Case Study on Modified Bitumen Mix Using the Benkelman Beam Deflection Test with Warm Mix Additives

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A B S T R A C T

Several new processes have been developed to reduce the mixing and compaction temperature of hot mix asphalt without scarifying the quality of resulting pavement. Research in the laboratory was carried out to determine if the addition of Zycotherm has potential to increase the stability comparison with hot mix asphalt (HMA). For the present study, the use of an additive called Zycotherm has been tried to achieve the higher stability at low temperatures. The addition of Zycotherm to bituminous mix has been evaluated by testing their laboratory performances as compared to HMA mixes with different modified binders such as CRMB-55 and CRMB 60. Marshall Mix properties namely stability, flow, bulk density, air voids, VFB and VMA was evaluated for both HMA and WMA. For same Marshall mix design criteria and., the test track has been laid down. Rebound deflection survey has been carried out in order to assess the residual strength of the existing pavement and also to design the overlay thickness of pavement layers to be provided to withstand the future projected traffic loading as per IRC 81:1997. Deflection measurements were taken on left and right wheel paths of carriageway. Tests were conducted on BC mixes using two modified binders and one warm mix additives as Zycotherm with 0.1% of mix, in ward no 04 of yelahanka Satellite town Sub Division Bangalore for six cycle to check the performance of pavement under different climatic condition.

Keyword: HMA, WMA, OBC, CRMB, BBD ,BITUMEN

1.0 Introduction

Warm mix asphalt has been used with all types of asphalt materials, including dense graded, stone mastic, porous, and mastic asphalt (WMA). It has been applied to WMA with different aggregate types, all binder grades, polymer modified bitumen's, and asphalt pavement, as well as a variety of layer thicknesses and traffic densities. These results imply that the use of WMA is typically not constrained. However, there are specific WMA design techniques that may differ from HMA and should be paid attention to if you want to achieve performance that is equal to or better than hot mix asphalt (HMA). The Benkelman Beam Deflection (BBD) test is a non-destructive method used to evaluate the structural capacity of flexible pavements by measuring the pavement's rebound deflection under a standard wheel load.A loaded truck (typically with a standard wheel load and tire pressure) is used. The Benkelman beam, a simple lever-arm device, measures the pavement surface rebound (deflection) as the truck moves away. The probe end of the beam, supported by a rigid reference beam, measures the deflections using a dial indicator. Deflection measurements are taken at intervals along the road.

1.1Applications

- Evaluating the structural capacity of existing pavements.
- Estimating overlay designs for strengthening weak pavements.
- Determining areas requiring rehabilitation treatment.

1.3 Benefits of Using WMA

Use of WMA effectively reduces the energy consumed and limits emissions seen in HMA production. WMA technologies offer considerable benefits, including longer paving seasons, increased compaction and enabling longer hauls. Thus, WMA technologies currently are getting more approvals and usage in the asphalt sector compared to HMA. Certain key benefits are discussed in following sections.

1.4. Objectives of the Present Study

- To develop laboratory mix designs and analysis procedures for WMA for a wide range of warm mix processes.
- To assess the effect of additives like Zycotherm on physical properties and characteristics of bituminous binders like CRMB-55 and CRMB-60 and their subsequent performance in mixtures.
- To determine the feasibility of WMA mixes for flexible pavements using various binders and warm mix additives.

- To assess field performance by laying of test track and evaluation of performance using Benkelman beam deflection test.

2.0. Literature Review

2.1 General

For any research or study assessing different existing researches or allied (say, relevant) literatures help researchers to identify gaps, scopes and further research orientation. With this motive, in this chapter some of the key literatures pertaining to the target research domain and/or variables such as WMA, HMA, environmental issues caused due to WMS applications (say, different WMA solutions and their impact on the environment) properties of the different materials, technologies applied towards designing or developing different WMA solutions and their corresponding performances, etc are discussed. The various technologies currently employed in industry to achieve WMA properties are examined in this chapter. It also examines the current problems with field performance as well as industry standards for producing and testing WMA. Environmental issues related to these technologies, the influence of the different components on the mixture performance, and WMA technologies using Zycotherm relation to how they influence the properties of the mixture and how these compare with those of HMA mixtures are discussed in this chapter. The detailed discussion of the aforesaid variables is given in the subsequent sections.

