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Comparative Study On Hot Mix And Warm Mix Asphalt Using Zycosoil And Densicryl Additives For BC Mix

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Abstract

Warm Mix Asphalt (WMA) is a technology that allows significant lowering of the production and paving temperature of conventional Hot Mix Asphalt (HMA), by reducing the viscosity of bitumen and increasing the workability of mixture. In the present study, the main objective to investigate the properties of bituminous concrete (BC) mix using zydex warm mix additives i.e. Zycosoil and Densicryl and compare them with that of HMA.The bituminous concrete (BC) mix specimens were prepared with and without additives by varying temperature like 100°, 105°, 110°, 115°, 120°, 125°, 130°C to determine the properties of WMA mix with these temperatures.The experimental design includes aggregate source, 60/70 grade bitumen, two warm mix additives, i.e. Zycosoil and Densicryl. Zycosoil is liquid reactive ant-stripping additive. Densicryl is high molecular weight acrylic polymer dispersion. Total of 189 specimens was casted & tested in the study. 63 control mix specimens and 126 modified bitumen mix specimens.The evaluation of WMA and HMA mixture included the following testing procedure such as engineering properties on bitumen, coarse aggregate and fine aggregate, Marshall Stability test, Indirect tensile strength, Aging test, stripping value test and comparative costs analysis of HMA and WMA.A Zydex WMA additive resolves the issue of moisture susceptibility with improved strength and compatibility at economical cost. Zydex industries warm mix additives of Zycosoil and Densicryl it can used as alternative for HMA. Based on present study it has been found that volumetric properties of WMA specimens of 125°C mixing temperature satisfy the volumetric properties of HMA specimens at 160°C temperature.

Keywords: *Warm mix, Harm mix asphalt, volumetric properties, ITS, stripping test, Aging test.*

1. INTRODUCTION

Conventional hot mix asphalt (HMA) has been primary material used in asphaltic paving in past decades.Hot Mix Asphalt (HMA) is typically produced in either batch or drum mix plant at a discharge temperature ranging from 160°C to 180°C.[1] It has been necessary to use these elevated temperature to dry the aggregates, coat them with the asphalt binder, achieve the desired workability, and provide sufficient time to compact the HMA mat.Warm mix asphalt (WMA) technology, which has been gaining popularity in recent years, warm mix asphalt has been widely studied and gradually applied in the paving industry since it was initiated in the late 1990s.[2] WMA production temperature typically ranges from 100°C to 140°C, whereas for HMA it ranges between 150 and 170°C.Warm asphalt technology seems to be quite promising. It consumes 30% less energy, reduces carbon dioxide emission by 30%, and reduces dust emission by 50-60 % compared to hot mix asphalt. [3]

1.1 Classification of asphalt mixes are

a) Cold mix asphalt (CMA) – asphalt mix is made in environmental temperature using bitumen emulsion and foam.
b) Half warm mix asphalt (HWMA) – asphalt mix is made in temperature which is below water vaporization.
c) Warm mix asphalt (WMA) – asphalt mix is made in (100-140) °C temperature.

d) Hot mix asphalt (HMA) – asphalt mix is made in (150-180) °C temperature in relation with the used binder.[1]

1.2Warm mix processes WMA

There are many different WMA processes, and products, that can be used to achieve reduction in temperature, but generally WMA technologies can be separated into four categories [1]

1. Water based processes
2. Water bearing additives
3. Organic additives (wax additives)
4. Chemical additives

2. OBJECTIVE OF THE PRESENT STUDY

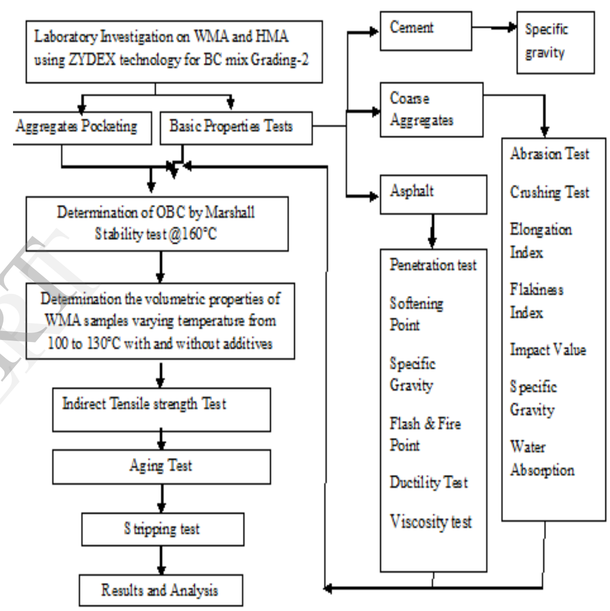
This study mainly deals about the properties of Bituminous Concrete (BC) mix produced using zydex warm mix technology and to compare them with that of HMA

