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Utilization of Zycotherm as an Admixture for Bituminous Road Construction

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Abstract

In India, roads are the dominant mode of transportation and form the backbone for economic development of the country. The road network in India is over 4.86 million kilometers which is the second largest in the world. Most of the roads in the country are flexible in nature, with an average life span of 10-15 years. There are multiple factors which influence the life of flexible pavement mainly traffic, environment, material properties, pavement thickness, strength of pavement as well as subgrade properties which affect the mechanical characteristics of a pavement. Generally, a well-designed flexible pavement requires frequent maintenance after certain period of time due to development of defects like potholes, longitudinal cracking, and transverse cracking, raveling and flushing etc. However, various studies have concluded that the addition of certain admixtures such as fly ash, rice husk ash, High-density polyethylene (HDPE) etc. can reduce these defects by strengthening the pavement so as to extend the lifecycle.

In the present study, an attempt has been made to access the influence of a chemical admixture known as Zycotherm on Dense Bituminous Macadam (DBM) mix of grade II. In view of this, the Stability-Flow analysis was carried out for DBM mix of grade II by varying the percentage of bitumen modified with Zycotherm. It was found that the bitumen modified with chemical admixture resulted in an increment of Marshall Stability and improved mix flow.

Keywords: DBM, Chemical Admixtures, Zycotherm, Marshall Stability

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1. Main text

The economic development of any country depends on the quality and efficiency of its transportation system. In India, the road transport carries almost 80% of passenger traffic and 70% of freight transport. The quantitative density of Indian road is 1.66 km of roads per square kilometers of land which is higher than Japan, United States, China, Russia and Brazil, however qualitatively Indian roads are a mix of modern highways, narrow unpaved roads which are still under development. Most of the roads in the country are flexible in nature, which are typically designed for a life span of 10-15 years. The asphalt binder is the key element in these types of pavements, which forms adhesion bond with aggregates. The strength of the adhesion bond between aggregates and asphalts mainly determines the performance of a pavement. For acceptable performance, this adhesion bond must withstand the presence of water for prolonged periods of time. Pavement failure at the aggregate-asphalt interface due to water is termed as water stripping and the technology which is used today is not serving the purpose, because every year seasonal rains leave the roads in a miserable condition. This leads to pavement defects like potholes, longitudinal cracking, transverse cracking, raveling and flushing etc, which requires frequent maintenance.

Moisture damage is a major problem in asphalt pavements, and shows itself in various forms with multiple mechanisms, such as adhesion failure between asphalt and aggregate, moisture-induced cohesion failure within the asphalt binder, cohesion failures within the aggregate, and freezing of entrapped water. Among those, the reduction of adhesion between asphalt and aggregates in the presence of water and the deterioration of asphalt due to cohesive failure within the asphalt binder itself have been known as two primary driving mechanisms of moisture damage. In view of above, the modification of binder is a better alternative to ensure the appropriate pavement quality. The material used as modifier should be capable of resisting temperature susceptibility, fatigue loading and various environmental effects. The utilization of modifiers such as styrene based polymers, polyethylene based polymers, polychloroprene, and various oils to improve the engineering properties of asphalt is new. Various studies have concluded the benefits of using mineral admixtures for asphalt road construction.

In the present study, the impact of utilization of a new nanotechnology material known as zycotherm in DBM mix was investigated by analyzing the Marshall properties of the mix. The results obtained from the tests shows that the use of zycotherm enhances the properties of the mix up to a desirable extent.

2. Material

The materials used in this study include coarse aggregates, fine aggregates, filler and bitumen which along with their requisite specifications is shown in table 1.

Table 1. Specifications of various materials used for sample preparation

Material Used	Properties
Coarse Aggregate	Coarse aggregate for DBM mix consist of crushed rock, crushed gravel, or other hard materials retained on I.S. Sieve of size 2.36 mm. The aggregates shall satisfy the requirement specified in MORTH V[th] Revision.
Fine Aggregate	Fine aggregate shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the I.S. sieve of size 2.36mm and retained on the 75micron sieve. It should satisfy the requirement specified in MORTH V[th] requirement.
Bitumen	Bitumen used in this study is paving bitumen of viscosity grade VG 30. Bitumen should satisfy the requirements specified in IS: 73-2013.
Filler	Filler shall consist of finely divided mineral matter such as rock dust, hydrated lime and cement.

