	10% + 90%	20% + 80%	30% + 70%	40% + 60%
Voids in Mineral Aggregate (%)	13.48	13.67	13.70	13.54	13.56

Fig-4: Variation of Voids in Mineral Aggregate of Asphalt with VG-30 and Different % of Thiopave + Bitumen

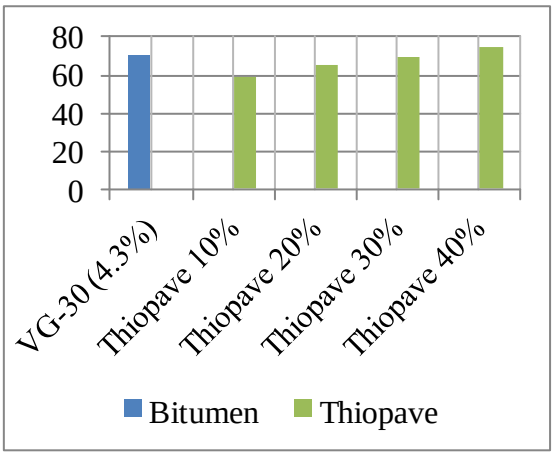


It shows that a high percentage of voids in mineral aggregate is with 80% Bitumen + 20% Thiopave i.e. 13.70% and less percentage of voids in mineral aggregate is with VG-30 Bitumen.

Table 16: Voids filled by Bitumen of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG - 30 %	Bitumen + Thiopave %			
Percentage	4.3%	10% + 90%	20% + 80%	30% + 70%	40% + 60%
Voids Filled by Bitumen (%)	69.94	59.43	65.03	68.96	73.44

Fig-5: Variation of Voids Filled by Bitumen of Asphalt with VG-30 and Different % of Thiopave + Bitumen

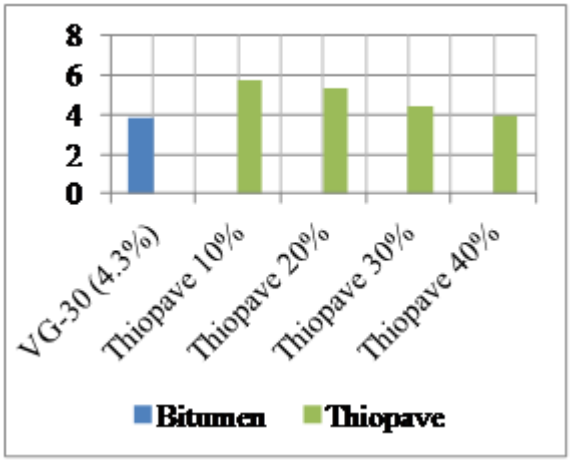


It shows that a high percentage of voids filled by bitumen are with 60% Bitumen + 40% Thiopave i.e. 73.44% and less percentage of voids filled by bitumen is with 90% Bitumen + 10% Thiopave.

Table 17: Flow of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG - 30 %	Bitumen + Thiopave %			
Percentage	4.3%	10% + 90%	20% + 80%	30% + 70%	40% + 60%
Flow (mm)	3.88	5.77	5.33	4.4	3.98

Fig-6: Flow of Asphalt with VG-30 and Different % of Thiopave + Bitumen

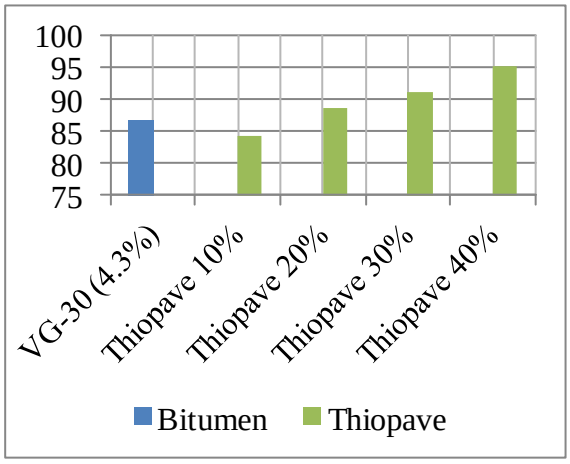


It shows that a higher value of flow is with 90% Bitumen + 10% Thiopave i.e. 5.77 mm and less flow is with VG-30 Bitumen.

