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Studies on Resilient Characteristics of modified binder (CRMB – 55 & 60 grades with grade-I aggregates) on pavement surface course

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Abstract

In order to determine the optimal binder content (OBC) for Grade-I aggregates with nominal sizes of 19 mm, the present paper examines the physical and engineering properties of modified binders, specifically Crumb Rubber Modified Bitumen (CRMB - 55 grade and CRMB - 60 grade) with Cement as a mineral filler of 2%. By using OBC as the bitumen content and changing stress levels from 10% to 40%, the specimens were cast for indirect tensile strength (ITS) with moisture susceptibility.

When compared to CRMB - 50 grade with grade-I aggregates, there is an incremental difference in the engineering properties of specimens evaluated for IT'S and fatigue values made of CRMB - 60 grade with grade-I aggregates.

Keywords: *Stability, Modified binder, In-direct tensile strength, fatigue strength of modified binders.*

INTRODUCTION

Resilient modulus

The resilient modulus, or MR, is a crucial design factor for flexible pavements and typically measures how well a material bounces back from exterior shock or disturbance. The percentage of applied deviator stress to recoverable or resilient strain is essentially how it is defined.

This characteristic of the material actually serves to determine its modulus of elasticity E, whereas the stress-strain curve's slope in the case of slowly moving vehicular wheel loads will be in the linear elastic region and will yield to MR for rapidly applied wheel loads. The structural behavior of the pavement under traffic loading can be determined by understanding the resilient modulus of the pavement substance. However, obtaining MR is a very challenging job that can be determined by testing the bituminous pavement materials in a lab and in the field. The pavement responses caused by temperature were more substantial than the pavement responses caused by traffic. This is a very significant finding that could have significant design repercussions. Deflections are measured under single-axle and tandem-axle loads, with the connection between these two kinds of loading established for a number of types of pavement. However, not always, deflections are directly proportional to load. The design of a resiliometer for measuring the resilient qualities of flexible pavements and the design of a fatigue testing machine for determining the relative flexibility of pavements are two laboratory techniques that are covered in the discussion.

When loading circumstances do not cause a pavement system to completely fail, the resilient modulus is used to describe the pavement materials. The pavements can be designed to bear specific wheel loads throughout their design lives by varying layer thickness with the proper adoption of suitable materials & bituminous material stiffness. With a rise in confining pressure and modest increases in axial stress, the impact of aggregate density, aggregate gradation, and degree of saturation on the resilient modulus is significantly increased. With a drop in confining pressure and an increase in repetitive stresses, Poisson's ratio also rises.

Aggregates

Resilient modulus of asphalt mixes is influenced by the coarse aggregate morphology as measured by angularity and surface texture characteristics. Although the relationship between the coarse aggregate morphology and the resilient modulus was not significantly impacted by changes in aggregate gradation, a reduction in the nominal maximum aggregate size from 19 mm (layer thickness of 50 mm) to 9.5 mm indicated an increasing positive influence of aggregate morphology on the resilient modulus of asphalt mixes. Over a certain size, aggregates respond linearly elastically, resulting in effective resilient properties. Although the average laboratory-determined maximum dry density was a little bit higher than the average field-measured in situ dry density, the laboratory optimum moisture content was similar to the field-measured in situ moisture content.

Modified binders

Materials with beneficial properties like increased resistance to rutting at high temperatures and better resistance to cracking at intermediate and low temperatures are known as modified binders. Modified asphalt binders are usually used in high stress applications and have been used in intersections with stop-and-go traffic, high volume truck routes, and high volume interstates because they are more workable than neat bitumen or binder. Additionally, in harsh climates like desert climes and in places with extremely low temperatures like -34 degrees and -40 degrees, modifiers have been used to slow bitumen aging. When used properly and in the appropriate locations, modified bitumen can be a very economical method to reduce climatic-related pavement distresses and failures. Asphalt mix is a composite substance made up of asphalt binder, stone aggregates, and air voids; it is also referred to as "binder mix" because it is believed that the small stone aggregates, asphalt binder, and air voids will act as one cohesive unit. The aggregates make up about 85% of the mix's total volume, the asphalt binder makes up about 10%, and the remaining 5% is made up of air spaces.

