LABORATORY EVALUATION OF INTEGRABASE MODIFIER FOR USE IN BITUMINOUS BINDER COURSE

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LABORATORY EVALUATION OF INTEGRABASE MODIFIER FOR USE IN BITUMINOUS BINDER COURSE

1.0 INTRODUCTION

The best way to build a durable and long lasting structure such as a road pavement is to start with a solid foundation. The designing of a road with a strong base course can provide the load-bearing capacity needed to handle heavy axle loads. Strong base course also provides the load-spreading ability to relieve stresses and strains coming on to the wearing course placed above it.

This study has been carried out with reference to the letter dated 8/4/2005 from M/s Security Solutions LLC requesting Central Road Research Institute, New Delhi to perform detailed laboratory evaluation of their product called "Integrabase modifier" in bituminous binder course.

2.0 SCOPE AND OBJECTIVE OF THE STUDY

The primary objective of the study undertaken is to evaluate the engineering properties of modified bitumen and mixes by using "Integrabase modifier" as an additive for modification of bitumen, and for its potential application in bituminous binder courses like DBM.

The scope of the study included the following:

(i) Determination of engineering properties of modified bitumen at various dosage of Integrabase modifier.

(ii) Determination of volumetric and mechanical properties of bituminous mixes prepared with modified bitumen at varying dosage of Integrabase modifier.

(iii) Determination of performance characteristics (fatigue, rutting and water susceptibility) of bituminous mixes in the laboratory prepared with modified bitumen.

(iv) Selection of optimal dosage of Integrabase modifier for modification of bitumen.

3.0 LITERATURE REVIEW

General Directorate of National Roads and Highways in Poland had reported that bituminous binder courses modified with IntegraBase showed improved characteristics to permanent deformation and fatigue resistance in comparision to conventional ones. They also showed that compared to the untreated sections, IntegraBase modified binder courses provided an increase in stiffness of over 55% at 20°C. IntegraBase had also shown ability to improve the strength and temperature susceptibility of asphalt binder courses. In both moderate (23°C) and high temperatures (40°C, 60°C), IntegraBase exhibited a lower susceptibility to temperatures than SBS Elastomer 50, SBS Elastomer 80, 35/50 bitumen and 50/70 bitumen. IntegraBase doubled the fatigue life of the binder course as compared to the untreated section at 300µm/m. This modifier (Integrabase modifier) was previously known as Chemcrete. Sebaaly, P.E. carried out the studies to determine the thickness of unmodified hot mix asphalt layer required to obtain equivalent performance to a pavement with chemcrete modified hot mix asphalt (HMA) layer. He reported equivalent layer of unmodified HMA mix would be around 20 inches as compared to 8 inches of modified HMA. Caltrans, the California Transportation Department has introduced the use of Integrabase modifier in its specifications for new roads. This product was used for construction of 389 km highway linking Kabul and Kandahar.

4.0 LABORATORY STUDY

The following laboratory tests were planned and carried out to evaluate the performance of Intregrabase modifier in Dense Bitumnious macadam (DBM) course:

- Characterization of materials
- Preparation of additive
- Design methodology for DBM
- Moisture susceptibility by tensile strength ratio
- Permanent deformation characteristics
    - Hamburg wheel tracking test
    - Dynamic creep test
- Resilient modulus
- Flexural fatigue test

4.1 Materials

4.1.1 Bitumen

The bitumen used in the present study was 60/70 penetration bitumen which was characterized for various physical properties. The test results obtained are shown in Table-1. The values obtained are compared with specified values as per BIS 73-2001 specifications. Results indicate that bitumen used was indeed 60/70 penetration grade. This bitumen was used for development of formulations with integrabase and subsequently for preparation of bituminous mixes.

Table-1: Physical Properties of 60/70 Bitumen

Property	**Results**	**Specified Limits as per BIS : 73,1992**
Penetration at 25ºC/100 gm /5 sec, dmm	65	60-70
Softening Point, ºC	51.7	40-55
Ductility, cm	+75	> 75
Specific Gravity, at 27ºC	1.01	>0.99
Viscosity at 60ºC, Poise 135ºC, cSt	 1032 265	 1000±200 >150
Properties after Thin Film Oven Test, TFOT (Residue)		
Loss on heating, % by mass	0.5	1 (Maximum)
Retained Penetration after TFOT, 25ºC, 100 gm, 5 sec., percent of original	58	55 (Minimum)

4.1.2 Aggregates

Quartzite aggregates obtained from Pali quarry in Haryana were used for this study. Different sizes of aggregates viz. 25mm, 20mm, 10mm, Stone dust and lime were used for preparation of bituminous mixes. The physical properties of aggregates as obtained in the laboratory are shown in Table-2. Results indicate that aggregates meet MoRTH -2001 specification requirements for Dense Bituminous Macadam.

