Investigation of the Impact of Zycosoil Chemical Additive on Polymer Modified Bitumen Mix (PMB40)

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***Abstract* – The second largest road network in the world is India which has of over 4,689,842 kilometers in 2013. Qualitatively India's roads are a mix of modern highways paved and unpaved roads. 98 percent of roads are flexible pavement. Rapid growth of traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations of conventional bitumen performance. Since roads indirectly contribute to the economic growth of the country it is extremely essential that the roads are well laid out and strong. India is home to several bad roads be it the metropolitans, the cities or the villages. Hence it is prime responsibility of highway engineers and those associated to it in projects has to see that quality of life pavement is sustained.**

The present paper aims to highlight this variability involved in the polymer modified mix design process and develop a procedure to find out optimum bitumen content by Marshall Mix design method which attains maximum stability. An attempt is made to investigate the changes taking place in Polymer modified bituminous mix prepared as per specification with 4.2% optimum value of modified bitumen content by the addition of Zycosoil chemical in 0.03%, 0.04% and 0.06%. Owing to improved good results, the tests authenticated to opt for chemically modified DBM mix and hence can be suggested for the construction of Flexible pavement.

Key Word – Optimum Bitumen Content, Marshall Mix Design, Dense Bituminous Macadam

I. INTRODUCTION

The onset of modern and universal process of urbanization in India is associated with economic development of it and is relatively a phenomenon which is closely related with industrial revolution generating rapid growth in highly laden vehicles which cannot be matched by a corresponding expansion in road space putting high stresses on limiting roads imposing greater distress resulting in decreasing serviceability which directly increases the maintenance cost and resource consumption. India's roads are a mix of modern highways and unpaved roads. The task of maintaining the road network in the country which now totals about 98 % of the paved roads is colossal. Due to lack of funds timely maintenance of road is not carried out. India is now faced with the tremendous challenge of preserving and enhancing the quality of roads.

Binder modification is the only choice, to cater to the ever-increasing traffic demand meeting the quantity and quality of pavement. The material should significant resist variations in daily and seasonal temperatures. It is the responsibility of engineers to design precisely a suitable Marshall Mix for flexible pavement engineering as per MoRTH to meet the long lasting pavements for the reliable performance of the in-service highway for economic and environmental sustainability.

For sustaining stresses of vehicles in high density corridors, a bituminous mixture needs to be flexible enough with temperature variations and sustaining loads without any compromise with other quality and quantity of life span and performance of road. In order to focus on the goals, an attempt is made to use polymer modified bitumen (PMB40) for dense bituminous macadam design based on the guidelines given in the Asphalt Institute Manual MS-2 and investigate the essential properties of it and bituminous mixes with and without Zycosoilchemical additive in suitable doses. Also an investigation is made to determine moisture susceptibility of it.

II. LITERATURE

Khattak and Baladi (2001) showed that rheological and engineering properties of polymer mixed binders mixtures largely depend on the polymer type and content. The mix design of the conventional bitumen and polymer mixed bituminous mixtures were conducted using the Marshall mix-design procedures. At the optimum polymer content, the strengths of the polymer modified mixtures were approximately 1.45 times higher than the mixtures made with bitumen binder subjected to the same processing conditions. Further, empirical relations for predicting fatigue life of polymer modified bituminous mix were also developed considering different polymer content, plastic deformation, viscosity and indirect tensile strength. Khattak and Baladi (2001) also showed the improvement in the resistance to plastic deformation with polymer modification. It is shown that the required number of load cycles to accumulate any value of plastic deformation increases as the polymer content is increased until 5% optimum polymer content is reached.

Ashok Pareek,Trilok Gupta and Ravi K Sharma (2012), showed that the bituminous mixtureneeds to be flexible enough at low service temperatures to prevent pavement cracking and to bestiff enough at high service temperature to

prevent rutting. Bitumen modified with polymer offers a combination of performance related benefits as the physical properties of the bitumen isimproved without changing the chemical nature of it. They state that rutting resistance, indirect tensile strength and resilient modulus of the bituminous concrete mix with polymer modified bitumen is significantly improved.