Analysis of elastic modulus characteristics

Resilient modulus is used to describe the pavement materials under different loading circumstances without causing the pavement system to fail. But by varying layer thickness & stiffness, pavement systems can be designed to handle design axle load applications throughout their design life. Pavements are designed to withstand various magnitudes of design axle & their load applications. Asphalts fall under the category of thermoplastic materials because they progressively liquefy at high temperatures and solidify upon cooling, with their behavior being temperature-dependent. Asphalts are quite comparable to many polymers in this regard because the thermoplastic property of the asphalt binder greatly affects the resilient modulus of asphaltic mixtures. Fine-grained or subgrade soil is referred to as stress softening, which means that with increased stress deformation, the stiffness or resilient modulus can be decreased. Granular materials are stress hardening materials with increased applied stress, material exhibits less deformation therefore greater stiffness or resilient modulus.

The amount of air voids reduces as the asphalt content percentage rises. A part of the asphalt is taken by the mineral aggregates during mixing and compacting. The properties at the asphalt-aggregate interface and the asphalt film have a greater impact on the mix's physical reaction than this absorption. The mixture is too stiff and fatigue and/or thermal cracking may be issues if the modulus is above the top limit of this band. It has been determined that resilient modulus at low temperatures is somewhat related to cracking because stiffer mixes (higher MR) at low temperatures tend to crack earlier than more flexible mixtures (lower MR), with also the resilient modulus versus temperature relationship plotting below the lower limit, making the mixture too soft and potentially susceptible to deformation.

LITERATURE REVIEW

D.N. Little and E. Tal

This study has developed a number of methods for measuring asphalt concrete's modulus, giving the Department the capacity to conduct this test in support of both design activities and the validation of non-destructive field testing. A production testing technique was tried, along with procedures focused on mechanistic design methods and techniques that are readily adaptable to new research findings. The creation of two test configurations resulted in the uniaxial compression test with sinusoidal loading being applicable to a variety of materials and stress levels. A method that can be applied to relatively short field cores has been devised. Short (two inches) specimens of dense graded asphalt concrete can be used for the diametric indirect tension test, which can be completed very rapidly. Poisson's ratio and the resilient modulus measurements are both possible in both test setups [(1)].

Amir Modarres and E. Tal

One of the stress-strain measurements used to assess the elastic properties of these mixes is the resilient modulus of bituminous mixes, which is calculated using the ASTM D4123-04 technique. The majority of paving materials, which are generally known to be non-elastic, undergo some permanent deformation after each application of pressure. However, if the load is light in comparison to the material's strength and is applied repeatedly over a significant number of times, the deformation caused by each repetition of the load is nearly entirely recoverable, proportionate to the load, and can be regarded as elastic.

$M_R = [\{P*(\mu + 0.27)\} / \{(t * \delta_h)\}]$

where P is the maximum dynamic load, N; μ is the Poisson’s ratio (assumed 0.35); t the specimen length, mm; δ_h is the total horizontal recoverable deformation, mm. In the M_R test the loading frequency was set as equal to

1 Hz, including 0.1 s loading and 0.9 s recovery time. Both ITS and M_R Tests were performed at 20 C. Furthermore, the stress level in the Mr test was selected as equal to 20% of ITS(2).