Table 18: Retained Stability of Asphalt Mix with VG-30 Bitumen and Different % of Thiopave + Bitumen

Content	VG - 30 %	Bitumen + Thiopave %			
Percentage	4.3%	+ 10% 90%	+ 20% 80%	+ 30% 70%	+ 40% 60%
Retained Stability (%)	86.73	84.28	89.53	91.29	95.16

Fig-7: Retained Stability of Asphalt with VG-30 and Different % of Thiopave + Bitumen



It shows that a higher % of retained stability is with 60% Bitumen + 40% Thiopave i.e. 95.16 % and less retained stability is with 90% Bitumen + 10% Thiopave.

IV. RESULTS

Results: Physical Properties

1. Results of physical properties of the paving grade (VG-30) bitumen used for this study were tested and presented respectively and the test results are satisfactory the requirements as per IS: 73-2006.
2. Results of physical properties of the aggregates used for present study are presented and the tests results are almost meeting the requirements as per table: 500-8 of MoRT&H specifications (Fourth Revision).

Marshall Properties

1. The marshall properties of DBM grade –I using original paving grade (vg-30) and different % of replacement of bitumen with thiopave satisfies requirements of MoRT&H specification Revision IV.
2. From graphs, it is found that optimum binder content for DBM grade- I is 4.3% with VG-30 bitumen.
3. Results and chart shows the marshall test indicate that density is gradually increasing with increase in thiopave replacing bitumen percentage in the DBM mix. For VG-30 – 2.569 and Bitumen a thiopave mix (60+40) % is 2.593.
4. Marshall Stability of VG-30 bitumen for DBM is 25.74 KN and with bitumen and thiopave mix (70:30 and 60:40) is 26.47 KN and 28.60 KN respectively.
5. Marshall Flow of VG-30 IN DBM is decreases compared to thiopave and bitumen mix. VG-30 is 3.88 mm and bitumen and thiopave mix are increases.
6. Air voids in VG-30 was 4.05% is less, compared to bitumen and thiopave mix percentages.
7. Voids filled with mineral aggregates in VG-30 are 13.48% is lesser than the bitumen and thiopave mix percentages.
8. Voids filled with bitumen with VG-30 was 69.94% is less, compared to bitumen and thiopave mix of 60 +40 ratio. Laboratory Investigation of Conventional Asphalt mix using Shell Thiopave for Indian Roads.

Retained Marshall Stability

1. Retained Marshall Stability of bitumen VG-30 was 86.73% is lesser, compared to bitumen and thiopave % values of ratios 80:20, 70:30 and 60:40 respectively

V. CONCLUSION

1. With the help of this study is concluded that thiopave can be a most effective for replacement for bitumen at 30 to 40 %.
2. The Thiopave dense bituminous mixtures have higher Marshall Stability value indicating that it is a rutting resistant mixture. The Marshall Stability values were increased higher with thiopave dense bituminous macadam mixtures when compared with conventional DBM.
3. The maximum stability and density will increase in the % of mix with thiopave bitumen is 70:30 and 60:40 ratios.
4. The maximum Air voids and voids in mineral aggregate will increase in the % of mix with thiopave and bitumen is 90:10 and 80:20 ratios.
5. The maximum flow will be increases in the % of mix with thiopave and bitumen is 90:10 and 80:20 ratios. And flow will increased stability and density will be decreases.
6. The voids filled is increases in the % of mix with thiopave and bitumen is 60:40 ratio. The density and stability also increases.
7. Retained stability will be increases in the % of mix of thiopave and bitumen 70:30, 80:20 and

90:10 ratios. The increased in stability pavement life will be more.

8. Compared to normal hot mix asphalt with bitumen and thiopave the cost reduction of about 20 to 30 % can be saved.

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