Molenaar and Nirmal (1998) carried out tests (resilient modulus, tensile strength and fracture toughness of mixes) with conventional bitumen and polymer modified bitumen. It has been concluded in this study that polymer modified binder has significant increase of pavement life.

III. Materials And Methods

The crushed stone aggregate (coarse, fine and filler) obtained from Timba Quarry village Panchamahal, Godhra was used to prepare the dense bituminous macadam mix specimens. The dense bituminous macadam mix as specified in Ministry of Road Transport and Highways) specifications in India were evaluated.

Laboratory Tests

Physical Requirements for Coarse Aggregate for Dense Bituminous Macadam (As Per MoRTHTable: 500-8)

Sr. No	Property	Test	Specification	Test Result
1	Cleanliness (dust)	Grain size analysis	Max 5 % passing 0.075 IS-Sieve	Pas.37.5-Ret.24mm- 0.48
				Pas.24-Ret.14 mm- 0.78
				Pas. 14 -Ret. 7 mm- 0.88
2	Particle shape	Flakiness & Elongation Indices (Combined)	30% Max	25.65
3	Strength	Aggregate Impact Value(AIV)	27 % Max	11.50
4	Durability	Soundness		
		Magnesium Sulphate	Max 18 %	0.70%
		Sodium sulphate	Max 12 %	0.59%
5	Stripping	Coating and Stripping Bitumen Aggregate Mixtures	Min. Retained Coating 95 %	100.00
6	Atterberg's Limit (As per 507.2.3)	Plasticity Index	4 %Max	Non-Plastic
7	Water absorption value	Water absorption value	2 % Max	1.080

Properties of Aggregates

Size of Aggregate	Aggregate Proportions	Bulk Sp.Gravity	Apparent Sp.Gravity	Water Absorption
50 - 28 mm	16%	2.853	2.928	0.90
28 - 22 mm	8%	2.849	2.930	0.97
22 - 14 mm	23%	2.861	2.955	1.11
14 - 8 mm	4%	2.854	2.956	1.21
8 mm down	46%	2.850	2.963	1.33
Filler	3%	2.650	-	-

Three aggregate gradations selected are shown in the graph upper limit, mid value and lower limit**(as shown in Fig. 1).**

IV. Polymer Modified Bitumen (PMB40)) Plus Modifier

Polymer Modified Bitumen (PMB40) is obtained from Hincol Industry, Savli, Vadodara district, Gujarat and is recommended for hot climate areas. It possess high cohesiveness, high stiffness modulus leading to greater resistance to permanent deformation and improves bonding between bituminous layers.

V. ZYCOSOIL AS MODIFIER

The chemical used in the present study is Zycosoil supplied by M/S. Zydex Industries, Vadodara. Zycosoil is a reactive organo-silicon compound. It forms Si-OH silanol groups upon hydrolysis. These silanols are reactive and can form Si-O-Si siloxane bonds with surface silanol groups of inorganic substrates. The reaction leads to permanent nanosiliconization of the surfaces by converting the water loving silanol groups to water repellent alkyl siloxane surfaces. Zycosoil chemically bonds with the aggregates surface and eliminates debonding of asphalt binder. Zycosoil in suitable dosages of 0.03%, 0.04% and 0.06% be added directly by weight of binder and blending to proper mixing at 175°C.