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has described the resilient characteristics of the areas where dense and semi-dense asphalt concrete experimental studies have been conducted by removing core samples from the pavements. The proposed technique for determining MR included full characterization of these cores. The wearing and binder courses of these airports' pavements were where the cores were removed. According to ASTM D6927 [14], tests for flow value, Marshall Stability, and density-void analysis were performed on these cores. The findings are shown. When the DAC and SDAC specimens were evaluated at 60°C, the Marshall Stability values were discovered to be 765 kg and 725 kg, respectively. When compared to DAC samples, the flow value of the SDAC specimens was discovered to be slightly greater. The DAC and SDAC specimens' typical bulk densities were discovered to be 2.36 and 2.33 g/cc, respectively. Using the Shell nomograms, the stiffness modulus of the mixture was calculated based on the parameters of the mixture, including density, air voids, aggregate voids filled with bitumen, and bitumen content, as well as the bitumen's characteristics, including penetration, softening point, temperature susceptibility, penetration index, and specific gravity, and the aggregate characteristics, including specific gravity(3).

Kalhan Mitra Etal The binder mix samples are tested in indirect tensile test set-up, where load is given at constant deformation rate. The suggested numerical model of the binder mix is calibrated using the experimental findings of the binder mix. The numerical model of the asphalt mix is created using the characteristics of the aggregates and binder blend as input. At a fixed deformation date, the asphalt blend sample is also put through the indirect tensile test setup. Typically, "5% asphalt mix" refers to an asphalt mix that contains 5% (by weight) asphalt binder as compared to the overall weight of the mix. On an Instron machine, samples of asphalt mix and binder mix are put through an indirect tension test. The measured force-versus-time curves are seen to vary significantly from sample to sample for all binder contents between 5.5% and 6.5% (4).

H. Di Benedetto E. tal These characteristics can only be added if the material's behavior can be regarded as linear. An assessment of the bituminous mixtures' linear viscoelastic domain taking the axis into account The ratio of the base-10 logarithms of the tension amplitude and the number of cycles applied. Conclusions regarding test facilities, specimen preparation, testing, and calibration procedures for stiffness properties testing of bituminous mixtures under cyclic (and not dynamic, as explained further) loading were made from the results of inter-laboratory tests conducted by 15 laboratories in order to increase the repeatability and reproducibility of this type of testing. When sinusoidal cyclic tests are taken into consideration, it can be said that determining the one-dimensional linear viscoelastic properties of bituminous mixtures is feasible with good accuracy for a variety of test methods and sample sizes(5).

David H. Timm provides a description of the material properties and makeup of the individual pavement layers. Triaxial resilient and dynamic modulus tests were carried out in the lab, and they are detailed. Models were created to describe relationships between pertinent pavement parameters and mechanistic material properties after statistical analysis of the data from the laboratory and field. Air voids, binder grade, gradation, and asphalt content were not found to be highly important by the analysis, and the HMA layer showed the strongest effects of cracking on moduli. [(6)].

Ramprasad, D.S., and E. Tal The specifications for bituminous binders in India are based on a variety of empirical tests that hardly have any bearing on the performance characteristics that are stated. The physical and rheological characteristics of bituminous binders, which are frequently used in India, are described in this article in terms of their performance characteristics at high and intermediate field temperatures. The effects of temperature variations, loading rates, and loading amounts are taken into consideration along with other variables that have an impact on how bituminous binders behave. It has been documented how the properties of widely used grades of (60-70) bitumen, both in their unmodified and modified forms, have changed. For the specimens created at the optimum binder content (OBC) for bituminous concrete (BC) grading-2, the Marshall properties and indirect tensile strength ratio are examined. Higher Marshall Stability, reduced flow, a higher ITS ratio, and better rheological rutting properties are all displayed by crumb rubber modified bitumen. Despite having a slightly higher optimal binder concentration than plain bitumen, CRMB exhibits greater strength in terms of improved Marshall stability and reduced flow value. The stability and flow value suggests improved life and service condition, which will lead to reduced life cycle cost. Additionally, it is noted that the indirect tensile strength ratio for CRMB has slightly increased. [(7)].