Table-2: Physical Properties of Coarse Aggregates used

Property	**Results**	**Specifications**
Aggregate Impact Value, %	19	Maximum 27
Flakiness and Elongation Indices, %, (Combined)	29	Maximum 30
Water Absorption, %	0.3	Maximum 2
Coating of Bitumen on Aggregates in a Mix, %	> 95	Min. retained coating 95
Specific Gravity	2.665	-

4.1.3 Additive

The Integrabase modifier is a viscous material (liquid) and black in colour. Literature review indicates that it is a multi-metallic catalyst (MMC) in asphalt soluble form.

4.2 Preparation of Mofified Bitumen

The Integrabase modifier in quantities of 1%, 2% and 3% by weight of bitumen was added to 60/70 bitumen. The blends of bitumen and Integrabase were stirred using a high shear blender for 10 minutes at a temperature of 120°C.

4.3 Design Methodology for Dense Bitumnious Macadam (DBM)

For the purpose of this study, the applicability of integrabase modifier was studied only for Dense Bituminous Macadam (DBM) course. The gradation of DBM mix was selected based upon the thickness of the layer. This study was carried out for 50-75 mm thick layer of DBM as per clause of MoRTH specification (Fourth Revision). The individual gradation of selected component aggregates and their proportioning achieved by trial and error method is given in Table-3. The designed gradation alongwith specified limits is shown in Figure -1.

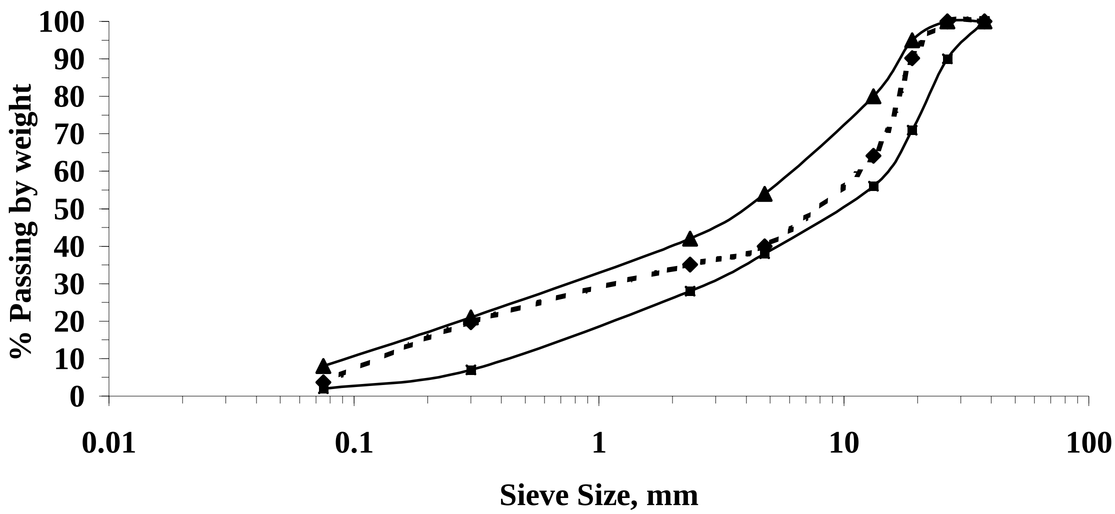

Figure -1: Adopted Gradation and Specification Limits for DBM Mixes

Table-3: Gradation & Proportioning of the Dense Bituminous Macadam Mix (DBM)

Sieve Size (mm)	**% Passing by weight**					**Designed Gradation with Proportioning of 20:19:25:34:3**	**MoRTH Specifications**
	25mm	20mm	10mm	Stone Dust	Lime		
37.5	100	100	100	100	100	100	100
26.5	97.8	100	100	100	100	100	90-100
19	54.6	96.2	100	100	100	90	71-95
13.2	-	17.7	99.1	100	100	64	56-80
4.75	-	-	14.1	100	100	40	38-54
2.36	-	-	-	97.3	100	35	28-42
0.300	-	-	-	52.1	100	20	7-21
0.075	-	-	-	5.0	98.2	4	2-8

4.3.1 Determination of optimum binder content with 60/70 bitumen

Marshall method of the mix design as per ASTM D1559, was used for determination of the optimum binder content. To determine the optimum binder content (OBC), Marshall samples were cast at varying percentage of 60/70 binder. Volumetric and mechanical parameters obtained for DBM with 60/70 bitumen such as Bulk density, Marshall stability, Flow, and other volumetric properties were then obtained which are given in Table-4. The test values obtained are plotted graphically and shown in Figure-2. Using the above parameters, optimum binder content was found to be 5.2 percent by wt. of aggregates. The % optimum binder content was used for evaluating the effect of different percentage of Integrabase modifier on the strength of performance characteristics of mixes.