Recalling the overall research intend(s), which is to assess deformation responses in pavements, studying a brief of the deformation response, also called as rutting in asphalts can be of great significance. Understanding different rutting problems, its causative factors and characteristics can help identifying a better solution towards pavement structure (design). The snippet of the deformation response nature of asphalt is given in the subsequent section.

2.2 WMA Used in Different Country [(4)]

WMA is becoming more and more well-known across the nation, with at least 45 states either actively using WMA materials or having constructed a test project. A large number of states, including Alabama, California, Florida, Illinois, New York, North Carolina, Ohio, Pennsylvania, Texas, Virginia, Washington, and Wisconsin, have approved permissive specifications that allow the use of WMA on a variety of highway projects. Around one million tonnes of WMA have been ordered in Texas, and another million tonnes are under contract. The Pennsylvania Department of Transportation (DOT) intends to produce 20% of its 2009 asphalt tonnage using WMA blends. The Alaska DOT advertised a bid for a 25,000-ton warm-mix project on Mitkof Island (Walker 2009). The Nebraska Department of Roads (NDOR) is interested in this new technology. NDOR began the WMA field trial in 2007 using different dosages of Sasobit, a wax-like WMA additive. In 2008, NDOR installed two WMA pavements (Evotherm WMA and Advera zeolite WMA) along with their corresponding control HMA portions in four trial sections in Antelope County, Nebraska. The trial portions started in Elgin and ended on US Highway 20.

2.3 HMA/WMA with Sasobit and Zycotherm additives

Ayazi et al. studied the effect of Sasobit and Zycotherm on the characteristics of RA pavement (RAP)-WMA (2017). Susceptibility to moisture was assessed using indirect tensile strength, fracture energy, and resilient modulus ratio. The experiments revealed that Zycotherm WMA was more resistant to moisture damage than mixtures of Sasobit WMA and HMA. The stiffness of the mixture dramatically increased with an increase in RAP content, and using Sasobit made this issue worse.

Behbahani et al. (2017) compared the RAP-containing WMA to similarly graded HMA and examined how WMA additives affected the WMA's physical characteristics. Zycotherm and Sasobit, which are chemical and organic additives, were used to create WMA mixtures. RAP was present in these combinations in a range of concentrations, from 0% to 75%, in increments of 25% of the total aggregates. To examine the specimens' resistance to permanent deformation, wheel track and dynamic creep tests were used. Compared to Sasobit WMA mixes, Zycothem WMA mixes had a lower robust modulus for rutting resistance. It was shown that raising RAP in combinations improved both parameters across the board.

Another study (Meghana and Kavitha, 2017) employed the ZycoTherm additive to prepare WMA in the lab in various ratios and temperatures. For a WMA mix including 70% virgin aggregates and 30% RAP, ZycoTherm additive was added to bitumen at a mixing temperature of 135°C (or 0.07 percent by weight). This mixture provided superior performance and stability compared to other blends, suggesting that a 30:70 blend is the best option. According to the cost analysis, the expected construction cost for this mix was INR 950,000/km, which represents a savings of around 33.25 percent compared to HMA construction.

2.4 Benkelman beam deflection test

The Benkelman Beam (Figure 2.1) was developed in 1952 at the WASHO Road Test Association (US). It is a simple arrangement based on the principle of levers. This arrangement is used alongside a loaded truck having a load of about 80 kN on one axle having two tires with 480–550 kPa tyre pressure. Measurements are taken by keeping the beam tip in between the two tires and readings of the rebound of the pavement surface are obtained as the vehicle is moving away. This test, though having a low-cost arrangement, is time consuming and laborious with no deflection basin (Rohith et al., 2018).

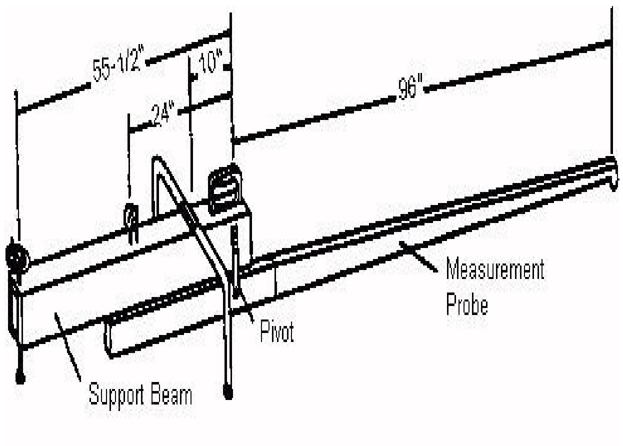

Fig 2.1 Benkelman Beam Test arrangement

The rebound deflection at 20°C shall be calculated as follows:

$$D20 = DT + (20 - t)/110 \qquad (2.1)$$

where D_{20} is the temperature-corrected rebound deflection in millimetres and t the temperature (°C) 40mm beneath the pavement surface

3.0 Material and Methods

3.1 Selection of Materials

3.1.1 Selection of Modified Bitumen

Modified Bitumen CRMB-55 and CRMB-60 grade were chosen as modified bitumen for preparation of HMA and WMA mix.