Moe Aung Lwin E. Tal The recycling rate can be increased while the expense of incineration is reduced by recycling tires as crumb rubber tires and incorporating them into bituminous paving mixtures. Five (5) different Open Graded Wearing (OGW) course road samples were created using a dry mixing method, each weighing 1.15 kg. Each OGW mix comprised between 4% and 6% bitumen Pen 60/70 and 1% fixed crumb rubber tyres, bringing the total amount of crumb rubber tyres in the bituminous samples to between 14% and 20%. The PG 76 bitumen properties were reached by combining bitumen Pen 60/70 with 20% crumb rubber tyre content. OGW made from crumb rubber modified bitumen (CRMB) had superior physical characteristics than bitumen alone. Open Graded Wearing (OGW) mix design was chosen for this study because it has a broader range of applications for different road types and has many advantages. OGW, also known as Green Asphalt Paving Mix, was developed for use in roadway applications as an alternative to W3B's densely graded wearing course. OGW mix has more air voids than W3B mix because it contains a greater percentage of coarse aggregates (retained on sieve size > 1.18 mm) [(8)].

Nabiin Rana Magar, CRMB's rheology is affected by both internal and external variables, including the amount, type, size, source, and composition of the crumb rubber as well as the mixing time, temperature, and process. (dry process or wet process). The purpose of the current research is to analyze the experimental results of bitumen modified with 15% by weight of crumb rubber of various sizes. There will be four distinct sizes of crumb rubber used: coarse (1 mm - 600 m), medium (600 -300 m), fine (300 -150 m), and superfine (150 -75 m). The modified bitumen will be subjected to standard laboratory experiments using different sizes of crumb rubber, and the results will be analyzed. For mix design, the Marshall Stability technique is used. CRMB, or crumb rubber modified bitumen, is produced. Its benefits include decreased sensitivity to daily and seasonal temperature variations, increased resistance to deformation at high pavement temperatures, better age resistance properties, higher fatigue life of mixes, better adhesion between aggregate and binder, prevention of cracking and reflective cracking, and overall improved performance in extreme climatic conditions and under heavy traffic conditions. The sample made using crumb rubber with a size range of 0.3 to 0.15 mm has the greatest stability value (1597.64 kg), the lowest flow value, the highest unit weight, the highest amount of air voids, and the lowest VMA and VFB% values. Therefore, it can be recommended that the best size to be used for crumb rubber modification is (0.3 - 0.15mm) size for commercial production of CRMB [(9)].

Ambika Kuity and E. Tal All of the aggregates, asphalt binder, and filler used in this research were gathered locally. Bituminous Concrete (BC) made to Indian specifications is the asphalt mix used in the current research. During the preparation of the BC samples, mid-point grading is used. This article presents a thorough analysis of the performance of five distinct fillers used in asphalt mix: brick dust, fly ash, lime dust, recycled concrete waste aggregates dust, and conventional stone dust. With regard to the weight of the aggregates excluding the filler, the asphalt content was maintained at 5.66%. Due to the different densities of the fillers, a volume proportioning scheme was used in the current task in place of the stone dust fillers. In other words, all the asphalt mix samples tested for creep, indirect tensile strength, and moisture sensitivity test in the current work are maintained at the same uncompacted bulk volumes of all the fillers (7.6510 _ 10_5_m3 per 1.14 kg of aggregate mix), and the results are compared. Only 4 to 10 percent of the blend is made up of fillers, but they appear to have a big impact on the qualities of the asphalt [(10)].

Georges A.J. Mturi and E. Tal Using a dynamic shear rheometer, rheological research provides a better characterization. (DSR). However, testing CRM bitumen with existing techniques and tools is difficult due to its heterogeneous morphology. To prevent any impact from the rubber granules during the DSR testing of CRM bitumen, the plate gap must be adjusted. This has been accomplished by observing how altering the DSR plate gap setting affects the binder's measured linear viscoelastic properties. In order to characterize the properties of CRM bitumen with aging, an adjusted gap was chosen for rheological observations. It is impossible to separate the binder from surfacing seals or asphalt mix as a unique component due to the heterogeneous nature of CRM bitumen. The rubber crumbs and the solvent soluble portion, which contains the base binder, are recovered separately. Additionally, the CRM bitumen blend's chemical equilibrium is destroyed during the solvent extraction procedure. Due to this, it is impossible to combine the isolated components again to create CRM bitumen that has the same qualities as the in situ binder. Therefore, there is presently no way to extract and test the recovered CRM binder in order to learn more about the in situ binder's characteristics. As a result, there are now covert ways to look into the condition of the in situ binder [(11)].