In the present work, Zycotherm is used as a chemical admixture, which is an organosilane additive to bitumen binder. It enhances the bonding between aggregates by forming a nano layer over the aggregates (figure 1). This is an odour free, chemical admixture that has been developed to work at lower production and compaction temperature.

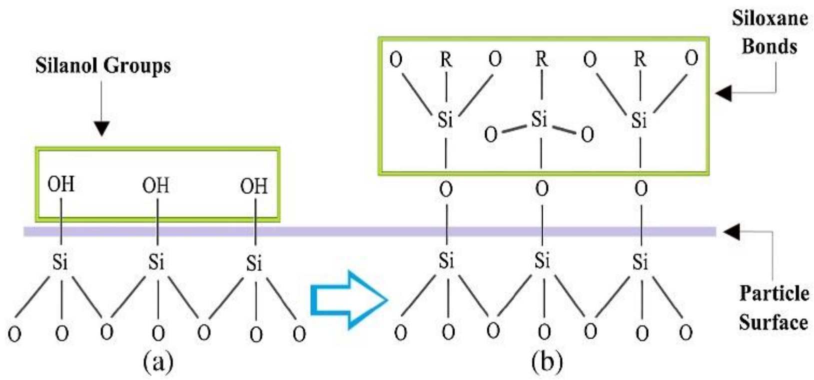

Fig.1: Chemical bond formation (a) before and (b) after addition of Zycotherm

It also has anti-stripping potential which helps to develop a mix which is able to bear various environmental stresses. It is a reactive organosilane compound which form Si-OH silanol group on hydrolysis. These silanols are reactive and can form Si-O-Si siloxane bonds with surface silanol group of inorganic substrates such as aggregate, which are nature's strongest bond which can survive for centuries. The physical and chemical properties of zycotherm are shown in table 2.

Table 2. Physical and Chemical Properties of Zycotherm

Physical Properties		Chemical Properties	
Colour	Light yellow	Compound	Percent (%)
State	Liquid	Hydroxyl Alkyl Alokoxy-Alkyl Silyl Compound	65%-75%
Freezing Point	5°C		
Specific Gravity	1.01		
Viscosity	1-5 Pascal-second	Benzyl Alcohol	25%-27%
Flash Point	80°C	Ethylene Glycol	3%-5%

The zycotherm was added in percentage by weight of the bitumen and the Marshall Test was conducted using design mix grade II of DBM. After that Optimum Bituminous Content (OBC) is found by taking average of bitumen content at maximum Marshall Stability, maximum Bulk Density and at 4% air void. Zycotherm is doped at OBC and its dosage is taken as 0.05%, 0.075%, 0.10% and 0.12% of bitumen by weight at OBC.

3. Methodology

The overall methodology followed in this study is shown in figure 2.