3.1.2 Selection of WMA Additive

In this research, Zycotherm warm mix additive were selected for preparation of warm mix asphalt

3.2Zycotherm

Zycotherm, a warm mix addition that is soluble in water and produces polymeric material and alcohol when in contact with moisture, was also used in this study. Zycotherm is thought to be stable at normal pressure and temperature. It has a 25–27% benzyl alcohol content, a 3–5% ethylene glycol content, and a 65–75% hydroxyalkyl–alkoxy–alkylsilyl content.The bitumen and aggregate surface are chemically bonded strongly and permanently thanks to Zycotherm's superior organo-silane chemistry. The permanent chemical bonding enables the high moisture resistance, complete coating of asphalt on aggregates, and a wider temperature range for mixing and compaction, resulting in a pavement with a longer life cycle. Zycotherm's quicker wetting and complete coating process makes it simple to mix, adhere, and improve the stability of bituminous roads. Additionally, the silane ingredient enables bituminous mixes to be compacted at temperatures that are around 350–400°C–lower than hot mix asphalt. Warm mix asphalt helps to achieve the desired compaction density at lower temperatures since it lowers the likelihood for temperature segregation due to the lower compaction temperature. Lower temperature compaction results in fewer CO2 and other greenhouse gas emissions. ZycoTherm is a green technology product as a result. The modified binder with ZycoTherm produces a product that is extremely stable, permits safe mixing, and has the physical and chemical characteristics listed in tables 3.1 and 3.2.

Table 3.1 Physical Properties of Zycotherm

Properties	Zycotherm
Physical state	Liquid
Color	Cloudy liquid
Dosage rate	0.1 %
Odor	Odor Free
Flash point	➢ 200^{0}C
Viscocity (25^{0}C)	350cps
Solubility in Asphalt	Soluble

Table 3.2 Chemical Properties of Zycotherm

Chemical Compounds	Percentage
Hydroxyalkyl -alkoxy-alkylsilyl compounds	65 % - 70 %
Benzyl Alcohol	25 % -27 %
Ethylene Glycol	3 % -5 %

3.3 Aggregate

Virgin aggregate was chosen for sample preparation since it met MoRT&H specifications' requirements. For the preparation of the specimens, granite material from the quarry near Bangalore has been chosen. As coarse aggregate, we will use the aggregate fraction that was retained on a 4.75mm filter. Fine aggregate will be made from the portion that passes a 4.75 mm filter and is retained on a 75 micron screen. As filler, crusher dust is used. The tables 3.3 and 3.4 display the specific gravity and other aggregate parameters employed in the current investigation according to MoRT&H requirements. it is evident that aggregates selected for the present investigations satisfy the requirements to be used for construction of BC grade II.

Table 3.3 Specific Gravity of Aggregate

Sl. No.	Type of Aggregate	Specific Gravity
1	Coarse Aggregate	2.62
2	Fine Aggregate	2.77
3	Filler Material	2.65

Table 3.4 Physical Properties of Aggregate

Sl. No.	Properties	Test method	MoRTH Specification	Obtained Value
1	Impact Value	IS-2386 Part-IV	10-30%	27.03%
2	Crushing Value	IS-2386 Part-IV	Max 30%	25%
3	Abrasion Value	IS-2386 Part-IV	30-40%	34%
4	Water Absorption	IS-2386 Part-III	Max 2%	1.2%
5	Flakiness Index	IS-2386 Part-I	Max 40%	19%
6	Elongation Index	IS-2386 Part-I	Max 15%	12%

3.4 Establishment of Design Aggregate Structure

Design aggregate structure for BC grade II mixes were selected using MoRT&H gradation specifications adopted by Indian Highway agencies. The mineral aggregate chosen were blended and proportioned and several trial blends for Bituminous Concrete (BC) with nominal aggregate sizes of 12.5 mm is prepared. This is done in order to check and ascertain whether the aggregate gradation established using Job Mix Design criteria satisfy the MoRT&H gradation specification. The final aggregate blend proportion is selected satisfying the as MoRT&H recommendations shows in figure 3.1 and table 3.5. The aggregate blend selected using job mix design criteria for BC grade II was superimposed on MoRT&H gradation envelope, plotted using upper and lower limits of aggregates passing specified sieve sizes.

