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A Study on Warm Mix Design on Bitumens Mixes (VG 30) Using Rediset-WMX

Aamirhamaza Chariwala[1], Shivam Patel[2], Mursalin Shaikh[3], Shivam Gangani[4], Sagar Tailor[5].
Department of Civil engineering [1, 2, 3, 4, 5], *Gujarat technological university* [1, 2, 3, 4, 5]
Email: aamirhamaza.lit@lvs.co.in[1],*shivampatel19897@gmail.com*[2]

Abstract- The purpose of this study is mainly to find out the optimum temperature by which the bituminous concrete mix temperature is reduced through the warm mix asphalt technology. Warm mixing with additive is becoming popular because of mixing at lower temperature which reduces the fuel usage and emission of hazardous gases consequently decreases the mixing as well as compaction temperature of mix. Reduction of 20º C to 40º C have documented, such reduction have the obvious benefits of cutting fuel consumption and decreasing the production of greenhouse gases. Also, there will improvement on performance of pavement. In present study, warm mix design of Bituminous Concrete, Rediset-organic additive is used as adhesion with used as a binder viscosity grade-30(VG-30). The Optimum Bitumen Content (OBC) using a binder will obtained by the Marshall Test. Then after Optimum dosage of Rediset and Temperature are found i.e., the temperature at which Rediset perform effectively. Also, comparative study is making to know the stability of Rediset with Binder. The Warm mix with VG-30 satisfied all the Marshall Stability test of bituminous mixes and well suited for construction of road with heavily traffic. Also, Laboratory testing is carried out to find the physical properties of Aggregate and bitumen test for VG-30 with and without Rediset.

Index terms- Warm mix asphalt (WMA), bituminous concrete (BC), hot mix asphalt (HMA), warm mix asphalt, MORTH,Optimum binder content (OBC), Optimum temperature (OT), Viscosity grade (VG), Volume of voids (Vv), Bituminous concrete(BC), Warm-mix (WMX)

1. INTRODUCTION

The area of work of this study covers laboratory study on bitumen, bituminous mixes and bituminous mixes with additive. The purpose of this study is mainly concentrated to find out the optimum temperature by which the bituminous concrete mixing temperature is reduced through the warm mix asphalt technology. The asphalt industry is the great concern existing in the world related to the atmosphere emissions for the greenhouse effect and the energy consumption. The current industrial tendency is trying to improve the working systems in order to reduce the emissions of harmful components to the atmosphere and the consumption of energy as well. Until recent years the two fundamental criteria uses in deciding the best pavement to be uses are economical and technical considerations whereas today the environmental impact must also be taken into consideration. In the road sector the main research goal is the development of new systems which allow reducing the manufacturing and the application temperatures of the bituminous mixes. Bituminous mixes are most commonly use all over the world in pavement construction. Most of the highway in India is flexible pavements, within which are included surfacing of various types and thickness. Various studies are under taken to improve the strength characteristics of bituminous surfaces by modifying bitumen grades, aggregate gradation mix proportion and by adding different additives to the bitumen. It is seen from various literature reviews that strength of paving mixes can be enhanced by using modified binders. Such binders also improve temperature susceptibility and help eliminating some common Problems like bleeding in peak summer temperature. Keeping these facts in minds it was felt that efforts can be made to use some modifier material or bitumen additive. As per MORTH - Section 509, bituminous concrete for wearing course should be made with bitumen of viscosity grade-30 (VG-30) for nominal aggregate size 19mm with bitumen content 5-6% having layer thickness 50-65mm and for nominal aggregate size of 19mm with bitumen content 5-7% having layer thickness 30-45mm. Bitumen VG-30 improves the performance of the binder to minimize the stress cracking that occurs at low temperature and plastic deformation at high temperature. Use of binders is a logical, practical and economical approach to meet required performance standard for pavement today. This enhances durability of existing road surfacing which results in reducing maintenance and surfacing operations. The use of Warm mix additive - Rediset in bitumen VG-30 is to reduce the mixing and compaction temperature of Bituminous Concrete. The warm mix asphalt (WMA) is an asphalt mixture which is mixed at temperature lower than conventional hot mix asphalt (HMA).

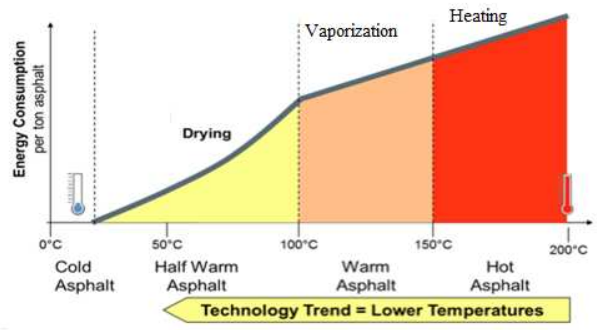

Fig.1 Classification by temperature ranges

1.1 Objective of study

The main objective of the study is to focus on lowering the mixing temperature of bituminousmixby warm mix asphalt technology.This study has carried out to meet the following Objectives:

• To improve cohesive strength of the mix thereby reduces rutting.
• To reduce mixing and compaction temperature of BC mixture.
• To check the suitability of Binders (VG-30) in Warm mix design of BC.