1. To compare the properties of WMA to that of HMA for the BC grade specified by MORT&H.
2. To know whether the WMA produced by zydex warm mix products meets the requirements and will it be used as the alternative for HMA. To achieve this objective, the scope included the following:
   a) Testing of engineering properties on bitumen, coarse aggregates and fine aggregates.
   b) Determination of Marshall stability test
   c) Determination of Indirect tensile strength test
   d) Determination of Aging test
   e) Determination of stripping test
3. To elevate the best mixing temperature for WMA mixtures.

3. SCOPE OF THE PRESENT STUDY

In the present study, the binder used are tested in accordance with the standard testing produces i.e. 60/70 bitumen is tested for penetration, ductility, specific gravity, and softening point, flash and fire point. The aggregate are tested for impact value, los angles, abrasion value, specific gravity, water absorption and crushing value. HMA specimen were prepaid at 160°C temperature varying bitumen content from 5% to 7% to determine the optimum binder content.(OBC). From optimum binder content (OBC) value the WMA specimens were prepaid by varying temperatures like 100°, 105°, 110°, 115°, 120°, 125° and 130°C with and without additives and also varying additives dosage of 0.5% increment of Zycosoil and 0.2% of Densicryl to the weight of bitumen content and the following test were conducted Marshall Stability test, Indirect Tensile test (ITS), Stripping value test

4. MATERIALS and METHODOLOGY



4.1Aggregate Gradation

Bituminous concrete grading- 2: Bituminous grading -2 were selected as wearing and profile corrective courses. The bituminous mix design is done as per Marshall Mix design of MS-2,[5] and the gradations for these mixes were obtained from MORTH (2001)[4]. Gradation of aggregates for BC mix shown in table: 3.1

4.2 Material Characterization

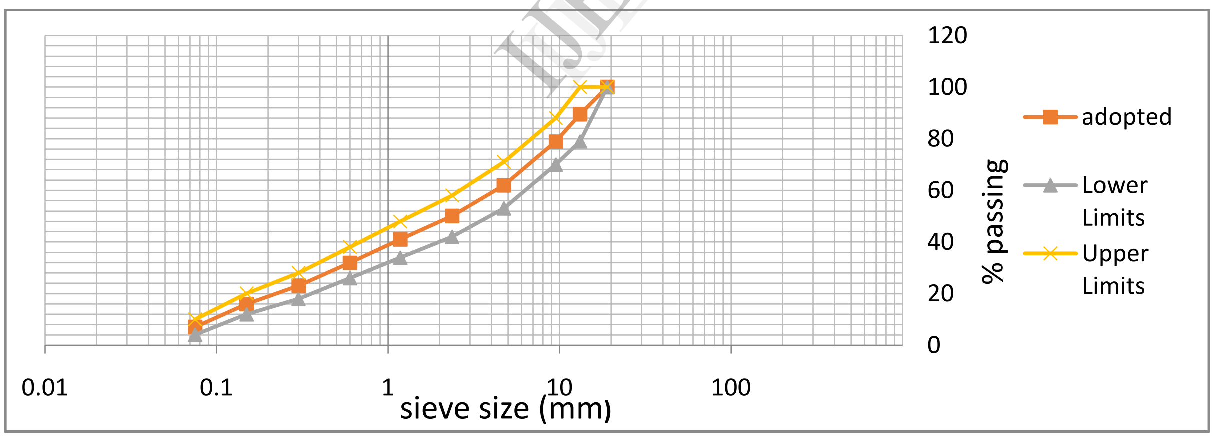
Coarse aggregate, Fine aggregate, Mineral filler (stone dust and cement), Bitumen (penetration grade 60/70)