Table 3.5 Bituminous Concrete (BC) Grade II Gradation Design

Bituminous Concrete with Nominal Maximum Aggregate of Size of 13 mm								
Sieve Size in mm	40 mm	20 mm	10 mm	4.75 mm	Stone Dust	Combined Grading	MoRT&H Specifications	
	Aggregate Proportions							
	0	0.28	0.42	0.25	0.05	1	Lower Limit	Upper Limit
19	0	28	42	25	5	**100**	**100**	**100**
13.2	0	10	45	25	5	**85**	**79**	**100**
9.5	0	6	38	25	5	**74**	**70**	**88**
4.75	0	3	28	24	5	**60**	**53**	**71**
2.36	0	1	22	24	5	**52**	**42**	**58**
1.18	0	0	15	18	5	**38**	**34**	**48**
0.6	0	0	10	15	5	**30**	**26**	**38**
0.3	0	0	8	10	5	**23**	**18**	**28**
0.15	0	0	2	8	5	**15**	**12**	**20**
0.075	0	0	0	0	4	**4**	**4**	**10**

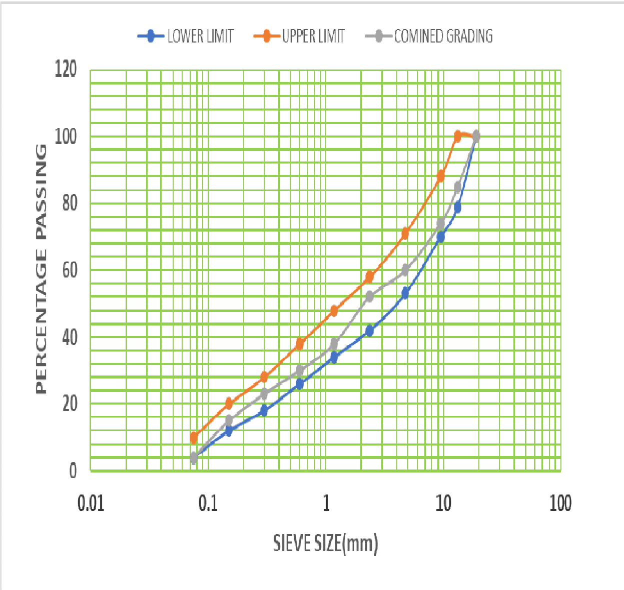

Fig 3.1 Adopted Gradation for BC Grade-II

3.5 Marshall test

The strength and flow characteristics of bituminous paving mixes are measured and reported using a common laboratory technique called Marshall Mix design. In India, this method of describing bituminous mixtures is very popular. This technique has been used by numerous researchers to test bituminous mixtures. This test method is well-liked because it is inexpensive and simple to use. Given the many advantages of the Marshall method, it was decided to use it to determine the Optimal Binder Content (OBC) of the mixes and to investigate various Marshall Characteristics, including Marshall Stability, flow value, unit weight, and air voids, among others. The specimen's resistance to plastic deformation is assessed when a compacted cylindrical bituminous mixture specimen is loaded diametrically at a deformation rate of 50 mm/min.. The Marshall method of mix design has the following two key characteristics.

- Stability, flow tests, and
- voids analysis

The Marshall stability of the mix is defined as the maximum load that the specimen can support at the specified test temperature of 60 °C. The flow value is the amount that the test specimen deforms while being loaded up to the maximum load.

3.6 Field Performance Test on WMA and HMA Mixes

Rebound deflection survey has been carried out in order to assess the residual strength of the existing pavement and also to design the overlay thickness of pavement layers to be provided to withstand the future projected traffic loading as per IRC 81:1997. Deflection measurements were taken on left and right wheel paths of carriageway.

The studies were carried out along the outer wheel paths i.e., 0.90 m from the outer edge of the main road pavement along Left Wheel Path and Right Wheel Path in the direction of traffic movement. The deflection measurements were recorded at every 50 meters i.e., 20 points for each Kilometer along the project corridor.