A**. Bashar Tarawneh,** By performing repeated load triaxial (RTL) laboratory experiments, the MR should be ascertained. However, this test necessitates highly skilled people and pricey lab supplies. Additionally, it is thought to take a fair amount of time. As a result, correlations with various in-situ test results and material index properties are used to determine MR. The precision of the prediction model determines how accurately the resilient modulus is calculated. Additionally, the use of ANN-based models greatly improved Mr. Prediction's accuracy. The ANN improvement was only apparent for models based on backcalculated FWD moduli using various software packages when the model took into account soil physical characteristics. The findings of the regression analyses demonstrated that, in comparison to using the AASHTO or Florida Equations, using a linear elastic software for the back calculation of the FWD modulus produced better predictions of laboratory-measured resilient modulus. [12].

Jorge B. Sousa, Etal The efficacy of asphalt pavements is significantly impacted by permanent deformation (rutting). Rutting shortens the pavement's useful service life and poses a significant risk to other road users by changing how vehicles handle. Due to the fact that the methods currently used for testing and assessing asphalt-aggregate mixes are empirical and do not provide a reliable indication of in-service performance, highway materials engineers have been hindered in their efforts to provide rutting resistant materials. Rutting is primarily brought on by repeated shear deformations under traffic stress, although mixture densification (volume change) has some influence. The size and pressure of tire loads, the number of traffic, the thermal environment, and different mixture properties are some of the variables affecting the quantity of rutting. Aggregate characteristics, especially their rough surface texture, angularity, and dense gradation, are among the important mixture properties that have a significant impact on the mixture's ability to resist permanent deformation. Lower asphalt contents and stiffer binders offer better resistance to permanent deformation. The amount and stiffness of the asphalt or modified asphalt binder are also essential. The significance of replicating field compaction and traffic loading conditions in laboratory-compacted specimens is highlighted by the significant impact of mixture density and aggregate structure. Currently, layer-strain and viscoelastic methods are used to forecast the emergence of permanent deformation in layers bound to asphalt. With more compactive energy, a low air-void content is typically attained in the area. Therefore, they advised using harsh mixtures—those that were relatively difficult to work—and hefty rollers to reduce the tendency for rutting. A better arrangement of the mineral skeleton should come from this combination, increasing internal friction. [13].

Jean-Pascal Bilodeau, et al. The resilient modulus is a crucial component of flexible pavement construction, but because testing for the resilient modulus is difficult and expensive, its value is frequently estimated using preset values or extrapolated from unreliable, indirect tests. An estimation model was developed for typical Canadian granular materials typically used in pavement bases and subbases using a database of reliable resilient modulus laboratory tests performed at the Quebec Ministry of Transportation. This model allows obtaining a more representative stiffness value for this crucial design parameter. The resilient modulus at any saturation level was then determined using two different models, using a two-step method that involves first finding the resilient modulus at the saturated state.[14].

MATERIALS AND METHODOLOGY

Materials

Bituminous modified binder (Crumb Rubber Modified Bitumen – CRMB) has been obtained from Mangalore Refineries & Petro-Chemicals Limited – MRPL of Grade namely CRMB – 55 & 60 grade bitumen.

Aggregates are obtained from Bangalore where in the stone quarry situated in Bidadi for the analysis.

Methodology:

Evaluate the physical &engineering properties of modified binders as per IS standard tests.

Conduction of Marshal Stability test for CRMB 55 & CRMB 60 grade to estimate the Optimum Bitumen Content (OBC) of grade-I aggregates.

Conduction of Indirect tensile strength (ITS) &moisture susceptibility tests of grade –I aggregate specimens.