4.2.1 Warm mix additives (product description)

Zydex Industries, India has recently developed a new polymer-based Warm Mix additive that is **Zycosoil** and **Densicryl.** Zydex WMA technology resolves the issue of moisture susceptibility with improved strength and compatibility at economical cost. The additive combination of Densicryl and Zycosoil works synergistically to micro-reinforce the binder and make the aggregates asphalt loving. The WMA additive combination shows remarkably excellent resistance to moisture susceptibility and debonding even in presence of salt (NaCI). This is a very important advantage because asphalt pavements are routinely subjected to de-icing salts during snowy, winter season. Coastal roads along sea are also subjected to salt exposure. The sodium ion in the salt generally makes Carboxylated asphaltenes highly moisture susceptibility

Table 3.1: Showing the gradation of aggregates for BC mix and its percentages

IS Sieve (mm)	Upper limits	Middle limits	Lower limits	Adopted	% retained	Wt of aggregate(gm)
19	100	100	100	100	0	0
13.2	100	89.5	79	89.5	10.5	126
9.5	88	79	70	79	10.5	126
4.75	71	62	53	62	17	204
2.36	58	50	42	50	12	144
1.18	48	41	34	41	9	108
0.6	38	32	26	32	9	108
0.3	28	23	18	23	9	108
0.15	20	16	12	16	7	84
0.075	10	7	4	7	9	108
Filler					7	84
Total					100	1200



Graph 3.1: Aggregate mix for Bituminous Concrete (BC) mix

Densicryl is high molecular weight acrylic polymer dispersion additive that is designed to be used in conjunction with Zycosoil. Polymers, as a class of material, are known to be beneficial to improve reinforcement of material properties. Densicryl was designed to minimize the tensile strength reduction common in WMA in spite of the reduced oxidation of the asphalt binder at lower mixing and compaction temperatures and this technology is named as Zydex Warm Mix Technology.

Zycosoil is a liquid reactive anti-stripping additive. It chemically bonds to silanol’s (water loving) on aggregate, soil, clay, and stone powder surface to convert it permanently to an Alkyl Siloxane surface which makes it asphalt loving (hydrophobic) and water insensitive. The residual moisture in case of Zycosoil acts uniquely as a catalyst for accelerating Zycosoil reaction even at lower (100^{0}C) temperature.

Densicryl is a liquid polymer compatible with asphalt binder and can be mixed with it instantly it lowers the interfacial surface tension of asphalt binder and improves the coating during the mixing process even at higher viscosities due to lower temperature of 100^0C. The energy of mixing of Densicryl & asphalt binder released during 60-120 seconds mixing process helps to reduce the torque (mechanical effort) required. This also applies to high viscosity polymer modified asphalt binders. Densicryl polymer associates with polar asphaltenes& forms hard micro phases which tend to reinforce and improve the mix strength of WMA maintaining the flexibility.

Fig 3.1: Chemicals used Zycosoil and Densicryl

4.2.2Design of warm mix asphalt (WMA)

In preparing WMA samples the aggregates used are the same as that used for HMA. The composition of BC mix as specified by MoRT&H is used. Bitumen used for the preparation of WMA is been treated with Zycosoil and Densicry. In preparation of WMA samples, aggregates are heated to 100°C and above temperatures and the modified bitumen is added and mixed at a temperature of 100^0C. Compact the mixture by the Marshall Compaction hammer on each side of specimen giving 75 blows and prepared samples were extruded after 24hours.

4.2.3Procedure for Adding Zycosoil and Densicryl

The proportions of the chemicals to be added are bituminous concrete mix. The dosage of the zycosoil is 0.05% and densicryl is 0.3% of the bitumen content. The Zycosoil liquid anti-strip was pre-blended with the asphalt binder at a dose of 0.05% by weight of binder. The Zycosoil was added drop-wise to the hot asphalt binder from a 1ml syringe while it was continuously stirred with a glass stirring rod. A typical dosage for binder of approximately 1000 grams was approximately 0.5gm.The Zycosoil modified binder was continuously stirred for an additional 10 minutes after the Zycosoil was added. It was then allowed to heat for 30 minutes at the mixing temperature prior to mixing to allow the binder to re-heat and for the Zycosoil to distribute uniformly throughout the asphalt binder.