Summary of test results of PMB 40 grade bitumen with and without Zycosoil

Characteristics of tests	PMB 40	PMB 40 + 0.03 % Zycosoil	PMB 40 + 0.04 % Zycosoil	PMB 40 + 0.06 % Zycosoil	Min. Limit	Code
Penetration (mm)	45.33	42.67	39.67	39	30-50	IS 1203
Softening point (C°)	66.25	64.95	63.7	62.95	Min 60	IS 1205
Elastic recovery 15 (C°)	78.33	76.67	74.67	74.67	Min 70	IS 15462
Stripping Test	96	98	100	100	Min 95%	IS 6241

VI. DBM Mix Design Procedure

The steps involved in the DBM mix design are:

a) As per MoRTH specification, the suitable aggregate grading is selected.
b) Prepare the Marshall Test specimens with selected aggregate grading and varying bitumen content.
c) Test the specimens for Marshall Properties.
d) Select the optimum asphalt content in accordance to the criteria's laid down in MS-2, as the design bitumen content. The optimum binder content is worked out as 4.2% for DBM Mix Design grading – 1 for which on test property curves values of bulk specific gravity, stability, voids in mineral aggregate, voids filled with bitumen, flow value and air voids are determined.

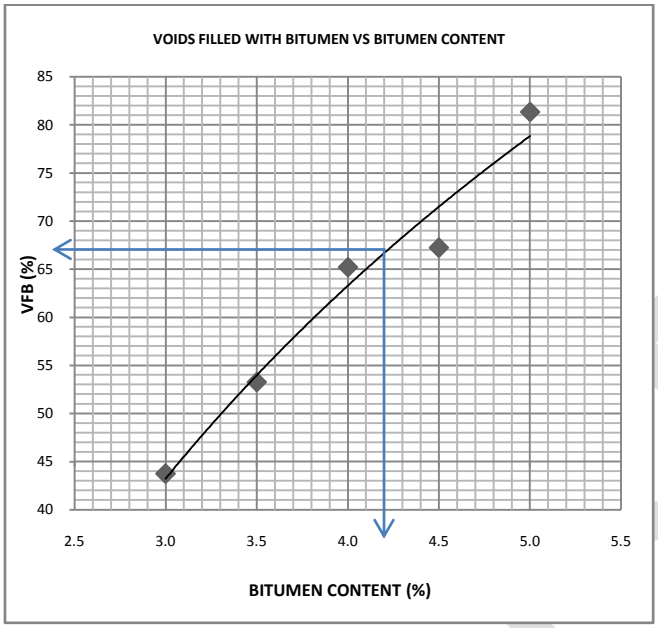

Fig. 2Voids Filled with Bitumen V/s. Bitumen Content