Table-4: Volumetric and Mechanical Parameters obtained for DBM with 60/70 Bitumen

Binder Content, % by wt. of Aggregate	Bulk Density, gm/cc	Stability, kg	Flow, mm	Air Voids, %	Voids Filled with Bitumen, %
4.0	2.351	906	2.1	6.5	58
4.5	2.368	1099	2.6	5.1	66.5
5.0	2.373	1154	3.2	4.3	72.5
5.5	2.370	941	4.4	3.7	76.5

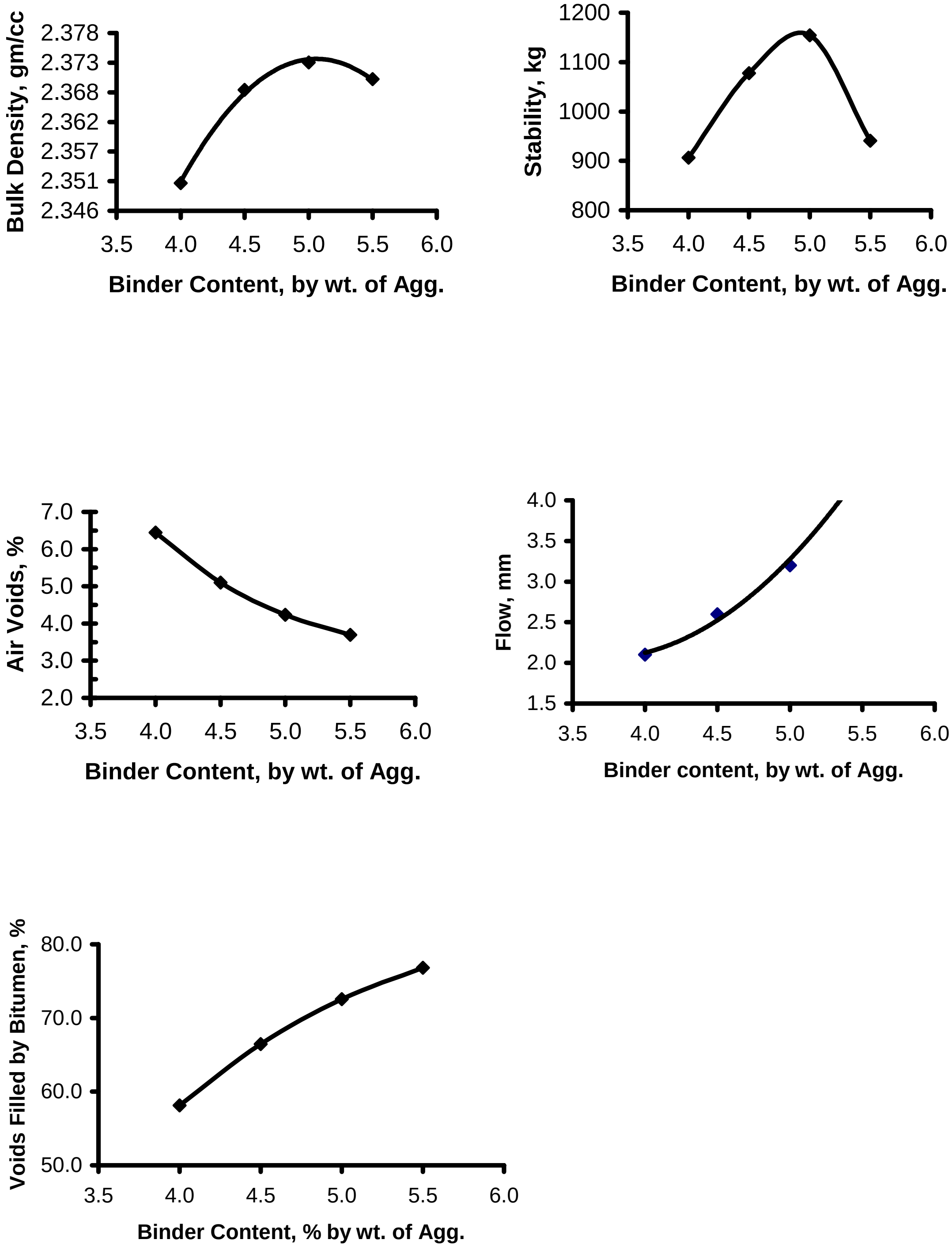

Figure-2: Marshall Parameters obtained for DBM with 60/70 Bitumen

The values obtained at the optimum binder content are indicated in Table -5. as can be seen they do are meet MoRTH specifications for DBM mix.

Table-5: Marshall Parameters Obtained at Optimum Binder Content with 60/70 Bitumen

Parameters	Values obtained at OBC	Specified Values
Stability, kg	1090	> 900
Flow, mm	3.6	2 – 4
Air Voids, %	4.0	3 - 6
Voids Filled with Bitumen, %	73.4	65 - 75

4.4 Moisture Susceptibility

It is a well known that presence of moisture in a bituminous mix is a critical factor, which leads to premature failure of the flexible pavement. The loss of adhesion of aggregates with bitumen was studied by utilising Retained Stability test and Tensile Strength Ratio test to examine the effect of modifier on resistance to moisture damage.

4.4.1 Retained Stability Test

This test measures the stripping resistance of a bituminous mixture. The test is specified in IRC: SP 53-2002 on modified binders and is conducted as per ASTM D 1075-1979 specifications. The standard Marshall specimens of 100 mm diameter and 63.5 mm height were prepared. The specimens were kept in water bath maintained at 60°C for 24 hours, and thereafter tested for stability value. The results are reported as the percentage of Marshall stability determined in normal condition of the test.

4.4.2 Tensile Strength Ratio Test

The tensile strength ratio of asphalt mixes is an indicator of their resistance to moisture susceptibility. The test was carried out according to AASHTO T283 specifications by loading a Marshall specimen with compressive load acting parallel to and along the vertical diametric-loading plane. The test was conducted at 25°C temperature and the load at which the specimen fails is taken as the dry tensile strength of the asphalt mix. The specimens were then placed in a water bath maintained at 60°C for 24 hours and then immediately placed in an environmental chamber maintained at 25°C for two hours. These conditioned specimens were then tested for their tensile strength.