The Densicryl WMA additive was added during the mixing process. First the aggregate was pre-heated to the desired temperature. Next, the required amount of Densicryl was extracted into a 5ml syringe.

The Densicryl was added at a rate of 0.3% by total weight of asphalt binder. At the beginning of the mixing process, the hot aggregate was added to the mixing bowl and stirred to form a small crater in the aggregate. The desired amount of asphalt binder is added to this crater, followed by the correct dosage of Densicryl (A typical dosage of Densicryl for 1000 grams of asphalt binder would be about 3gms). The Densicryl and asphalt are then immediately stirred together using a stirring rod to incorporate them. For a correctly prepared samples significant amount of 'bubbles' should be evident in the asphalt binder. This indicates the functioning of the nano-foaming technology. A photo of this mechanism is shown in Figure3. Preparation of the rest of the mixture sample is the same as above procedure.

Fig 3.2: Bubble formation on addition of Densicryl

4.3Experimental Set up- Marshall Test as per ASTM D 1559

4.4Experimental set up- Indirect Tensile Test

4.5Experimental set up- Stripping Value of Aggregates as per IS: 6241-1971(Reaffirmed 1998).

4. DATA COLLECTION AND ANALYSIS

Table 5.1: Avg volumetric properties of control mix

Bitumen content (%)	Bulk density G_b (kg/m^3)	Theoretical density G_t (Kg/ m^3)	Percent air voids V_a(%)	Voids in mineral aggregate VMA (%)	Voids filled with bitumen VFB (%)	Stability (kN)	Flow (mm)
5	2348.07	2512.73	6.55	18.06	63.72	9.35	2.90
5.5	2358.70	2495.43	5.48	18.20	69.89	10.81	3.2
6	2366.77	2478.51	4.51	18.43	75.54	9.96	3.87
6.5	2366.65	2461.99	3.87	18.95	79.57	8.83	4.0
7	2355.54	2445.83	3.69	19.86	81.41	8.18	4.2

Table 5.2 Optimum bitumen content (OBC) calculation

	Value	B.C %
Max Stability:	10.81 kN	5.5
Max Bulk Density	2366.77	6
Design Air Voids , 4%		6.39
O.B.C		5.96

Table 5.3 Comparison of Marshall Stability (kN) values for 100°C to 130°C, 160°C without and with additives

Bitumen content (%)	Mixing temperature(°C)	Plain bitumen	0.05%Zycosoil +0.3%Densicryl	0.1 % Zycosoil +0.5%Densicryl	0.15%Zycosoil +0.7%Densicryl
5.96	100	6.47	7.32	7.72	8.20
	105	6.71	7.91	8.46	8.81
	110	7.11	8.68	8.91	9.31
	115	7.70	9.24	9.55	9.90
	120	8.11	10.64	10.99	11.14
	125	8.48	11.35	11.50	11.90
	130	8.70	12.58	12.80	13.13
	160	10.55	-	-	-

Table 5.4 Comparison of Bulk Density (Kg/m^3) values for 100°C to 130°C, 160°C without and with additives

Bitumen content (%)	Mixing temperature (°C)	Plain bitumen	0.05 %Zycosoil + 0.3%Densicryl	0.1 % Zycosoil + 0.5%Densicryl	0.15 %Zycosoil + 0.7%Densicryl
5.96	100	2301.67	2316.86	2321.58	2326.14
	105	2304.29	2324.89	2331.48	2337.06
	110	2307.79	2336.01	2341.40	2348.42
	115	2312.77	2341.40	2349.10	2353.45
	120	2320.54	2349.47	2357.19	2360.12
	125	2327.55	2354.58	2360.42	2362.45
	130	2333.37	2359.09	2361.27	2363.13
	160	2349.75	-	-	-

Table 5.5 Comparison of Air voids values (%) for 100°C to 130°C, 160°C without and with additives

Bitumen content (%)	Mixing temperature (°C)	Plain bitumen	0.05 %Zycosoil + 0.3%Densicryl	0.1 % Zycosoil + 0.5%Densicryl	0.15 %Zycosoil + 0.7%Densicryl
5.96	100	7.19	6.57	6.38	6.20
	105	7.08	6.25	5.98	5.76
	110	6.94	5.80	5.58	5.30
	115	6.74	5.58	5.27	5.10
	120	6.42	5.26	4.95	4.83
	125	6.14	5.05	4.82	4.73
	130	5.91	4.87	4.78	4.71
	160	5.25	-	-	-