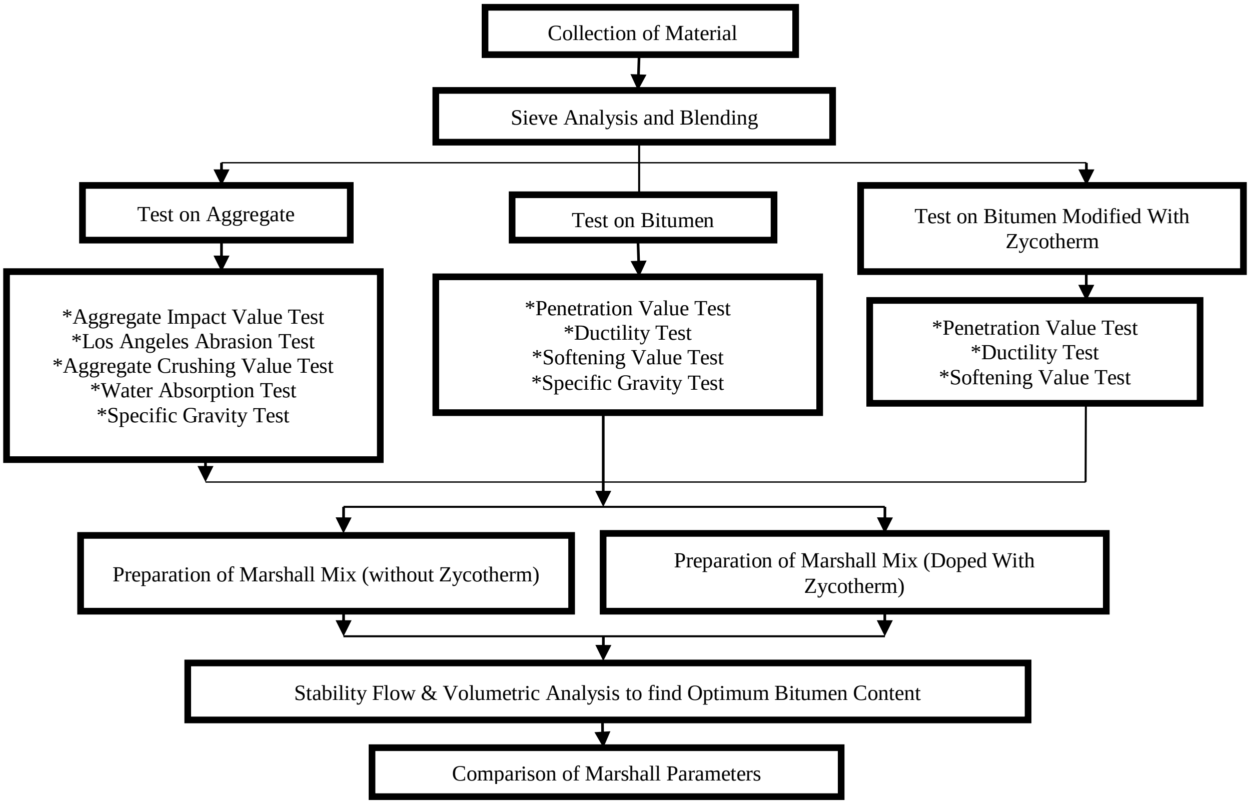

Fig. 2: Flow Chart of the methodology

3.1 Collection of Material

The materials used in the study such as coarse aggregates, fine aggregates, filler and bitumen (VG-30 grade) were collected from local site. Zycotherm, however, was imported from industrial manufacturer.

3.2 Sieve Analysis and Blending

Sieve analysis test was used to determine the aggregate sizes for a sample taken from quarry. Coarse sieve analysis (sieve size 26.5 mm to 4.75 mm) and fine sieve analysis (sieve size 4.75 mm to 75 micron) was done. The amount of aggregates retained on each sieve is weighed and blending of aggregates was done by Hit and Trial method. The results of the sieve analysis test are presented in table 3 and figure 3.

Table 3: Blending of Aggregate

Material used	Aggregate 1		Aggregate 2		Aggregate 3		Total Blend	Design Range
Sieve(mm)	%Pass	%Blend	%Pass	%Blend	%Pass	%Blend		
37.5	100	39	100	34	100	27	100	100
26.5	82.5	32.18	100	34	100	27	93.18	(90-100)
19	58.5	22.82	100	34	100	27	83.82	(71-95)
13.2	23.5	9.17	77.5	26.35	100	27	62.52	(56-80)
4.75	10	3.9	38	12.92	99.5	26.87	43.69	(38-54)
2.36	0	0	12	4.08	97	26.19	30.27	(28-42)
0.3	0	0	0	0	41.5	11.21	11.21	(7-21)
0.075	0	0	0	0	10	2.7	2.7	(2-8)