Evaluation of fatigue test of specimens casted with grade – I aggregates with CRMB – 55 & CRMB – 60 grade as a modified binders.

EVALUATION PHYSICAL PROPERTIES OF CRUMB RUBBER MODIFIED BITUMEN & AGGREGATES

Table – 1: Tests on Aggregates -

Si no	Name of the test / Characteristics	Value obtained	Permissible Limits *	Test Method
1	Aggregate Crushing test	24%	< 30%	IS – 2386-IV
2	Aggregate Impact test	16.9%	< 24%	IS – 2386-IV
3	Specific Gravity	2.56	2.5 to 3.2	IS – 2386-III
4	Water absorption	0.3%	< 2%	IS – 2386-III
5	Aggregate shape test	26%	< 35%	IS – 2386-I
6	Abrasion test	20%	< 30%	IS – 2386-IV

***As per MORTH specifications 5th Revision**

Table – 2: Tests on Modified Bitumen (CRMB – 55 & 60 Grades)

Si no	Name of the test / Characteristics	CRMB – 55 Grade	CRMB – 60 Grade	Permissible Limits – (CRMB 55 Grade)	Permissible Limits – (CRMB 60 Grade)	Test Method
1	Penetration test	52	50	< 60	< 50	IS 1203 - 1978
2	Softening point	58 degrees	60 degrees	55	60	IS 1205 - 1978
3	Specific Gravity	1.08	1.02	> 0.99	> 0.99	IS 1202 - 1978
4	Ductility test	50 cms	60 cms	Min 40 cms	Min 40 cms	IS 1208 - 1978
5	Elastic recovery	50%	60%	> 35%	> 35%	IS 15462 – 2004
6	Loss in mass	1%	0.6%	Max 1%	Max 1%	1206 (part 2) – 9382

EXPERIMENTAL PROCEDURES OF CRUMB RUBBER MODIFIED BITUMEN – 55 & 60 GRADES FOR OPTIMUM BITUMEN CONTENT (OBC) IN THE LABORATORY-MARSHAL MIX DESIGN-

The objective of the mix design is to produce a bituminous mix by proportionating various components so as to have:

Sufficient bitumen to ensure a durable pavement.

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Sufficient strength to resist shear deformation under traffic at higher temperature.

Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic.

Sufficient workability to permit easy placement without segregation.

Sufficient flexibility to avoid premature cracking due to repeated bending by traffic.

Sufficient flexibility at low temperature to prevent shrinkage cracks.

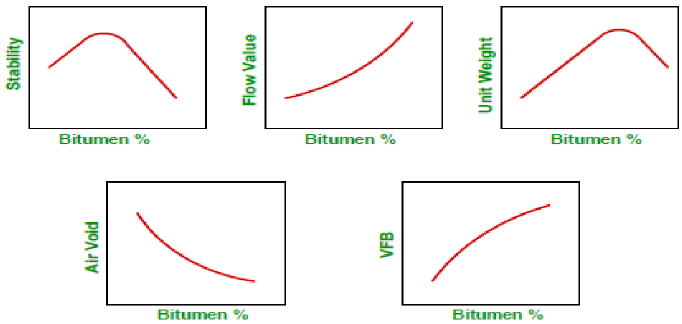
Determination of Optimum Bitumen Content-

Determine the optimum binder content for the mix design by taking average value of the following three bitumen contents found form the graphs obtained in the previous step.