Table 5.6 Comparison of Voids filled in bitumen (VFB) (%) values for 100°C to 130°C, 160°C without and with additives

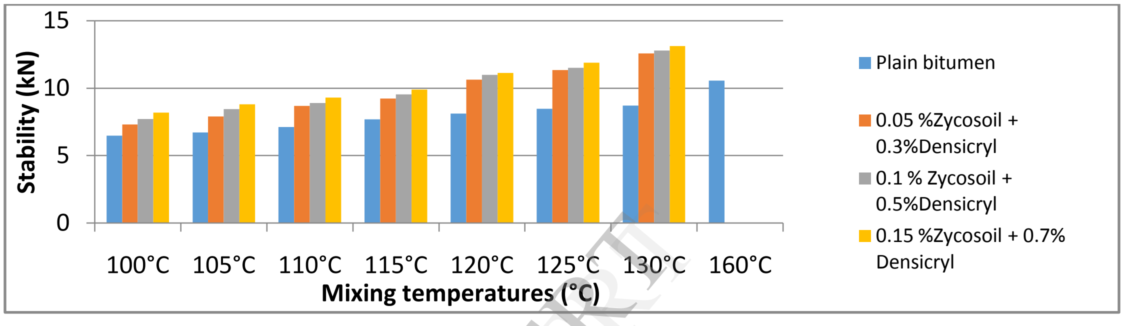
Bitumen content (%)	Mixing temperature (°C)	Plain bitumen	0.05 %Zycosoil + 0.3%Densicryl	0.1 % Zycosoil + 0.5%Densicryl	0.15 %Zycosoil + 0.7%Densicryl
5.96	100	65.18	67.32	68.00	68.68
	105	65.54	68.49	69.48	70.34
	110	66.03	70.18	71.02	72.14
	115	66.73	71.02	72.25	72.96
	120	67.85	72.31	73.58	74.07
	125	68.89	73.14	74.12	74.46
	130	69.77	73.89	74.26	74.58
	160		-	-	-

Table 5.7 Comparison of voids in Mineral Agg.VMA (%) values for 100°C to 130°C, 160° C without and with additives

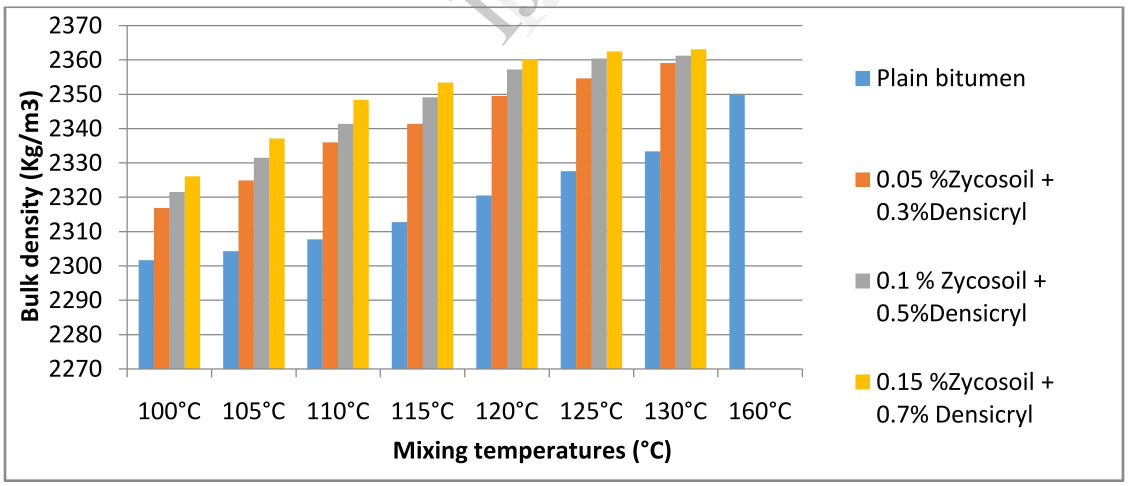
Bitumen content (%)	Mixing temperature (°C)	Plain bitumen	0.05 %Zycosoil + 0.3%Densicryl	0.1 % Zycosoil + 0.5%Densicryl	0.15 %Zycosoil + 0.7%Densicryl
5.96	100	20.63	20.11	19.95	19.79
	105	20.54	19.83	19.61	19.41
	110	20.42	19.45	19.26	19.02
	115	20.25	19.26	19.00	18.85
	120	19.98	18.99	18.72	18.62
	125	19.74	18.81	18.61	18.54
	130	19.54	18.65	18.58	18.51
	160	18.98	-	-	-