The ratio of the tensile strength of the water-conditioned specimens to that of dry specimens is the tensile strength ratio.

4.5 Permanent Deformation Characteristic

The rutting potential of conventional and modified mixtures was evaluated by Hamburg wheel tracking Test and dynamic creep test.

4.5.1 Hamburg Wheel Tracking Test

The wheel tracking test consists of a loaded wheel assembly and a confined mould in which a 300×150×50mm specimen of asphalt mix is rigidly restrained on its four sides. A motor and a reciprocating device provides the forward and backward motion to the wheel at the rate of 24 passes/minute along the length of the slab. The temperature during the test is maintained by a water bath over and around the mould. The steel wheel with a solid rubber tyre bears a total load of 31 kg with a mean normal pressure of 5.6 kg/cm^2. The test was conducted at 40°C and the specimens were subjected to 10000 cycles. Two specimens were tested for each mix and average data on rut depth and creep slope were found out. The rut depth was recorded at mid point of the specimen length.

4.5.2 Dynamic Creep Test

The dynamic creep test was conducted on Marshall specimen under unconfined conditions (Photo 1) according to British Standards. The test was conducted at 40°C temperature and specimens were conditioned in an environmental chamber for 2 hours prior to their testing. During testing also, the specimen was initially conditioned for 10 minutes with 100 kPa static load to compensate for any sample variation. Thereafter, it was subjected to repeated axial loading. The loading parameters consisted of a haversine wave shape with 100 kPa peak stress and 1 Hz frequency. The load was applied for 0.1 s followed by a rest period of 0.9 s. A maximum of 3600 load cycles were applied and accumulated strain and creep modulus were evaluated.