1.2 Scope of study

This study is conducted to explore the use of Rediset-WMX technology in bituminous concrete of pavement construction and detailed laboratory experiments are carried out to find out whether it is viable to use or not in terms of environment friendly. The study basically focuses on the use of Rediset as an adhesion promoter in bituminous concrete in flexible Pavement.

2. METHODOLOGY

In this study Bituminous concrete mix is design for 19 mm nominal size of aggregate. The Aggregate use in the study is crusher Aggregate from Quarry and VG-30 used as binder. First, Laboratory testing is carried out to find the physical properties of Aggregate by conducting tests like Grain size analysis, Aggregate Impact value, Abrasion Test, Crushing value test, Flakiness and elongation Index (combined), Water absorption, Specific Gravity etc. Also, by sieve analysis the Gradation of Aggregate has been decided which satisfied the requirement of Gradation of 19 mm nominal size of aggregate for BC design as per MORTH section 500 clause 509. Similarly, The Bitumen test for VG-30 with and without Rediset has been done including Penetration test, Softening Point test, Elastic Recovery Test, Viscosity, Specific Gravity etc. which satisfied the requirement of IS: 73-2006 “VG-30 Bitumen-Specification”. Secondly, prepared samples for Marshall Mix design and determine the Optimum bitumen content for mix using VG-30. After determining the OBC prepare sample at 110°C, 120°C, 130°C temperature and different dose of Rediset like 1.5%, 2.0%, and 2.5%. Based on this theOptimum Temperature and Optimum Dose of Rediset has been determined for both binders. Figure 1 shows the Study Methodology.

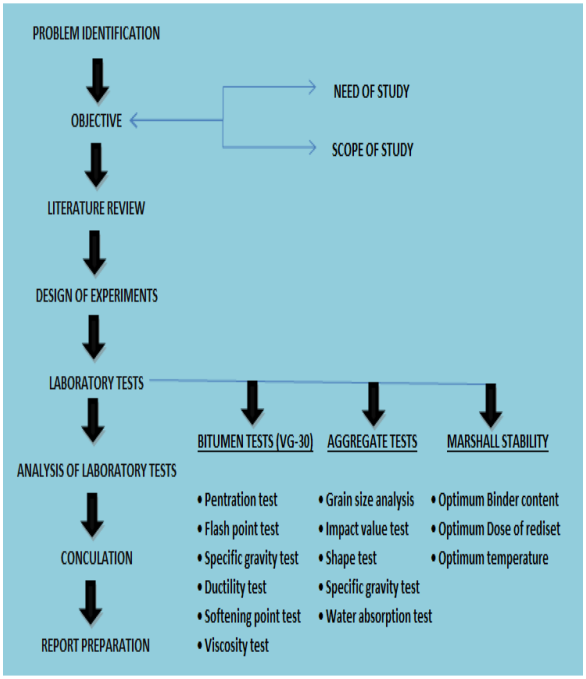

Fig.2 Study methodology chart

3. LITERATURE REVIEW

3.1 Materials

3.1.1 Rediset-WMX

Warm mix asphalt is a modified hot mix asphalt mixture that is produced, placed and compacted at 10°C to 40°C lower temperature than the conventional hot mix asphalt mixture. Warm mix is technology which gives you space to prepare bituminous mixes at lower temperature than conventional hot mix. This technology is classified in category like use of water or organic additives or Chemical additives. In this study use of Rediset WMX which is organic additives in the pellet form and does not contain water. Rediset is a combination of organic additives and surfactants that is developed to enhance the adhesion between asphalt and aggregates. The manufacturer of Rediset, AkzoNobel India Chemistry Ltd. claims that the surfactants improve the wetting ability of the asphalt binder for better coating with the aggregates, and the organic additives provide a reduction of the viscosity of the binder and a lubricating effect for easier coating and compaction. It is supplied in a

pellet form that can be added at a dose rate of 1.5% to 2.5% by weight of binder. According to the recommendation of the manufacturer, a dosage of 2% by weight of asphalt is used for preparing the specimens.

Advantages of Rediset:

- Easy to incorporate with existing equipment.
- Warm mix additive with adhesion promoting properties.
  Adhesion promoter is both active and passive to facilitate good coating during mixing and extended life expectancy.
- Formulated to suit a wide range of mix types and aggregates.
- Does not change VG grading of the bitumen.
  Moisture not introduced into the mix.