Table 5.8 Comparison of Flow (mm) values for 100°C to 130°C, 160°C without and with additives

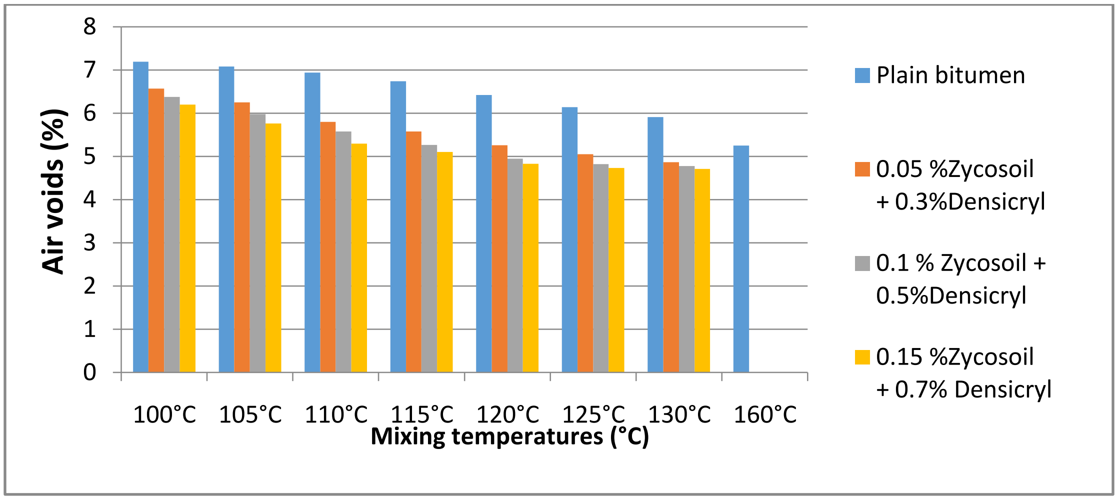
Bitumen content (%)	Mixing temperature(°C)	Plain bitumen	0.05 %Zycosoil + 0.3%Densicryl	0.1 % Zycosoil + 0.5%Densicryl	0.15 %Zycosoil + 0.7%Densicryl
5.96	100	1.83	2.37	2.67	2.83
	105	2.23	2.50	2.73	2.93
	110	2.37	2.87	3.10	3.33
	115	2.67	3.07	3.20	3.47
	120	2.80	3.33	3.50	3.73
	125	3.13	3.57	3.77	3.83
	130	3.33	3.87	3.93	4.10
	160	3.77	-	-	-



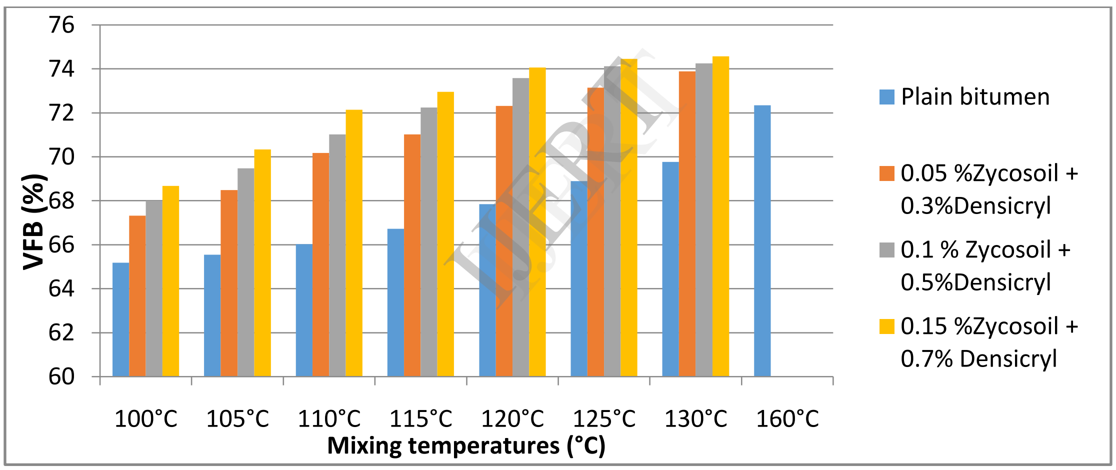
Graph 5.1 Comparison of Stability values Vs Mixing temperatures with and without additives