By observing the initial, intermediate, and final readings at each deflection observation point, the studies are conducted using the CGRA procedure. Rebound deflection studies on the road pavement were carried out using a standard truck with a load of 8200 kg placed at the rear and dual tyres inflated to a pressure of 5.6 kg/sq cm. The truck's two wheels are centred above the chosen location. Readings were taken at intervals of 0.0 m, 2.7 m, and 9.0 m in the chosen point and figure 4.9 shows the conduction of BBD survey in the field.

- The pavement temperature was measured at a depth of 50 mm as instructed because the deflection values depend on how hot the bituminous layer is.
- After digging and removing the pavement components all the way down to the subgrade level, soil samples from the subgrade were taken from the wheel paths where deflection studies were being done.
- Tests were performed on the samples of subgrade soil to determine the field moisture content and index properties for soil classification.
- In order to conduct the index properties test in the lab, the soil samples thus collected were immediately sealed in airtight polythene bags.The field moisture content of the subgrade soil is determined in the field using Rapid Moisture Meter.

Fig 3.2 BBD Measurement Survey

3.7 Analysis of Field Data for Characteristic Deflection

The Benkelman beam rebound deflection (BBD)data obtained were analysed as per IRC 81:1997. The statistical parameters viz., Mean Deflection (D) and standard deviation (a) of deflection values were calculated.

The characteristic deflection (Dc) values were determined by adopting the formula,

$$D_c = (D + 2a).$$

Where, D = Mean deflection, mm

A = Standard deviation, mm

D_c = Characteristic deflection

Using the results of the field tests, the temperature correction factors were established in accordance with IRC Guidelines. The type of subgrade soil, the field moisture content at the time of the deflection survey, and the area's typical rainfall all play a role in the correction for subgrade moisture variation. The collected samples of subgrade soil underwent laboratory testing and were categorized based on their index properties. The deflection correction factors for pavement subgrade moisture were established in accordance with IRC 81:1997 using laboratory test results for low annual rainfall below 1300 mm.

3.8 Effect of Temperature on Deflection

Temperature changes cause significant changes in both types of bituminous material. The stiffness may decrease by a factor of 5 to 10 as the temperature is increased from 10°C to 30°C (depending on the duration of the applied load). The temperature of bituminous surfacing must be recorded during deflection testing in order to make the necessary adjustments during the analysis and design phases.

3.9 Effect of Moisture on Deflection

In some other nations, the spring and early summer months have seen a slight increase in pavement deflection, possibly due to higher moisture contents under the pavement at these times. However, there isn't a clear-cut relationship between rainfall and deflection in the seasonal effect of moisture. Numerous factors, such as surface infiltration, the permeability of the pavement layers and subgrade, evaporation, and the site's drainage conditions, have an impact on it. The amount of water that can infiltrate the pavement and the subgrade is constrained by evaporation and drainage factors, while permeability affects the rate of infiltration and, as a result, the delay between the occurrence of rain and its impact on deflection. The impact still needs to be measured.

3.10 Correction for Seasonal Variations

The type of subgrade soil, its field moisture content at the time of the deflection survey, and the average annual rainfall in the region will determine how to correct for seasonal variation. As a result, the charts provided in IRC: 81 - 1997 for the given field moisture content, type of subgrade soil, and annual rainfall shall be used to determine the moisture correction factors (or seasonal correction factors). Table 3.6 lists the Benkelman Beam Deflection limits.

Table 3.6 The limits of BBD data is given based on the rebound deflection

Rebound Deflection (mm)	Strength of pavement
0.5-1	Reasonably strong
1-2	Moderate
2-3	Weak
>3	Very Weak (permanent Deformation)

4.0 Analysis of Result and Discussion of Results

4.1 Summary

Laboratory performance test was conducted to evaluate the effects of air voids, Marshal Stability test and Optimum Binder Content (OBC) for HMA and WMA mix for naturally available virgin aggregate for Bituminous Concrete mix for grade II and for obtained mix were performed in the field by laying test track. following result analysis discussed in following section

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4.2 Determinations of Optimum Binder Content