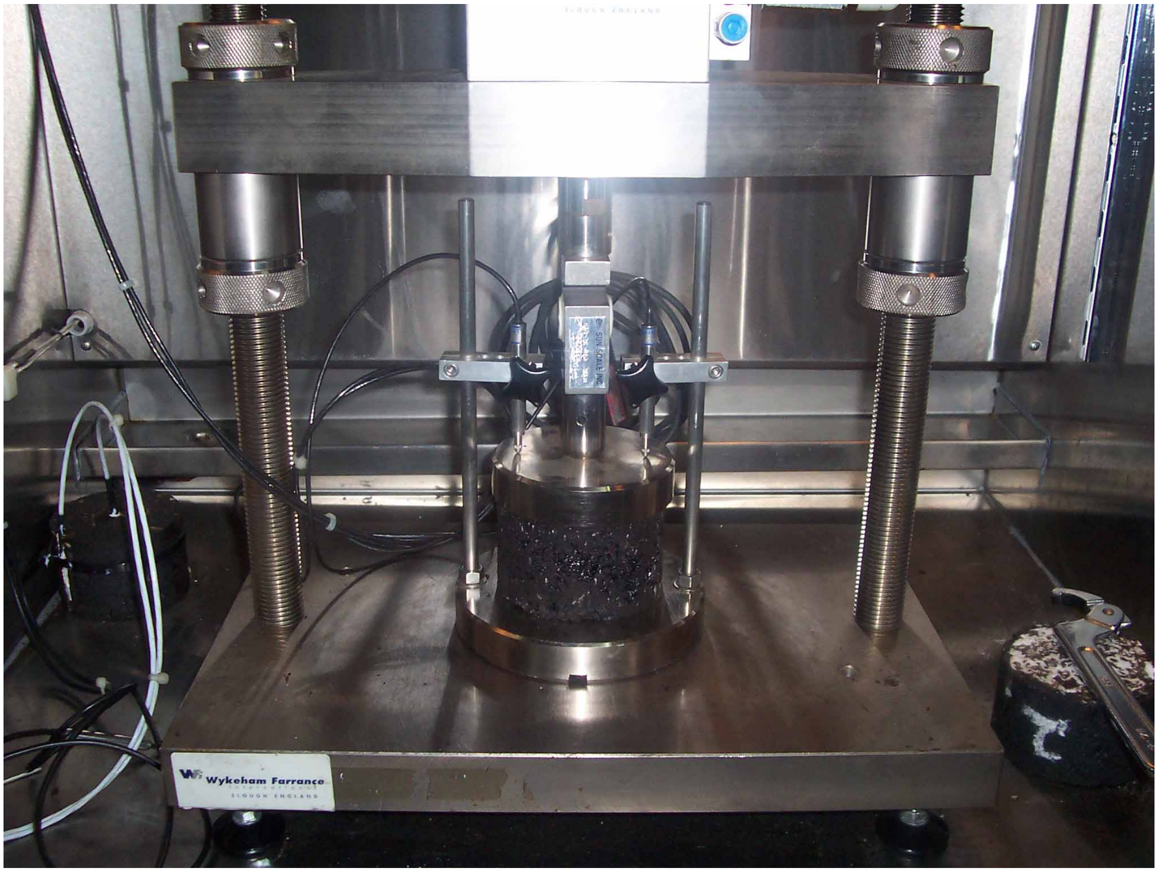

Photo-1 : Dynamic Creep Test in Progress

4.6 Resilient Modulus

The test was conducted on cylindrical specimen in an environmental chamber at 25°C temperature, as per ASTM: D 4123. A haversine loading pulse with a frequency of 1 Hz was used. The loading period of the pulse was 0.1 second followed by a rest period of 0.9 s. The specimens were pre-conditioned for about 2 hours at the test temperatures. The horizontal diametral deformation of the specimen under load pulse and its subsequent recovery was measured by two linear variable transducers placed at opposite horizontal diametral ends.

4.7 Flexural Fatigue Test

The beam fatigue tests were conducted under controlled strain mode in beam fatigue system complying with SHRP M009. Beams of 64 mm wide, 40 mm high and 400 mm long were prepared by static compaction with a compaction level of 94 to 96 percent. The sinusoidal wave shape loading of 0.1 s magnitude with no rest period was applied at the frequency of 10 Hz. Failure of the specimen was defined as the point at which repeated loading had reduced its stiffness to 50 % of initial value. Tests were carried out at strain levels of 300 and 700 microns. Poisson's ratio at 25°C was assumed to be 0.35 for all the mixes.

5.0 ANALYSIS AND DISCUSSION OF TEST RESULTS

The results obtained through various tests, as mentioned in section-3 above, are discussed and presented in this section of the report.

5.1 Effect of Integrabase Modifier on Mechanical Properties of DBM Mixes

As stated earlier, the integrabase modifier was varied from 1% to 3% by weight of bitumen to study its effect on mechanical properties of DBM mixes such as bulk density, stability, flow, indirect tensile strength and tensile strength ratio. The mechanical properties and water susceptibility of DBM mixes at varying percentages of modifier are shown in Table-6.