Fig.3 Rediset-WMX

3.1.2 Viscosity Grade-30(VG-30)

The bitumen used for the mix is of the viscosity grade-30 (VG-30). This VG-30 grade binder is used for the construction of heavy duty flexible pavement. These heavy duty flexible pavements are constructed for the tolerance of extensive traffic loads. The VG-30 can also be used in substitution for 60-70 penetration grades.

Advantages of viscosity grading of binder:

- The binder of grade VG-30 has outstanding property of adhesive and bonding with aggregates.
- This binder has admirable water proofing properties.
- This has a resistance over the mild acids and alkalis.
- As compared to tar coat the degradation of the bitumen is very deliberate when exposed to the extensive sun light.
- The pavement constructed using the bitumen has lesser construction time because it does not need the cure time.

3.2 Additional technology of WMA & Different Products

After the first evolution of warm mix asphalt technology in 1959 by Prof. Ladis Csanyi at Iowa State University, till now there are many technologies have come on rise. The additional technologies available for the pavement construction are divided in to three categories which are listed below.

- Use of Chemical Technologies
- Use of Foaming Technologies
- Use of Organic (Wax) Additives

All of the existing products use atleast one of these technologies, but there may be possibilities of combination of them.

3.3 Past studies on warm mix technology

3.3.1 David Jones, Bor-Wen Tsai, and JamesSignore, University of California, Pavement Research Center- Warm Mix Asphalt Study: Laboratory Test Results for AkzoNobel Rediset WMX (2010) carried out study and prepared report on Laboratory Test Results for AkzoNobel Rediset WMX for AkzoNobel Surface Chemistry LLC. his report describes alaboratory testing study that compared the performance of a control mix, produced andcompacted at conventional hot-mix asphalt temperatures, with a mix containing Rediset WMXwarm-mix additive produced and compacted at approximately 35°C (63°F) lower than thecontrol. Key findings from the study include:No problems were noted with producing and compacting the Rediset mix at the lowertemperatures in the laboratory. The air-void contents of individual specimens were similar forboth mixes, indicating that satisfactory laboratory mixed and compacted specimens can beprepared with the warm mix.

3.3.2 MUNSHI RAMIZRAJA, from SVNIT, Surat (2011) which was study on warm mixed design on bitumen concrete using modified binders. In this study he was carried out polymer modified binder (PMB) and crumb rubber modified binder (CRMB) used as a modified binder. The grade of this modified binder is PMB 40 and CRMB 60 used. In this study, he used 2% Rediset WMX with this modified binders. There has been 30-40°C reduction in mixing and compaction temperature of bituminous mixes by adding 2% additive and satisfied all volumetric requirement for both the binders resulting in better performance of bituminous mixes at lower temperature. Increased in Retained stability and Tensile strength ratio of warm mix using both binders become bituminous mixes less susceptible to ingress of water or moisture damage than conventional mixes.

Permanent deformation of warm mix with both the binders under static load is lesser than control mix and having higher rate of recovery at high temperature indicating better resistance to permanent deformation. Warm Bituminous mix with Polymer as well as Crumb rubber modified bitumen having higher fatigue life than conventional mix due to higher initial stiffness which indicates higher resistance to fatigue failure which occurred at lower temperature. Warm Bituminous mix with Polymer modified bitumen subjected to lesser rutting than conventional mix which indicates higher resistance to deformation under wheel path. Also, there has been no significant difference in the rut depth of warm and control mix with Crumb rubber modified bitumen but the rutting is not too high for both mixes indicating suitability of warm mix in bituminous mixes. Based on the Laboratory mechanistic evaluation Polymer as well as Crumb rubber modified bitumen is suitable for warm mix design of bituminous mixes.

4 LABORATORY TESTS

The warm mix design of the bituminous concrete starts with the laboratory tests originated by finding the physical properties of aggregate and bitumen which must satisfied the requirement of MORTH specification and relevant IS codes. Subsequently this determination of physical properties the Marshall Stability test for the determination of OBC as well as optimum temperature andoptimum doses of the Rediset for making the BC is carried out. At last the testing for certain engineering properties of controlled along with warm mix using binder of VG-30 can be carried out for checking the specification.

4.1 Aggregate Testing

Aggregates used in this study of designing the BC is crushed aggregate collected from the quarry. Before using the aggregate in design of bituminous mix it has been tested for their physical properties consist of Hardness, Toughness, Cleanliness, Particle shape, Water absorption, Stripping etc. These test should be performed as per procedure revealed in the applicable IS codes. The tests performed on the aggregate in the laboratory are as follows:

- Grain size analysis IS: 2386 (Part 1)-1963
- Impact value test IS: 2386 (Part 4)-1963
- Shape test IS: 2386 (Part 1)-1963
- Abrasion test IS: 2386 (Part 4)-1963
- Water absorption and Specific Gravity test, IS: 2386 (Part 3)-1963