Once the design aggregate structure for BC grade I and grade II mixes were selected, OBC for the mix was determined by compacting specimens at varying binder contents and the same were subjected to density voids analysis. OBC of the mix were determined using Marshall mix design criteria. Further specimens were prepared at their respective OBC using Marshall and subjected to Stability Flow analysis, this were done in order to verify that, the OBC established using mix design criteria satisfies MoRT&H mix design criteria which is adopted by Indian highway agencies for bituminous mix design. The Marshall method of mix design, according to ASTM D1559, was used to figure out the ideal binder content. Marshall samples were cast with varying percentages of different binders, including, CRMB-60, and CRMB-55, in order to determine the optimal binder content (OBC). To determine the Optimum Binder Content (OBC) for a selected aggregate blend, binder, and compactor, a minimum of four trail binder contents were tested. Additionally, a minimum of three specimens were prepared at each trail to calculate the OBC. For BC grades I and II, volumetric and mechanical parameters, including bulk density, Marshall stability, flow, and other properties, were then determined. The test results are graphically plotted and displayed in tables 4.1 to 4.2. The % optimum binder content was used for evaluating for the different studies. for obtained OBC were used for determining the optimum dosage of additive for warm mix asphalt, It was found that 0.1 % weight of bitumen dosage for zycotherm warm mix additives. Further it was conducted different tests parameter to evaluate performance of mix in both HMA and WMA results are shown in table 4.3.The optimum binder content and optimum additive content was used for field test track in order to assess the residual strength of the existing pavement and also to design the overlay thickness of pavement layers for different modified Binders and for warm mix asphalt.

Table 4.1 OBC For CRMB -55 grade Bitumen for BC grade-II

Sl.No	Properties	OBC	Average OBC Percentage
1	Max stability, Kg	5.6	5.4
2	Max. density, g/cc	5.6	
3	Air voids (%)	5.5	

Table 4.2 OBC For CRMB -60 grade Bitumen for BC grade-II

Sl.No	Properties	OBC	Average OBC Percentage
1	Max stability, Kg	5.7	5.5
2	Max. density, g/cc	5.5	
3	Air voids (%)	5.5	

Table 4.3 Properties at 5.4% OBC using Marshall stability For BC Grade- II

Sl. No.	Properties of CRMB-55 Binder	HMA	WMA with 4% SASOBIT	WMA with 0.1 % Zycotherm	MoRT &H Limits
1	Compaction Level	75 Blows on each face of the specimen			
2	Optimum binder content in (%) by Weight of mix	5.4	5.4	5.4	
3	Stability in (Kg)	2240	2291	2345	1000-1200
4	Flow in (mm)	4.5	4.5	4.7	2.5-5
5	Bulk Density in (gm/cc)	2.39	2.41	2.42	-
6	Volume of Air Voids in (%)	4	3.9	3.9	3-5
7	Volume in Mineral Aggregate in (%)	15.71	15.84	14.12	13
8	Volume of voids filled by Bitumen in (%)	74.77	74.12	71.87	65-75

4.3 Benkelman Beam Deflection Survey

Rebound deflection survey has been carried out in order to assess the characteristic strength of the existing pavement and also to design the overlay thickness of pavement layers to be provided to withstand the future projected traffic loading as per IRC 81:1997. On the carriageway's left and right wheel paths, deflection measurements were made. Based on the pavement condition survey, the length of the road to be surveyed is divided into uniform sections. The loading points on the pavement for deflection measurements are positioned along the wheel paths on a line 0.9 m from the pavement edge for pavements with a total width greater than 3.5 m. The separation from the edge is 0.6 m on narrower pavements. A minimum of ten deflection observations are recorded for each side. By observing the initial, intermediate, and final readings at each deflection observation point, the studies were conducted using the CGRA procedure. For conducting rebound deflection studies on the road pavement, a standard truck with a rear axle load of 8200 kg and dual tyres inflated to a pressure of 5.6 kg/sq cm was used. The truck's two wheels are centered above the chosen. Table 4.4 to 4.5 shows the values for bituminous concrete Mix with Nominal Aggregate Size 13 mm on HMA and WMA Mix observed during Benkelman Beam Deflection Test carried out Road.