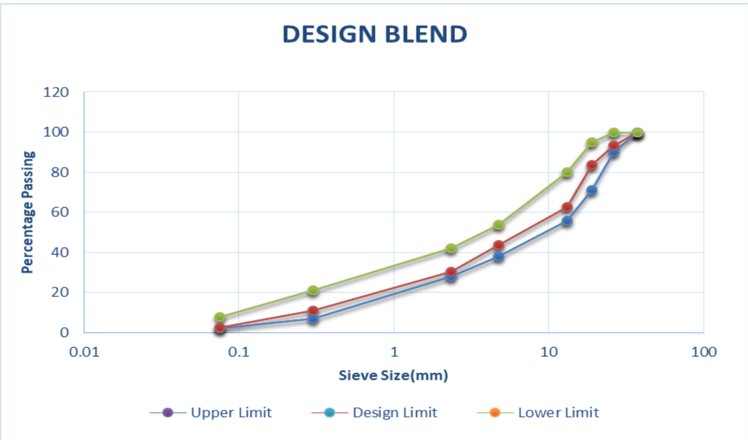

Fig. 3: Gradation curve

3.3 Tests on Aggregates

Various tests were performed on aggregates such as aggregate Impact Value, Los Angeles Abrasion, Aggregate Crushing, Water Absorption and Specific Gravity and the results obtained are shown in table 4 along with the required MoRT&H specifications.

Table 4: Results of various tests carried out on aggregates.

Test	Test Result	MoRT&H(V^{th} Revision)
Aggregate Impact Value (%)	15	Max 24%
Los Angeles abrasion value (%)	25.10	Max 30%
Aggregate crushing value (%)	22.72	Max 30%
Water absorption (%)	0.55	Max 2%
Aggregate Specific Gravity		
• Coarse Aggregate	2.66	Min 2.5
• Fine Aggregate	2.60	Min 2.5
• Filler	2.3	

3.4 Tests on Bitumen

In this study, viscosity grade VG-30 bitumen was used as a binder material and was tested for conventional tests like penetration value, ductility test, softening point and specific gravity. The results of tests are shown in table 5.

Table 5: Results of various tests carried out on bitumen.

Test	Test Results	Requirement as per IS:73-2013
Penetration Value at 25°C, 100g, 5 second	66	Min 45
Ductility value	72	Min 40
Softening Point value	52°C	Min 47
Specific Gravity	1.02	0.97-1.02

3.5 Tests on Bitumen Modified With Zycotherm

Different tests were performed on bitumen modified with zycotherm such as penetration value, softening point, ductility and the results obtained are given in table 6.

Table 6: Results of various tests carried out on bitumen modified with Zycotherm.

Bitumen Test	VG- 30	VG-30+ Zycotherm (0.05%)	VG-30+ Zycotherm (0.075%)	VG-30+ Zycotherm (0.1%)	VG-30+ Zycotherm (0.12%)	Requirement as per IS: 73-2013
Penetration at 25°C,mm	66	66	65	64	63	Min 45
Softening point(Ring and Ball)	52°C	52°C	53°C	53°C	54°C	Min 47°C
Ductility @ 27°C, mm	72	72	72	70	70	Min 40

3.6 Preparation of Marshall Mix (Without Zycotherm)

The DBM mix of grade II was designed by blending the aggregates by hit and trial method. The testing of samples was done as per standard procedures in order to determine the following parameters like Marshall stability, bulk specific gravity (Gm.), air void (Vv), void filled with bitumen (VFB), void in mineral aggregate (VMA) and flow values. The test results obtained on different samples are shown in table 7.

Table 7: Results of Marshall Test carried out on different samples

Test No.	Bitumen Content (%)	Flow (mm)	Theoretical Specific Gravity (Gt)	Bulk Density (Gm) g/cc	Total Air Void (%) Va	Volume Of Bitumen (Vb)	Void Filled With Bitumen (%) VFB	Void in Mineral Aggregate (%) VMA	Marshall Stability (KN)
1	4.50%	3.1	2.45	2.33	4.89	10.38	67.97	15.27	12.65
2		3	2.45	2.28	6.9	10.15	60	17.05	12.2
3		3.3	2.45	2.3	6	10.26	63.1	16.26	13.1
Average		3.13	2.45	2.303	5.93	10.26	63.7	16.19	12.51
1	5.00%	3.4	2.44	2.32	4.92	11.5	70	16.42	15.35
2		3.9	2.44	2.33	4.5	11.53	72	16	14.5
3		3.8	2.44	2.35	3.68	11.63	76	15.31	16.45
Average		3.7	2.44	2.35	4.36	11.55	72.66	15.91	15.43
1	5.50%	3.85	2.42	2.34	3.46	12.74	78.6	16.2	12.7
2		4.1	2.42	2.31	4.35	12.6	72.83	17.3	13.25
3		4	2.42	2.32	4.2	12.63	74.6	16.93	12.85
Average		4	2.42	2.32	4	12.65	75.34	16.81	12.93
1	6.00%	4.65	2.4	2.32	3.33	13.78	80.5	17.11	11.6
2		4.8	2.4	2.3	4.1	13.66	76.65	17.82	12.25
3		4.2	2.4	2.29	4.25	13.6	74.8	18.18	11.15
Average		4.55	2.4	2.25	3.89	13.68	77.32	17.7	11.66