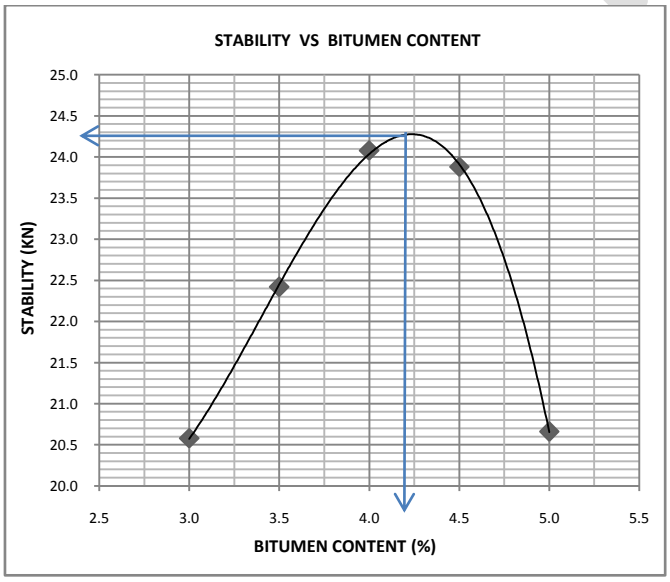

Fig. 3 Voids Filled with Bitumen V/s. Bitumen Content

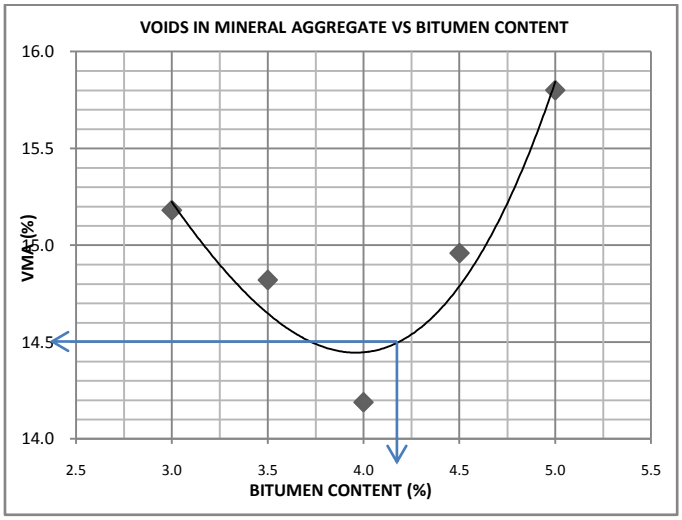

Fig. 4 Voids in Mineral Aggregate V/s. Bitumen Content

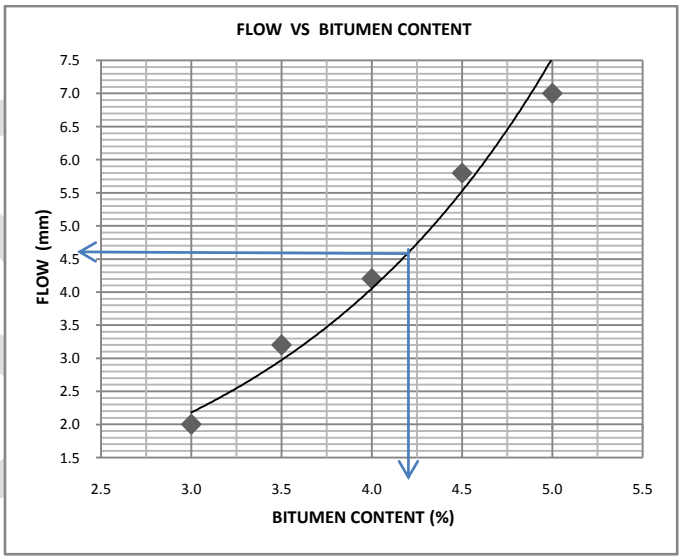

Fig. 5 Flow V/s. Bitumen Content

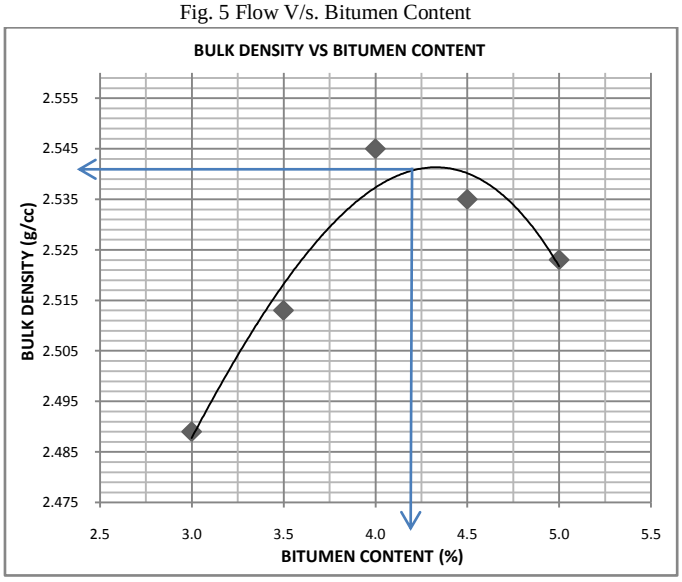

Fig. 6 Bulk Density V/s. Bitumen Content

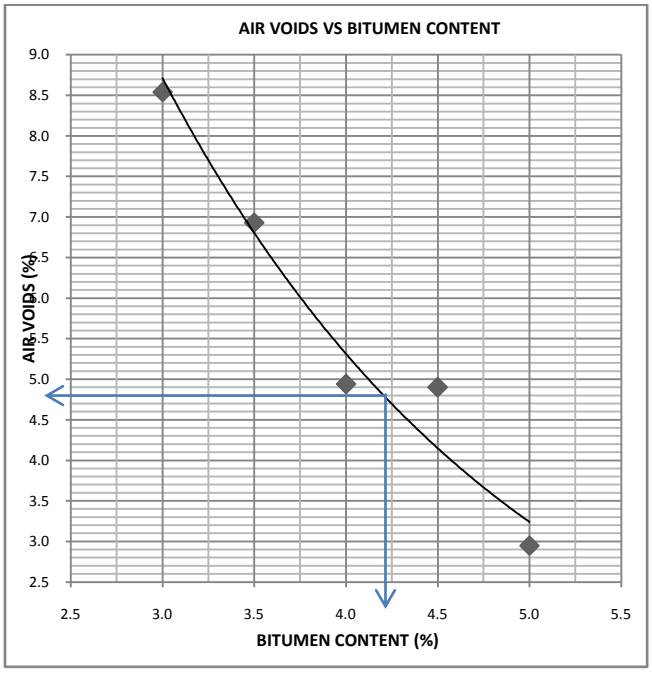

Fig. 7 Air Voids V/s. Bitumen Content

In order to arrive at homogenous mix with required standards, PMB 40 bituminous mix with 4.2% optimum bitumen content is taken into consideration for Modified Marshall mix design with and without addition of 0.03%, 0.04% and 0.06% dosage of Zycosoil chemical as an additive at temperature 175°C to compare properties by confirmatory test.

Abstract of Marshal Mix Design Test Values (confirmatory test)						
Bitumen content by wt. of total mix %	Stability (KN)	Unit Wight in gm/cc	Flow in mm	Air Voids in %	VMA in %	VFB in %
4.2%	24.25	2.541	4.60	4.77	14.50	67.00
0.03% Zycosoil	24.19	2.549	4.7	4.28	14.22	69.93
0.04% Zycosoil	24.49	2.555	4.80	4.06	14.03	71.07
0.06% Zycosoil	24.49	2.549	4.80	4.28	14.23	69.91
Specification Limits	20.25 KN	-----	3 - 6	3 - 6	Min.1 1.5	65 – 75%

VI. ASTM 3625 Boiling Test

Asphalt Grade: PMB 40 is heated at 175°C; to it 0.03%, 0.04% and 0.06% dosage of Zycosoil chemical is added in melted asphalt binder and is thoroughly mixed. The test samples (Regular & with Zycosoil) are prepared as per standard procedure. These samples are kept at room temperature condition. The prepared samples (regular & with Zycosoil) boiling test done at 100°C for 10 min, 30 min, 1 hr and 6 hr.

Test Sample at 100°C	10 min	30 min	1 hour	6 hour
4.2% asphalt binder by weight of mix(without Zycosoil)	97%	97%	96%	96%
4.2% asphalt binder containing Zycosoil (0.03%) by weight of mix	98%	98%	98%	97%
4.2% asphalt binder containing Zycosoil (0.04%) by weight of mix	100%	100%	99%	99%
4.2% asphalt binder containing Zycosoil (0.06%) by weight of mix	100%	100%	99%	98%

Specification : <95% Fails

Conclusions

The systematic investigation carried out in the laboratory following the procedures of codal practice, reflects that performance of modified bituminous mix is enhanced with the addition of Zycosoil as an additive compared to only polymer modified mix and can be utilized for flexible pavement. The key solutions drawn from this study are:

- Decrease in penetration value with the addition of Zycosoil as chemical with polymer modified mix indicates the material to have changed the properties and have enhanced condition of temperature susceptible thereby increasing the workability of bituminous mix also stiffness. The presence of polymer modification is evident with 0.04 % dosage of Zycosoil chemical and this change is associated with elastic recovery which is within permissible limit. Elastic recovery indicates more flexibility to the binder and will increase the life of pavement at low temperature.
- Proper gradation of aggregates for durable flexible pavement are of utmost importance to bring out a significant change in VMA as aggregate interlocking and packing mechanism enhances the shear resistance of mix. Also adequate voids in the total compacted mix permits a small compaction under traffic loads without bleeding and decrease in stability. The confirmatory test of marshall mix design using PMB40 with 0.03 % Zycosoil satisfies the criteria's laid down in codalMoRTH provision, also it is seen that at this percentage significant rise in stability, unit weight and flow values are observed for better compaction and improving the workability conditions. Boiling test showed better aggregate bonding too. This is evident as Zycosoil chemical forms a coating between the bitumen film and aggregate surface. In presence of water too it acts as an active adhesive preventing stripping.

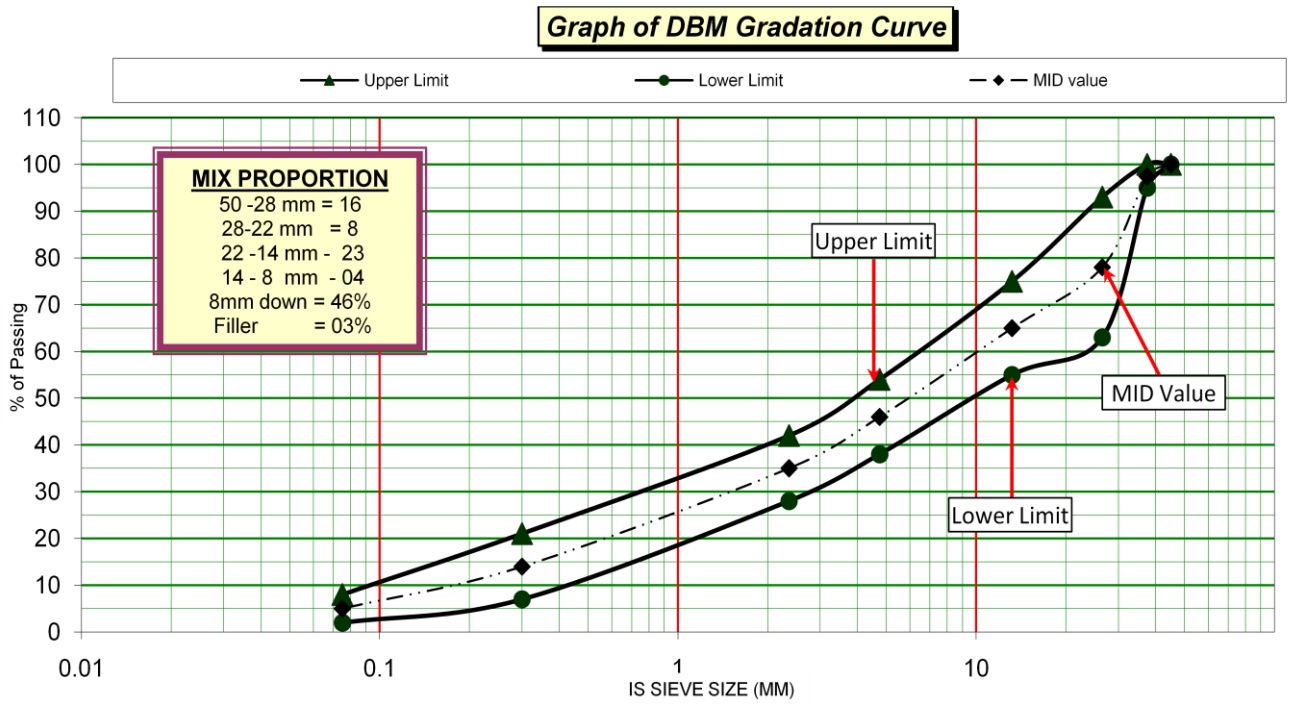

Fig. 1 Graph of DBM Gradation Curve

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