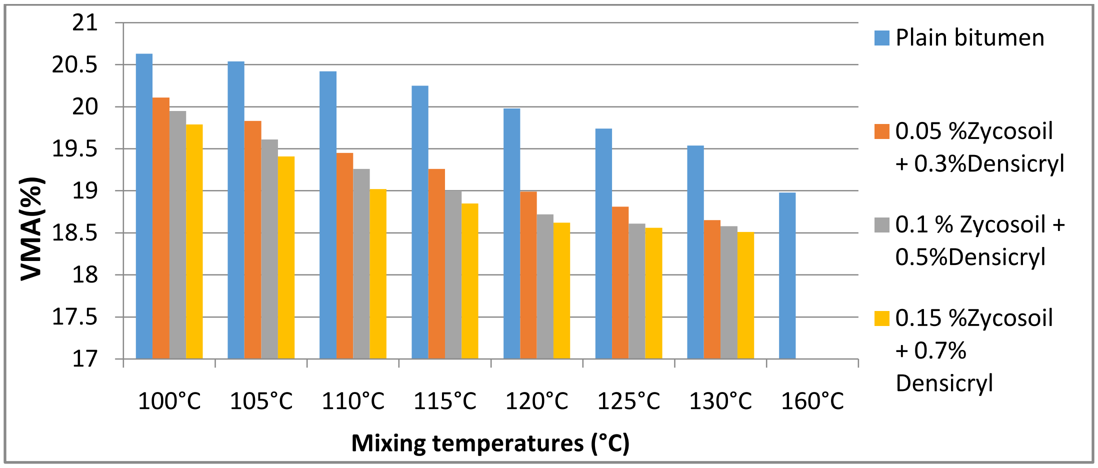
Graph 5.2 Comparison of Bulk density values Vs Mixing temperatures with and without additives



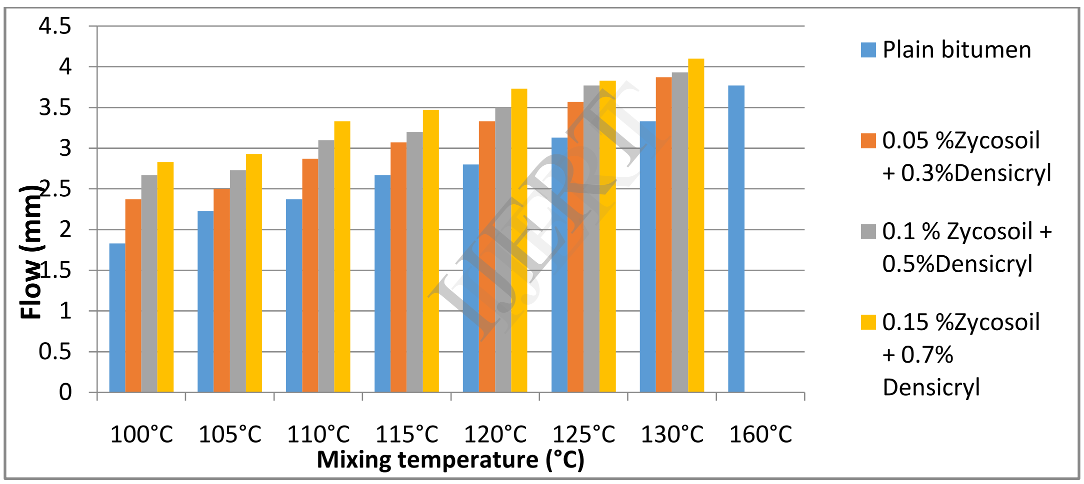
Graph 5.3 Comparison of Air voids values Vs Mixing temperatures with and without additives



Graph 5.4 Comparison of VFB values Vs Mixing temperatures with and without additives