Property	Test	Specification
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.75 mm sieve
Particle shape	Flakiness and elongation Index (combined)	Max 30%(combined)
Strength	Los Angeles Abrasion Value Aggregate Impact value	Max 30% Max 24%
Polishing	Polished Stone Value	Min 55
Durability	Soundness Sodium Sulphate Magnesium Sulphate	Max 12% Max 18%
Water absorption	Water absorption	Max 2%
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures	Minimum retained coating 95%
Water Sensitivity	Retained Tensile Strength	Min 80%

TABLE 4.1. Required physical properties of aggregate as per MORTH

4.2 Bitumen tests

Bitumen used in the warm as well as control design of BC is VG-30. Before use of bitumen in design

SR NO.	Type of test	No. of Sample
1	Marshall test for OBC	9
2	Marshall test for optimum dose of Rediset-WMX and temperature	27

Table 4.2. Recommended values as per IS-73:2013 mix it has been tested for their physical properties. All these test should be performed asper procedure in relevant IS codes.

Table 4.3. Requirements of bituminous mixes

Sr. no.	Test	Recommendation as per IS-73:2013
1	Penetration Test at 25°C, 0.1 mm, 5 sec	45
2	Softening Point Test at , °C, Min.	47
3	Ductility Test, 25°C Min.	40
4	Viscosity Test, 60°C , Poise, Min.	2400-3600
5	Specific Gravity Test	----

The tests performed on VG-30 are enlisted as follows:

- Penetration test, IS: 1203-1978
- Softening Point test, IS: 1205-1978
- Ductility test, IS: 1208-1978
- Viscosity test, IS: 1206-1978
- Specific Gravity test, IS: 1202-1978

4.3 Marshall Test

This test has been carried out to determine the marshall stability of BC mixes. The properties incorporate with the test are stability, flow value, Bulk specific gravity, Air voids, Voids filled with bitumen and Voids in mineral aggregate. Marshall Requirement of bituminous mixes shown in Table 4.3. The Voids in mineral aggregate must satisfied the requirement as shown in Table 4.4. The marshall test is performed to determine following things:

- Optimum binder content
- Optimum temperature
- Optimum dose of Rediset-WMX

Table 4.4. Requirements of voids in mineral aggregate

Minimum stability (kN at 60°C)	9
Minimum flow (mm)	2
Maximum flow (mm) 4	4
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Percentage air voids	3 - 6
Percentage voids filled with bitumen (VFB)	65 - 75
Loss of stability on immersion in water at 60°C (ASTM D 1075)	Min. 75% retained strength

Table 4.5 Sample preparation schedule

Nominal maximum particle size(MM)	Minimum VMA, Percentage related to design air voids, (%)		
9.50	14.00	15.00	16.00
12.50	13.00	14.00	15.00
19.00	12.00	13.00	14.00
25.00	11.00	12.00	13.00
37.50	10.00	11.00	12.00

4.3.1 Sample preparation

Warm mix design of bituminous mixes required preparation of sample for Marshall Mix design and performance evaluation tests. Table 4.5 shows the sample preparation schedule for the same.

5 ANALYSIS OF TESTS RESULT

5.1 Aggregate tests

Aggregate used in the study has been tested as per the procedure given in relevant IS codes. All these tests should satisfy the requirement given in MORTH section 500 clauses 509 Table 500-17. Test results of aggregate shown in Table 5.1.

Table 5.1.Test results of aggregates

Sr. No.	Test	Result	Recommended Value as per MORTH
1	Grain size analysis	2.11%	Max 5% passing 0.075 mm IS Sieve
2	Impact Value Test	15.17%	24% MAX
3	Shape Test	29.47%	30% MAX
4	Water Absorption Test	1.47 %(19 mm) 1.83 %(6 mm) 1.63 %(Stone Dust)	2% MAX
5	Specific Gravity	2.63(19 mm) 1.75(6 mm) 1.29(Stone Dust)	---

From above table it should clearly be seen that aggregate used in the study satisfied the entire requirement which indicates that the aggregate having all the required physical properties.
Therefore, study has been continued further along with this aggregate.

5.2 Bitumen tests

Bitumen used in the study is VG-30 which has been tested as per procedure given in relevant IS codes. All the tests must satisfy the requirement of physical properties of Binders as per IS: 73-2006. The test results of binder used in the study shown in Table 5.2.

Table 5.2.Test results of bitumen VG-30

Sr. no	Test	VG 30	VG 30+ 1.5 % REDISET-WMX	VG 30+ 2.0 % REDISET-WMX	VG 30+ 2.5 % REDISET-WMX	Recommendation as per IS 73:2013
1	Penetration Test at 25°C, 0.1 mm, 5 sec	65	66	67	69	50-70
2	Softening Point Test at , °C, Min	56	53	51	50	47
3	Ductility Test, 25°C	65+	60+	60+	60+	40
4	Viscosity Test, 60°C , Poise, Min.	2485	2468	2444	2400	2400-3600
5	Specific Gravity Test	1.026	1.01	0.99	0.98	----

Test result of binder clearly shows that they satisfied all the requirement of binder for with andwithout Rediset. The testing results of plain bitumen and bitumen mixed with additive showsignificant values which fulfil the requirements of relevant IS limits, hence the bitumen isappropriate to use for the Marshall mix design of bituminous concrete.