The variation in Marshall properties with Bitumen Content is shown in figure 4 which was further used for obtaining OBC by taking mean of bitumen content at maximum stability, 4% air void and maximum bulk density. The value for OBC was found to be 5.2%.

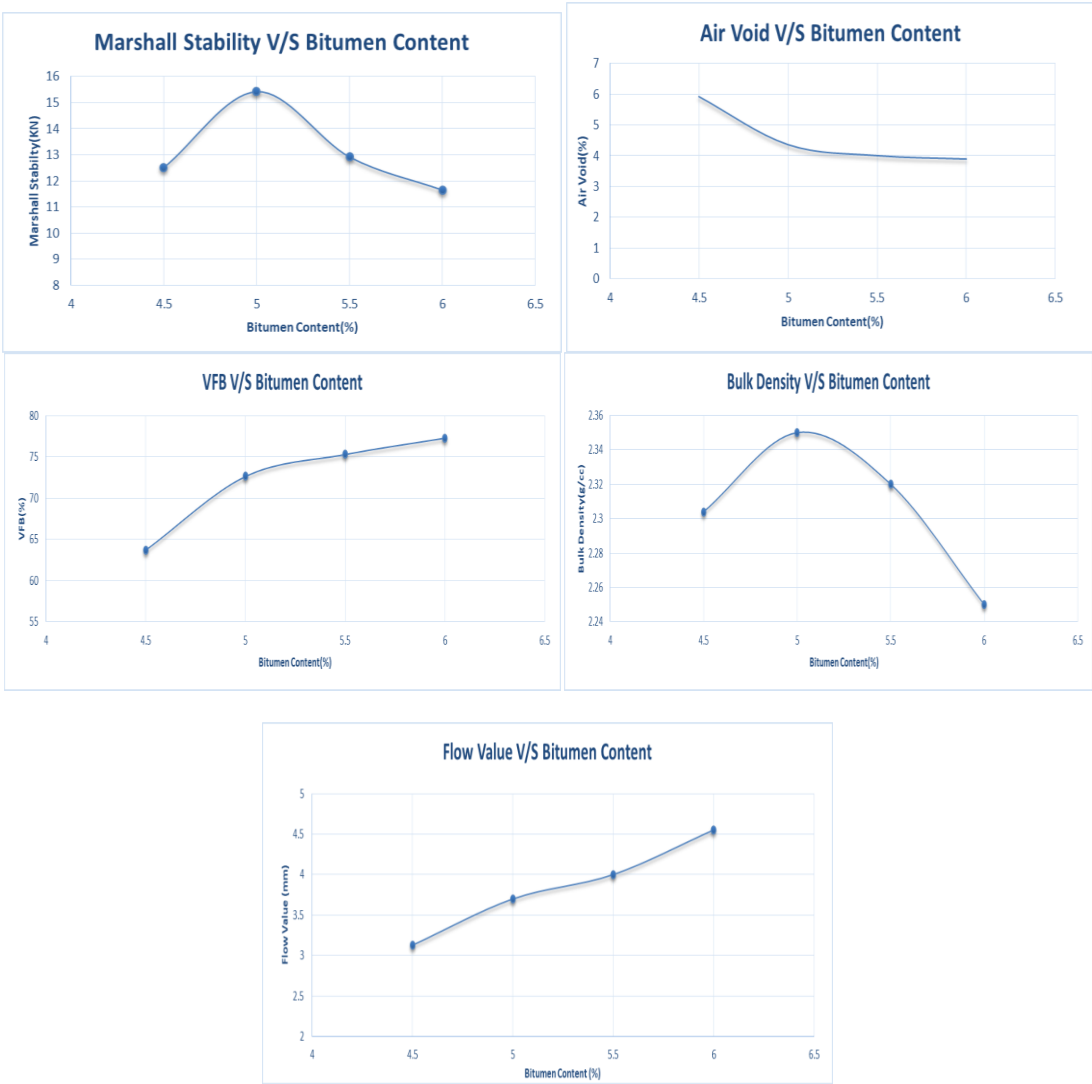

Fig. 4: Variation in Marshall Properties with Bitumen Content

3.7 Preparation of Marshall Mix (Doped With Zycotherm)

The Marshall samples were prepared with bitumen modified with zycotherm and the dosage of zycotherm was taken as 0.05%, 0.075%, 0.10% and 0.12% by weight of bitumen at OBC. The results for different Marshall parameters were obtained as shown in table 8.

Table 8: Results of Marshall Test carried out on different samples of bitumen modified with Zycotherm.

Test No.	Optimum Bitumen Content (OBC) %	% Zycotherm (By Wt of OBC)	Flow (mm)	Bulk Density, (g/cc)	Total Air Void, (%) Va	Void Filled With Bitumen, (%) VFB	Void In Mineral Aggregate, (%) VMA	Marshall Stability, (kN)
1	5.2	0.05	3.1	2.34	3.7	72.8	15.96	15.2
2			3.3	2.356	3.04	73.4	16.86	14.96
3			3.5	2.33	4.1	74.6	15.99	15.1
Average			3.3	2.342	3.6	73.6	16.27	15.08
1	5.2	0.075	3.1	2.35	3.3	72.8	15.96	16.95
2			3.35	2.38	2.05	75.6	16.08	17.21
3			2.85	2.36	2.88	74.8	15.75	16.6
Average			3.10	2.363	2.74	74.4	15.93	16.92
1	5.2	0.1	3	2.34	3.7	75.2	16.75	17.8
2			2.89	2.36	2.88	74.8	16.82	18.3
3			3.1	2.35	3.3	74.6	17.54	17.95
Average			2.99	2.35	3.29	74.8	17.04	18.01
1	5.2	0.12	3.33	2.355	3.08	77.1	15.2	16.65
2			2.78	2.365	2.67	72.8	17.04	15.9
3			3.1	2.352	3.2	74.6	16.1	16.3
Average			3.07	2.357	2.98	74.8	16.11	16.28

3.8 Comparison of Marshall Parameters