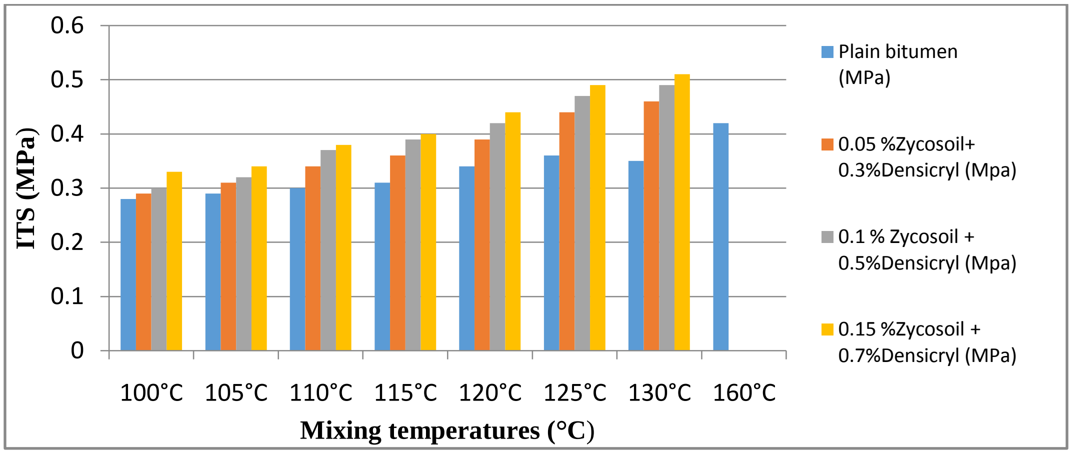
Graph 5.5 Comparison of VMA values Vs Mixing temperatures with and without additives



Graph 5.6 Comparison of Flow values Vs Mixing temperatures with and without additives

Table 5.9 ITS values for mixing temperature 100°C to 130°C and 160°C without and with additives

Mixing temperature (°C)	Plain bitumen	0.05%zycosoil + 0.3% densicryl	0.1% zycosoil + 0.5% densicryl	0.15% zycosoil + 0.7% densicryl
100	0.28	0.29	0.3	0.33
105	0.29	0.31	0.32	0.34
110	0.30	0.34	0.37	0.38
115	0.31	0.36	0.39	0.4
120	0.34	0.39	0.42	0.44
125	0.36	0.44	0.47	0.49
130	0.35	0.46	0.49	0.51
160	0.42	-	-	-



Graph 5.7 Comparison of ITS values Vs Mixing temperatures with and without additives

Table 5.10 Stripping value test result of HMA and WMA

Type of bitumen	**Mixing temperature (°C)**	**Percent stripping (%)**	**As per MORT&H (2001)**
HMA	160	3	Stripping value should not be more than 10 percent
0.05% Zycosoil + 0.3% densicryl	120	1	
0.1% Zycosoil + 0.5% densicryl	120	00	

5. CONCLUSION

- The WMA samples are prepared with and without additive for the temperature from 100 to 130°C. when compared the 125°C temperature test samples satisfy the results of HMA samples of 160°C and 125°C temperature of plain bitumen
- The Zycosoil and Densicryl warm mix additives was designed to allow mixing temperature of around 125°C at the dosage of 0.05% zycosoil and 0.3% densicryl.
- Zydex industries of warm mix additives of zycosoil and densicryl can be used as the alternative for HMA
- Zydex WMA additives resolve the issue of moisture susceptibility with improved strength and compatibility at economical cost.
- The optimum bitumen content is 5.96% for HMA mix at 160°C temperature
- Comparing the properties of HMA and WMA specimens from 100 to 130°C temperatures, the bulk density, Marshall Stability, VFA, flow, ITS values increases for additives of 0.05% zycosoil and 0.3% densicryl at 125°C mixing temperature and which also satisfy the HMA mix at 160°C temperature.
- Air voids, VMA values reduced with increase for additive dosage of 0.05%zycosoil and 0.3% densicryl at 125°C temperature which also satisfy the HMA mix at 160°C temperature
- The WMA samples of 0.05% of Zycosoil and 0.3% of Densicryl at 120°C mixing temperature satisfy the stripping value test. WMA mix is highly resistance to stripping even when subjected to worst moisture conditions

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