5.3 Gradation of aggregate

Sieve analysis has been carried out for the aggregate to be tested for their physical properties and Grading of aggregate is to be determining for Mix design which must satisfied the MORTH requirement for 19 mm nominal size of aggregate. The final blend of Gradation for aggregate used in the study shown in Table 5.3.

Table 5.3. gradation of aggregate used in study

Sieve size	19mm	6mm	Stone dust	Lime	Blend
19	100	100	100	100	100
13.2	41	100	100	100	73
9.5	1	97	100	100	55
4.75	0	45	91	100	38
2.36	0	4	90	100	28
1.18	0	0	66	100	20
0.600	0	0	59	100	18
0.300	0	0	32	99	12
0.150	0	0	20	91	8
0.075	0	0	2	65	3
	45%	**26%**	**26%**	**3%**	**100%**

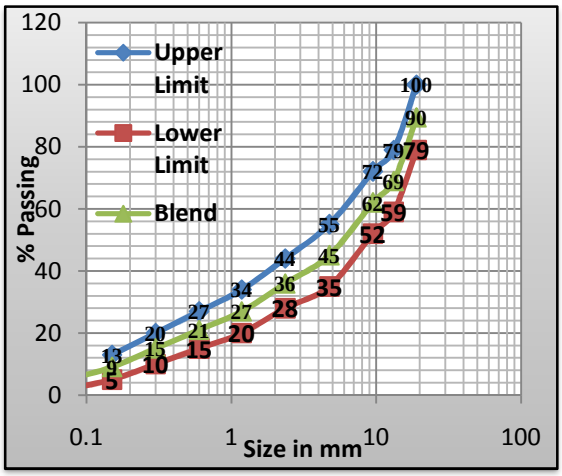

Fig. 4 Grading of aggregates

5.4 Marshall Mix design

Marshall Mix designs for warm mix of BC include the determination of optimum binder content and then optimum temperature as well as optimum Rediset dose for both the binders.

5.4.1 Optimum binder content

Optimum binder content of BC determine by performing Marshall Test on sample prepared at varying binder content. The volumetric properties of BC mix using VG 30 shown in Table 5.4 and it seen that design mix satisfied the all volumetric requirement of BC as per MoRTH section 500 clause 509.

Table 5.4. Volumetric property of mix using VG-30

Based on the volumetric properties of mix graph has been plotted as shown in Fig. 5.1, 5.2,5.3, 5.4 and 5.5. Optimum binder content of mix using VG 30 has been determined by average ofthree values shown in Table 5.5.

SR. NO.	BITUMEN (%)	STBILITY(Kg)	FLOW VALUE(mm)	BULK DENSITY(g/cc)	Vv (%)	VFB (%)	VMA (%)
1	5.0.	1616	3.37	2.35	4.69	69.9	15.27
2	5.5	1754	4.10	2.36	3.36	78.11	15.29
3	6	1733	5.23	2.34	3.21	75.0	16.07

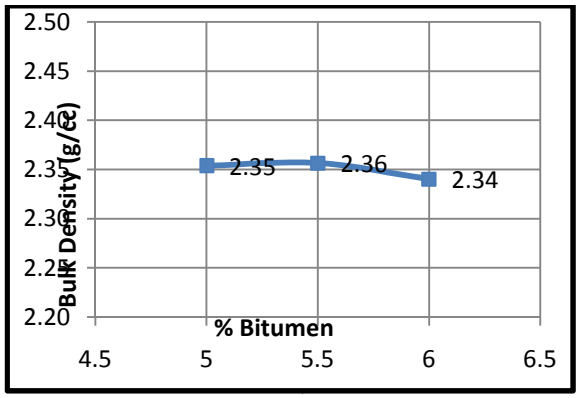

Fig. 5.1 Bulk density (g/cc) Vs. Bitumen (%)

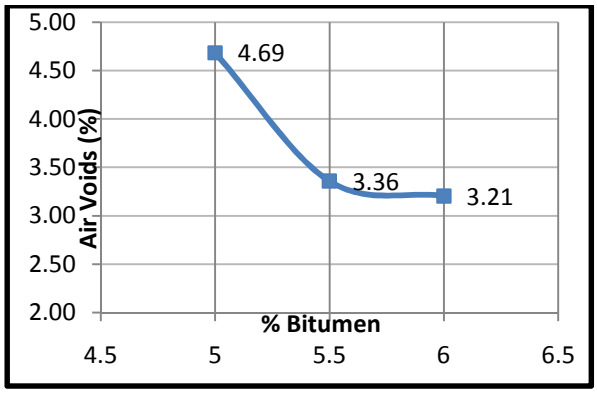

Fig. 5.2 Air voids(%) Vs. Bitumen(%)