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Table 4.4 Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on HMA Mix

Project Name : Improvements and Asphalting to in ward no 04 of yelahanka Satellite town Sub Division			
Study Area: SITE 1	**Subgrade Type : Sandy / Gravelly**	**State : Karnataka**	
Chainage: 0 To 0.300 km	**Plasticity Index : >15**	**Cycle: 1 ST**	
Moisture Content : 10 %	**Annual Rainfall : <1300**	**Bitumen Mix: HMA**	**Binder: CRMB -55**

Sl. No.	Location		Dial gauge readings			Temperature	Actual Deflection	Rebound Deflection	Temperature Correction	Seasonal Correction	Corrected Deflection	Mean Deflection	Standard Deviation	Characteristic Deflection
	Chainage	Side	Initial	Inter.	Final									
	Km		Do	Di	Df	T ^{0}C	Dact	Dr	Tc	Sc	D	Dm	Sd	Dc
1	0.000	Left	100	68	66	34	0.680	1.360	0.010	1.323	0.913	0.87	0.12	**0.94**
2	0.050	Right	100	72	70	34	0.600	1.200	0.010	1.323	0.807			
3	0.100	Left	100	71	68	34	0.815	1.629	0.010	1.323	1.091			
4	0.150	Right	100	67	65	34	0.700	1.400	0.010	1.323	0.939			
5	0.200	Left	100	73	71	34	0.580	1.160	0.010	1.323	0.781			
6	0.250	Right	100	71	69	34	0.620	1.240	0.010	1.323	0.833			
7	0.300	Left	100	74	72	34	0.560	1.120	0.010	1.323	0.754			

Table 4.5 Deflection Test Results of B C Mix with Nominal Aggregate Size 13 mm on WMA Mix with Zycotherm 0.1% Additive

Project Name : Improvements and Asphalting to in ward no 04 of yelahanka Satellite town Sub Division			
Study Area: SITE 1	**Subgrade Type : Sandy / Gravelly**	**State : Karnataka**	
Chainage: 0 To 0.300 km	**Plasticity Index : >15**	**Cycle: 1 ST**	
Moisture Content : 10 %	**Annual Rainfall : <1300**	**Bitumen Mix: WMA**	**Binder: CRMB-55**

Sl. No.	Location		Dial gauge readings			Temperature	Actual Deflection	Rebound Deflection	Temperature Correction	Seasonal Correction	Corrected Deflection	Mean Deflection	Standard Deviation	Characteristic Deflection
	Chainage	Side	Initial	Inter.	Final									
	Km		Do	Di	Df	T ^{0}C	Dact	Dr	Tc	Sc	D	Dm	Sd	Dc
1	0.000	Left	100	71	69	34	0.620	1.240	0.010	1.323	0.833	0.81	0.07	**0.88**
2	0.050	Right	100	72	70	34	0.600	1.200	0.010	1.323	0.807			
3	0.100	Left	100	69	67	34	0.660	1.320	0.010	1.323	0.886			
4	0.150	Right	100	70	68	34	0.640	1.280	0.010	1.323	0.860			
5	0.200	Left	100	77	75	34	0.500	1.000	0.010	1.323	0.675			
6	0.250	Right	100	71	69	34	0.620	1.240	0.010	1.323	0.833			
7	0.300	Left	100	74	72	34	0.560	1.120	0.010	1.323	0.754			

Table 4.6 to 4.11 represents the characteristic deflection test results of bituminous concrete mix with nominal aggregate size 13 mm on mixes for first cycle. It shows the pictorial representation of characteristics deflection values of Bituminous Concrete Mix with Nominal Aggregate Size 19 mm on bitumen Mixes such as HMA, WMA with 4% of Sasobit additive and WMA with 0.1% of Zycotherm additive.

Table 4.6 Characteristic Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on Mixes for First Cycle

Bitumen Mix	CRMB-55	CRMB-60
HMA	0.94	0.93
WMA WITH 0.1% ZYCOTHERM ADDITIVE	0.88	0.86

Table 4.7 Characteristic Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on Mixes for Second Cycle

Bitumen Mix	CRMB-55	CRMB-60
HMA	0.96	0.96
WMA WITH 0.1% ZYCOTHERM ADDITIVE	0.89	0.88

Table 4.8Characteristic Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on Mixes for Third Cycle

Bitumen Mix	CRMB-55	CRMB-60
HMA	0.99	0.98
WMA WITH 0.1% ZYCOTHERM ADDITIVE	0.91	0.91

Table 4.9 Characteristic Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on Mixes for Fourth Cycle

Bitumen Mix	CRMB-55	CRMB-60
HMA	1.08	1.05
WMA WITH 0.1% ZYCOTHERM ADDITIVE	0.95	0.94

Table 4.10 Characteristic Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on Mixes for Fifth Cycle

Bitumen Mix	CRMB-55	CRMB-60
HMA	1.36	1.35
WMA WITH 0.1% ZYCOTHERM ADDITIVE	1.10	1.09

Table 4.11 Characteristic Deflection Test Results of Bituminous Concrete Mix with Nominal Aggregate Size 13 mm on Mixes for Sixth Cycle