Table-6: Mechanical Properties and Water Susceptibility of DBM mixes at varying Modifier Percentages

Property	Percentage of Modifier			
	0	1	2	3
Bulk Density, gm/cc	2.373	2.379	2.384	2.381
Stability, kg	1270	1383	1686	1755
Flow, mm	3.6	3.2	3.1	3.1
Indirect Tensile Strength (dry),kg/cm^2	13.0	13.61	14.62	14.85
Tensile Strength Ratio	91.13	95.44	95.73	95.80

Figure-3 presents increase in bulk density and stability with increase in percentage of modifier, it can be seen that the bulk density increases with increase in percentage of modifier. The bulk density increased slight up to 2 % modifier and then decreased slightly after 2% modifier. As regards stability, the value increased with addition of modifier and all values obtained are more than the specified limit of 1200 kg. The percentage increase in bulk density was 0.25, 0.46 and 0.34 with the addition of 1, 2 and 3% of modifier. There was significant increase in stability values with the addition of modifier. The percentage increase in stability value was not significant at 3% modifier compared to 2% modifier. The flow value of DBM mix reduces after adding modifier. The reduction in flow value with increase in modifier content increases its resistance to plastic flow.

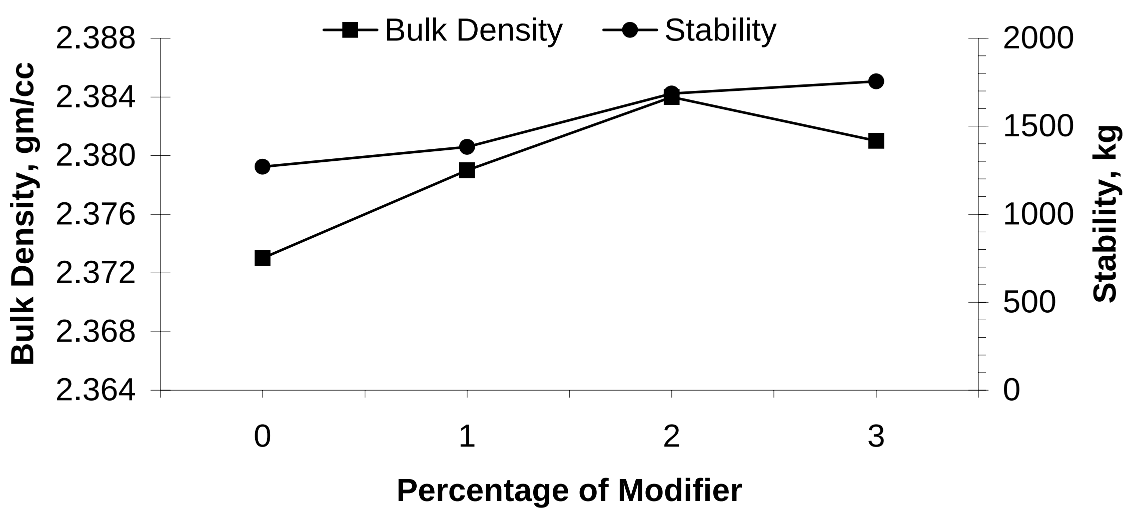

Figure-3: Effect of Modifier on Bulk Density and Stability of DBM Mixes

The indirect tensile strength (ITS) of mix increases with the addition of modifier. The percentage increase in ITS was 1.05, 1.12 and 1.14 with the addition of 1, 2 and 3% of modifier. Figure-4 presents the effect of modifier on indirect tensile strength and tensile strength ratio. It can be seen from Fig-4 that the percentage increase in ITS at 3 % modifier was not significant as compared to 2% modifier. There was improvement in the tensile strength ratio (TSR) of the modified mix with increase in modifier content. It indicates that the modifier improves the adhesion property of bitumen to the aggregates. This will exhibit superior water resistance property of the mix.