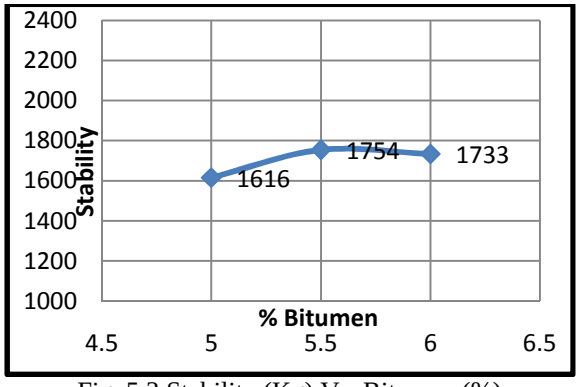

Fig. 5.3 Stability (Kg) Vs. Bitumen (%)

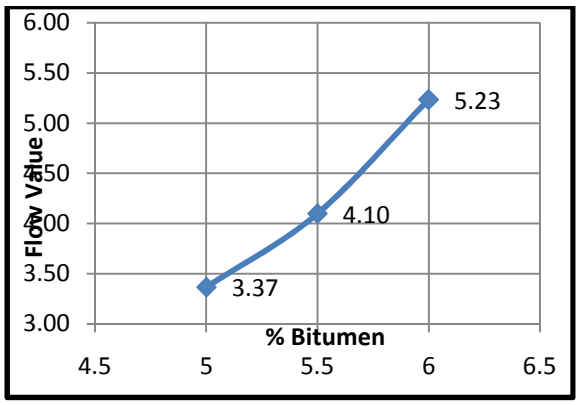

Fig. 5.4 Flow value (mm) Vs. Bitumen (%)

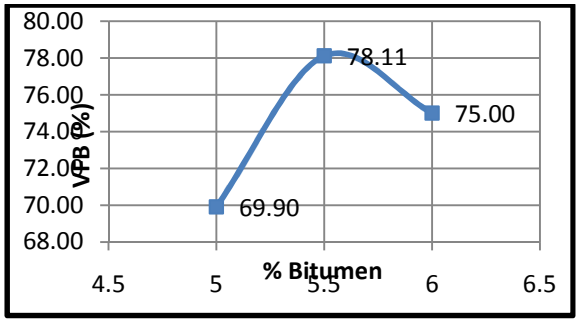

Fig. 5.5 VFB (%) Vs. Bitumen (%)

Table 5.5. OBC of BC mix using VG-30

Sr. No.	Description	Bitumen (%)
1	Binder content corresponding to maximum stability	5.5
2	binder content corresponding to maximum bulk density of mix (Gm.)	5.5
3	binder content corresponding to Air voids (Vv) in the total mix	5.3
	Average	5.43

5.4.2 Optimum temperature & optimum dose of Rediset-WMX

Test results of BC mix using VG-30 by addition of 1.5, 2 and 2.5% Rediset at temperature 110°C, 120°C and 130°C along with their volumetric properties shown in Table 5.6, 5.7, 5.8 respectively. Bituminous mix with 2% Rediset satisfied all the volumetric requirement of BC as per MoRTH section 500 clause 509 and test results of mix with addition of 1.5% and 2.5% for both binders does not satisfied all the volumetric requirements.

Table 5.6. Volumetric properties of mix (VG-30 with 1.5% Rediset-WMX

Table 5.7. Volumetric properties of mix (VG-30 with 2.0% Rediset-WMX

SR. NO.	TEMPERATURE (°C)	STBILITY (Kg)	FLOW VALUE(mm)	BULK DENSITY (g/cc)	Vv (%)	VFB (%)	VMA (%)
1	110	883	3.6	2.3	5.7	67.17	17.36
2	120	1056	4.7	2.34	4.16	73.59	16
3	130	991	4.7	2.32	4.93	70.47	16.68

SR. NO.	TEMPERATURE (°C)	STBILITY (Kg)	FLOW VALUE(mm)	BULK DENSITY (g/cc)	Vv (%)	VFB (%)	VMA (%)
1	110	1124	4.1	2.31	8.5	68.06	17.2
2	120	1656	3.6	2.33	4.45	72.7	16.25
3	130	1487	3.9	2.32	5.21	69.31	16.96

Table 5.8. Volumetric properties of mix (VG-30 with 2.5% Rediset-WMX

SR. NO.	TEMPERATURE (°C)	STBILITY (Kg)	FLOW VALUE(mm)	BULK DENSITY (g/cc)	Vv (%)	VFB (%)	VMA (%)
1	110	1067	3.8	2.3	5.44	63.16	17.09
2	120	1272	4.8	2.33	4.63	71.79	16.42
3	130	1146	3.6	2.32	4.75	71.24	16.52

Based on the volumetric properties of mix using VG-30 graph has been plotted as shown in Fig. 5.7, 5.8 and 5.9. It is clearly seen that optimum temperature for warm mix design at 2%addition of Rediset is 120°C.Addition of 1.5% Rediset cause reduction in stability whichobviously higher than the MoRTH requirement except at 110°C temperature.