Bitumen Mix	CRMB-55	CRMB-60
HMA	2.19	2.18
WMA WITH 0.1% ZYCOTHERM ADDITIVE	2.05	2.00

5.0 DISCUSSION OF RESULTS

5.1 General

Realizing the fact that, green highways are the highways constructed using materials that emits no or low concentration of pollutants and are eco-friendly. Use of green bitumen materials in highway construction has several advantageous including saving in natural resources and energy. Keeping the current trends in the road development activity in India, there is a need to construct green highways for the sustainable development. Green pavement materials such as bituminous emulsions and foam bitumen have been successfully used in other parts of the world to rehabilitate existing pavements. The central objective of this study was to evaluate suitability of warm mix asphalt Mix Design procedure for Indian traffic and climatic conditions and to establish a design procedure to suit Indian scenario. Presently Indian highway agencies are using Ministry of Roads Transport and Highways (MoRT&H) specifications for selection of binders, aggregate gradation and use Marshall method of mix design to determine the optimum binder content of a mix. Hence a comparative study was needed to evaluate the different mix design procedures affecting the performance of the mixtures. The performance parameters of the mixtures include moisture susceptibility, fatigue and rutting distresses and filed performance test for prepared test track with BBD study. The results of these tests were compared with respect to performance of HMA and WMA with two modified binders and one warm mix additive. The main goal of this study was to determine whether warm mix asphalt Mix Design procedure was appropriate for the traffic and climatic conditions in India and to create a design procedure that would work in that context. Currently, Indian highway agencies follow the Ministry of Roads, Transport, and Highways (MoRT&H) specifications when choosing binders, grading aggregate, and calculating the ideal binder content of a mix using the Marshall method of mix design. As a result, a comparative study was required to assess how various mix design techniques affected the performance of the mixtures. Moisture susceptibility, fatigue, rutting distresses, and filed performance test for prepared test track with BBD study are some of the performance parameters of the mixtures. Regarding performance of HMA and WMA with two binders and one warm mix additive, the results of these tests were compared.

5.2 Filed performance test using Benkelman beam deflection (BBD) study

Based on the pavement condition survey, the length of the road to be surveyed is divided into uniform sections. The loading points on the pavement for deflection measurements are positioned along the wheel paths on a line 0.9 m from the pavement edge for pavements with a total width greater than 3.5 m. The distance from the edge is 0.6 m on narrower pavements. On each chosen section of pavement, a minimum of ten deflection observations are made. Tests were conducted on BC mixes using two modifed binders and one warm mix additive (Zycotherm 0.1%) in ward no 04 of yelahanka Satellite town Sub Division Bangalore for six cycle to check the performance of pavement under different climatic condition ,results shows the values observed during Benkelman Beam Deflection Test carried out Road. The deflection test results for a bituminous concrete mix on HMA Mix with HMA Mix with 0.1 percent Zycotherm Additive. The aggregate's stated size is 13 mm. Clearly, the measured mean deflection (0.81) is less than that of the bituminous concrete mix with nominal aggregate size 13 mm on HMA Mix.

6.CONCLUSIONS

6.1 Based on the research conducted following conclusions are,

- The Materials used in the present research work, Results of coarse aggregate, fine aggregate, bitumen, and modified binders, shows suitability of the materials and the results are satisfying with IS/MoRT&H and other codal standards/ specifications.
- The Results of the Marshall Stability test on Bituminous Concrete BC Gr-II which is used as a surface/wearing course with conventional bitumen and with modified binders satisfy the Marshall test.
- Characteristic Deflection results obtained from BBD test correlated with all two modified binders and all six cycles using HMA and WMA technology
- Characteristic Deflection results obtained for HMA and WMA shows that WMA mix shows better resistance under different climatic condition and tyre pressure.
- From study, asphalt mixture prepared using S Zycotherm are a potential additive to prepare asphalt mixture at a lower temperature for use on Indian Climatic condition. The additives Zycotherm in warm mix asphalt shows better workability compared to HMA inspite at lower temperature.
- From Benkelman beam deflection (BBD) study, it was observed that CRMB-60 with warm mix additive shows better resistance compared to CRMB-55.
- From results its shows that CRMB-60 with warm mix asphalt work better resistance than the hot mix asphalt.

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