The Marshall parameters, with and without zycotherm were compared and results obtained are shown in graphical form in figure 5.

Fig.5: Comparison of Marshall Parameters

4. Conclusions

The addition of zycotherm to bitumen resulted in a decrease in penetration and ductility value and increase in the softening point, thus making modified bitumen stiff to some extent. It was observed that the utilization of zycotherm in DBM mix effectively improved the mix properties such as stability, flow values and strength. In addition to this, the following conclusions were drawn from this study,

- The maximum stability obtained in case of conventional mix was 15.43 kN and with the addition of Zycotherm to DBM mix (grade II), the value of maximum stability was increased to 18.01 kN at 5.20% OBC at a dosage rate of 0.10%. Thus, the stability is improved by 16.72% when zycotherm is added to the conventional mix at a dosage rate of 0.10%.
- The minimum flow value was found out to be 2.05 mm at a dosage rate of 0.075% of zycotherm.
- The dosage rate of 0.075% of zycotherm to DBM mix gave minimum Air voids in comparison to other dosage (0.05%, 0.10% and 0.12%).
- The bulk density was found to be maximum at a dosage of 0.075% of Zycotherm with value of 2.36 g/cc.
- The void filled with Bitumen (VFB) is maximum at 0.10% of Zycotherm with a value of 74.8%.

Thus, from the study it can be concluded that the addition of zycotherm to bitumen has enhanced its properties which has further increased the strength and durability of design mix. Therefore, on the basis of the test results obtained it is recommended to use zycotherm at a dosage of 0.10% to achieve maximum strength of pavement.

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