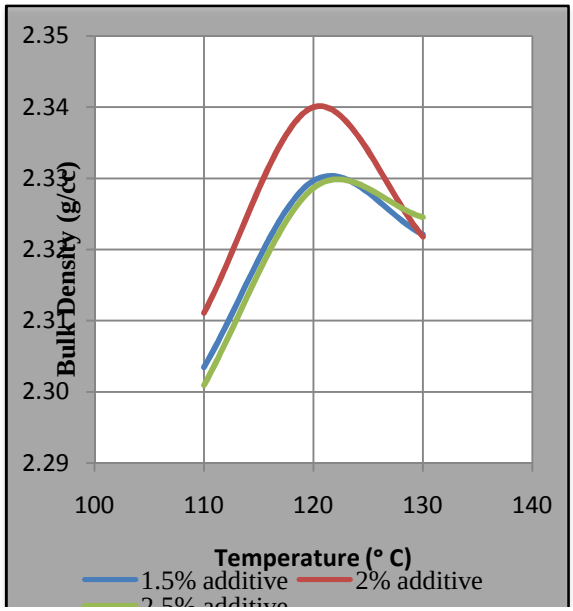

Fig. 5.7 Bulk density (Kg) Vs. Temperature (°C)

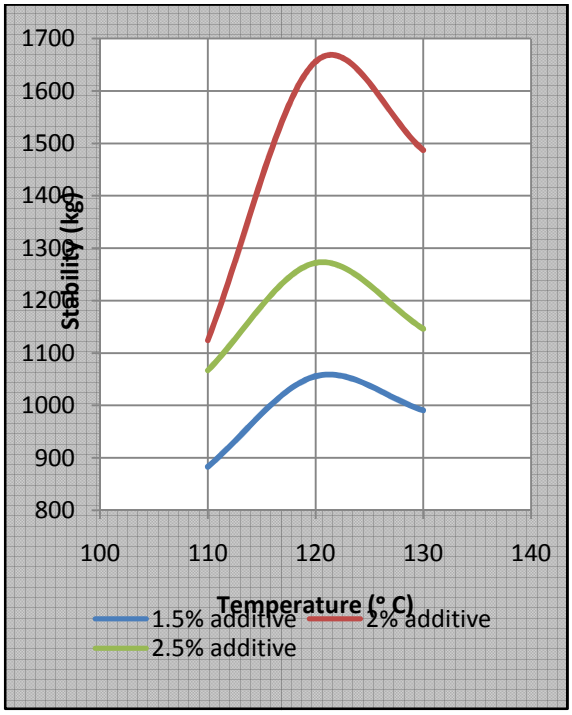

Fig. 5.8 Stability (Kg) Vs. Temperature (°C)

There has been also increase in air voids which clearly mean that there is not proper compaction of mix attemperature 110°C, 120°C and 130°C.

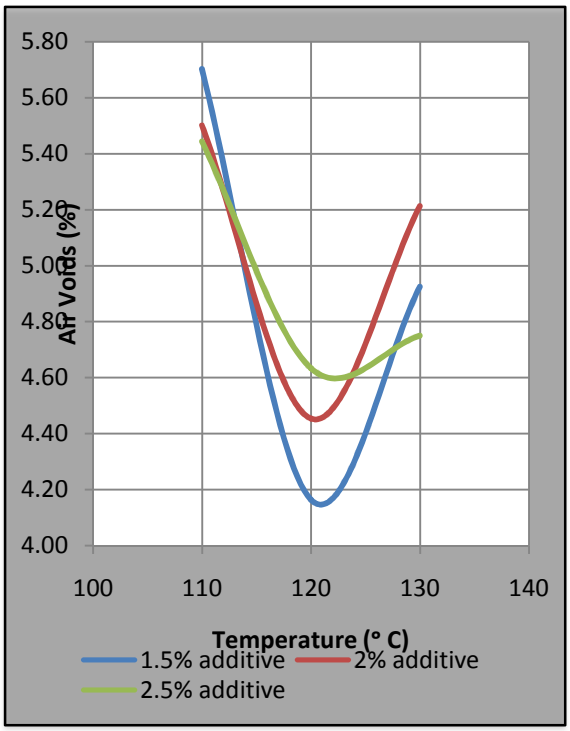

Fig. 5.9 Air voids (%) Vs. Temperature (%)

Similarly, addition of 2.5% Rediset cause reduction in stability which obviously higher than theMoRTH requirement. There has been also increase in air voids which clearly mean that there is not proper compaction of mix at temperature 110°C, 120°C and 130°C.