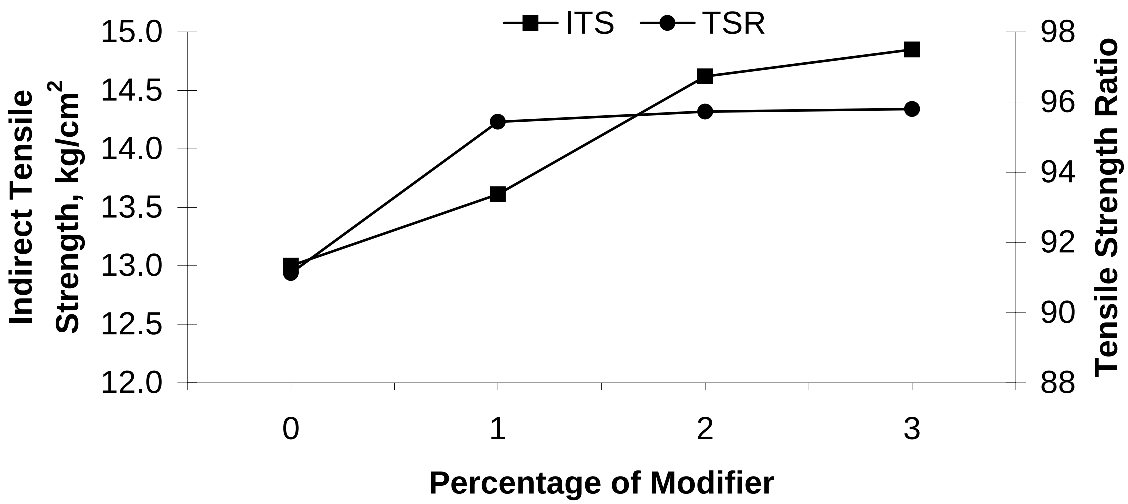

Figure -4: Effect of Modifier on Indirect Tensile Strength and Tensile Strength Ratio

The optimum percentage of modifier based on results of Marshall stability and ITS was found to be 2% by weight of bitumen. This percentage of modifier was used further for detailed evaluation.

5.2 Physical Properties of Modified Bitumen

The physical properties of modified bitumen at optimum modifier content as obtained for mix with 60/70 binder (2% by weight of 60/70 bitumen) is given below in Table-7.

Table-7: Physical Properties of 60/70 Bitumen with 2% Modifier

Property	Results
Penetration at 25ºC/100 gm /5 sec, dmm	66
Softening Point, ºC	51.4
Ductility, cm	+75
Elastic Recovery, 15ºC	20
Specific Gravity, at 27ºC	1.02
Properties after Thin Film Oven Test, TFOT (Residue)	
Loss on heating, % by mass	0.3
Retained Penetration after TFOT, 25ºC, 100 gm, 5 sec., percent of original	62

5.3 Effect of Modifier on Resilient Modulus

The resilient modulus of DBM mix obtained with conventional binder and of modified bitumen at 2% modifier at 25°C is given belowin Table-8 .

Table-8: Resilient Modulus of DBM Mix with Conventional and Modified Bitumen

Set of Results	Resilient Modulus, MPa	
	Conventional Binder	Modified Bitumen with 2% Modifier
1	2199	2851
2	2241	2723
3	2273	2656
4	2262	2545
5	2255	2492
Mean	2246	2653

There was significant improvement in resilient modulus of DBM mix with modifier. The percentage increase in resilient modulus of DBM mix with modified bitumen was 10-15% as compared to conventional bitumen. This may be due to series of chemical reactions which ultimately cross link the asphalt molecules and consume the catalyst. The increased resilient modulus of DBM mix prepared with modified binder indicates its better load spreading property as a binder course in comparision to conventional DBM.

5.4 Rutting Characteristics

The rutting characteristics of DBM mixes was evaluated both by Hamburg wheel tracking device and dynamic creep test.

5.4.1 Hamburg wheel tracking test

The relationship between number of cycles and rut depth was obtained for conventional as well as for modified mix, as shown in Figure-5. The rut depth observed after 10,000 cycles was 9.0 mm for conventional DBM mix. The rut depth reduces to 4.4 mm for modified mix after same number of cycles. This shows that Integrabase modifier improves the rut resistance property of the mix. There was a sudden steep change in slope after 9000 cycles in DBM mix with 60/70 binder. This may be attributed to the stripping of the aggregates. No stripping was however, observed after 10,000 cycles for modified mix. This is due to better tensile strength ratio of modified mix as compared to conventional mix because of improved water resistant characteristics of the modified mix.

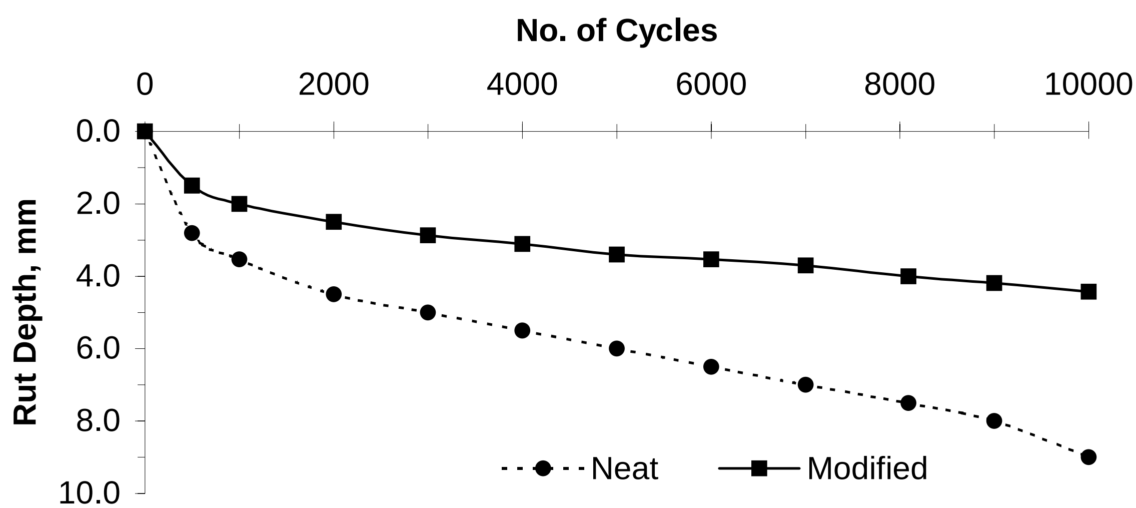

Figure-5: Number of Cycles Versus Rut Depth

5.4.2 Dynamic Creep Test

The values of accumulated strain and creep modulus of DBM mix at end of 3600 cycles, with neat and modified bitumen (at 2% Integrabase modifier) are shown in Table-9.

Table- 9 : Accumulated Strain and Creep Modulus at the end of 3600 Cycles

Type of Mix	Accumulated Strain (micron)	Creep modulus (MPa)
DBM with 60/70 Bitumen	448	223
DBM with 2% Integrabase modifier	297	337

Lower accumulated strain for modified mix at the end of 3600 cycles, indicates high resistance to permanent deformation of modified mix than the unmodified mix. As regards creep modulus, DBM mixes with Integrabase modifier showed value higher than conventional bituminous mix indicating its high resistance to rutting.

5.5 Fatigue Characteristics

There was found to be improvement in the fatigue life DBM mix as prepared with Integrabase modifier as compared to conventional mix. The fatigue life in terms of number of cycles obtained for conventional and modified mix at low and high strain levels are shown in Table-10. The average percentage increase in fatigue life of the modifier mix was 1.2 to 1.3 %. The increase fatigue life implies that the mix prepared with Integrabase modifier is more durable than the conventional mix prepared with 60/70 binder.

Table -10: Fatigue Life (in terms of number of cycles) of DBM Mixes

Type of Mix	**Low Strain (300 micron)**	**High Strain (700 micron)**
DBM with 60/70 bitumen	56243	12566
DBM with Integrabase modifier	69741	14576

6.0 CONCLUSIONS

The laboratory results obtained under this study clearly demonstrate that there is a significant improvement in the properties of modified mix such as water susceptibility as indicated by tensile strength ratio and retained stability, Marshall stability, resistance of DBM mix to permanent deformation as indicated by dynamic creep and Hamburg wheel tracking test, and increase in resilient modulus and fatigue life of the mix as compared to conventional mix prepared with 60/70 binder. The laboratory results also indicate that the Integrabase modifier used for modification of bitumen has shown improvement in the volumetric, mechanical and performance related properties of the binder course (DBM). There are a few engineering properties and/or interrelationship between certain engineering properties which are not yet fully understood and are unexplainable. Further thought and laboratory work may have to be carried out to find out the reasons of such behaviour of modified mixes with Integrabase modifier. The results will need to be validated/verified in the field by constructing experimental test sections which will be required to be monitored with regard to their long term performance under different traffic and environmental conditions.

7.0 RECOMMENDATIONS

The modifier called “Integrabase Modifier” as evaluated in the laboratory under this study for use as modifier to bitumen in application to binder course (DBM) is indeed a potential additive which does improve the properties of the bituminous mix. This modifier will however, need to be applied in full scale field trials under varying operating conditions before it can be recommended for wide scale use in the country. In addition, the economics of the product in comparision to other modifiers will need to be established before it can find large scale applications.