6 COST ANALYSIS

Warm mix technology of bituminous mixes using binders gives obvious advantage in terms of performance of pavement as per laboratory test analysis. But in spite of this it is necessary to carry out its cost analysis in order to accept this technology in real field. In this study attempt has been made to analyse the cost in terms of fuel saving and addition of 2% Rediset in bituminous mixes, because as per most of research papers there would be 20% saving in fuel by using this technology. Table 6.1 shows the prices for different materials used in the cost analysis:

Table 6. Price of materials for cost analysis

SR NO.	MATERIALS	PRICE
1	Light diesel oil (LDO)	77.92 Rs./ Litre
2	Rediset-WMX	150 Rs./ Kg

6.1 Calculation

Calculation has been carried out to prepare warm as well as control bituminous mix for 1 cum. athot mix plant.

6.1.1 Addition of 2% Rediset WMX by weight of binders

- Density of mix = 2340kg/cum.
- Volume of mix = 1 cum.
- Weight of mix required = 2340 kg
- Optimum binder content = 5.4%
- Bitumen required for prepared bituminous mix @ OBC 5.4% = 126 Kg
- Addition of 2% Rediset WMX by weight of binder per cum. = 2.52 kg
- Additional cost of Rediset WMX to prepared mix @ 150 Rs/Kg per cum. = 378 Rs.

6.1.2 Saving in Fuel consumption

LDO required to prepared control bituminous mix at 160°C temperature per cum. =19.2 litre
LDO required to prepared warm bituminous mix at 120°C temperature per cum. = 14.4 litre

6.1.3 Cost Analysis

Additional cost required to prepared warm bituminous mix at 120°C and adding 2% Rediset WMX temperature per cum = 378 - 374 = 4 Rs.
Based on above cost analysis it has been seen that there is 1.05 % increase in cost of preparingwarm bituminous mixes than control mix at hot mix plant. Obviously there has been 25%reduction in fuel consumption by preparing warm mix at 120°C than control mix at 160°C.Overall, preparation of warm bituminous mix required additional cost of 4 Rs. per cum. which isbeen affordable as their performance is better than control mix may increase the maintenanceperiod of pavement with BC.

7 CONCLUSION AND FURTHER WORK

7.1 Conclusion

Objective: Lowering the bituminous mixing temperature through warm mix asphalt technology.
Fulfilment: The aim of the study including the experiments and the results observed here fulfil the objective of the reduction in mixing temperature of bituminous concrete by adding the warmmix adhesion additive. The temperature reduction (about 40°C**)** is observed through thelaboratory experiments.The results of Marshall Test to determine the optimum temperature represents the most suitabletemperature are 120°C. The tests satisfied the Marshall properties notably at this temperature.The mixing temperature of bituminous mix is lowered from 160°C to 120°C in this study.

Theresults of Marshall Properties for both, bituminous mix without Rediset and with Rediset,fulfilled the requirements, hence this technology is acceptable for bituminous concreteproduction. The results from comparative analysis represent the acceptance of bituminousconcrete production at 120°C temperatureby warm mix asphalt technology.The results from bitumen penetration and viscosity tests in both the cases show that, the bitumenadded with Rediset is less viscous than the plain bitumen. So, it provides better coating to theaggregate surface thoroughly. It also gives better bonding by its viscous property; hence, theadhesion is improved. It reduces the mixing efforts of bituminous mix in comparison to thebituminous mix with plain bitumen. Also, some amount of fumes is observed during mixing ofhot bituminous concrete mix while in warm bituminous mix, there is no such fumes observed. Itproves that this technology of warm mix asphalt production by adding Rediset is way better thanthe conventional production technology for hot mix asphalt in terms of energy savings andambient working exposure. Therefore, it justified the use of this warm mix technology isappropriate.Hence, the conclusion summarize that, the warm mix asphalt technology by Rediset can reducethe energy consumption (fuel) during the bituminous concrete production. Also, theenvironmental degradation by emission of toxic gases and fume generation can be decreased bythis technology. And as the overall results are positive, the advantages of this technology havebeen cemented.

7.2 Further Work

The presented study work can be treated as a base for the further new investigations in similarresearch field. It can be act as a supporting or reference work for other studies in warm mixsector.As per the limitation of this study, the scope is restricted only to the laboratory evaluationof the warm mix asphalt technology by the additives. Hence, the performance evaluation ofthe same type of mix can be carried out in future study.Performance of this design can be evaluated by conducting various tests on control andwarm mix samples; such as fatigue test, indirect tensile test, creep test, rutting test etc. future study. The economic parameters such as cost effectiveness, energy (fuel) savings can beevaluated in further studies.The long term characteristics of this type of warm mix technology can be the future scopeof further study.This study can be utilized for the warm mix technology with other types of additivesunder different warm mix technologies.

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