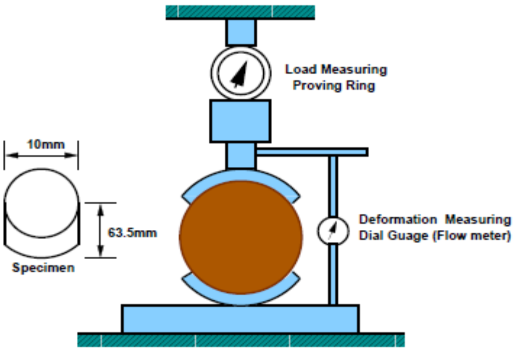
1. Binder content corresponding to maximum stability

2. Binder content corresponding to maximum bulk specific gravity (Gm)

3. Binder content corresponding to the median of designed limits of percent air voids (Vv) in the total mix (i.e.



4%)



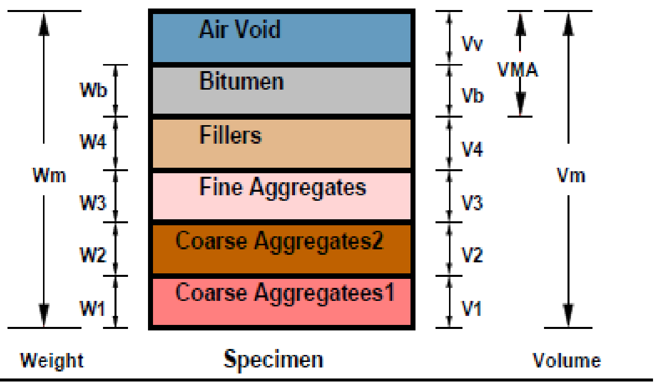


TABLE – 3 SPECIFICATIONS FOR BITUMINOUS CONCRETE AS PER MORTH SPECIFICATIONS 5th REVISION-

Grading	1	2
Nominal aggregate size	19 mm	13.2 mm
Layer thickness	50 mm	30 – 40 mm
IS sieve in mm	Cumulative % by weight of total aggregate passing	
19	90 - 100	100
13.2	59 – 79	90 – 100
9.5	52 – 72	70 – 88
4.75	35 – 55	53 – 71
2.36	28 - 44	42 – 58
1.18	20 – 34	34 – 48
0.6	15 – 27	26 – 38
0.3	10 – 20	18 – 28
0.15	5 – 13	12 – 20
0.075	2 – 8	4- 10
Bitumen content % by mass of total mix	Min 5.4	Min 5.6

TABLE – 4 – GRADATION BLEND OF AGGREGATES

Sieve Size mm	Cumulative Percent by Weight of Total Aggregate Passing				Blend Proportions And Obtained Gradation	Gradation Requirement as per Table 500-18 of MORTH Specifications (Grading – 1)
	19.0 mm Down Size	13.2 mm Down Size	6.0 mm down size	Cement as filler		
26.5	100.00	100.00	100.00	100.00	**100.00**	**100**
19	87.83	100.00	100.00	100.00	**95.98**	**90-100**
13.2	15.00	94.40	100.00	100.00	**71.28**	**59-79**
9.5	0.17	28.40	100.00	100.00	**58.46**	**52-72**
4.75	0.00	0.60	39.00	98.30	**44.06**	**35-55**
2.36	0.00	0.00	14.00	85.60	**34.91**	**28-44**
1.18	0.00	0.00	7.00	69.40	**27.56**	**20-34**
0.6	0.00	0.00	3.70	55.25	**21.62**	**15-27**
0.3	0.00	0.00	2.50	38.40	**15.02**	**10-20**
0.15	0.00	0.00	0.75	26.60	**10.24**	**5-13**
0.075	0.00	0.00	0.00	13.20	**5.02**	**2-8**

TABLE – 5- PROPORTION OF AGGREGATES FOR THE MIX

Sl. No.	Materials	Proportion	Remark
1	19.0 mm down size aggregates, %	**46**	% by Weight of aggregate Mix
2	13.2mm down size aggregates, %	**12**	
3	6 mm aggregate, %	**39**	
4	Cement as filler, %	**3**	

TABLE – 6 MIX DESIGN SPECIFICATIONS FOR BITUMINOUS CONCRETE BY MORTH 5th REVISION-

Minimum Marshal stability value in Kgs	1200
Marshal flow value in mm	2.5 to 4
Air voids in total mix, V_v in %	3 to 5
Voids filled with bitumen VFB in %	65 to 75

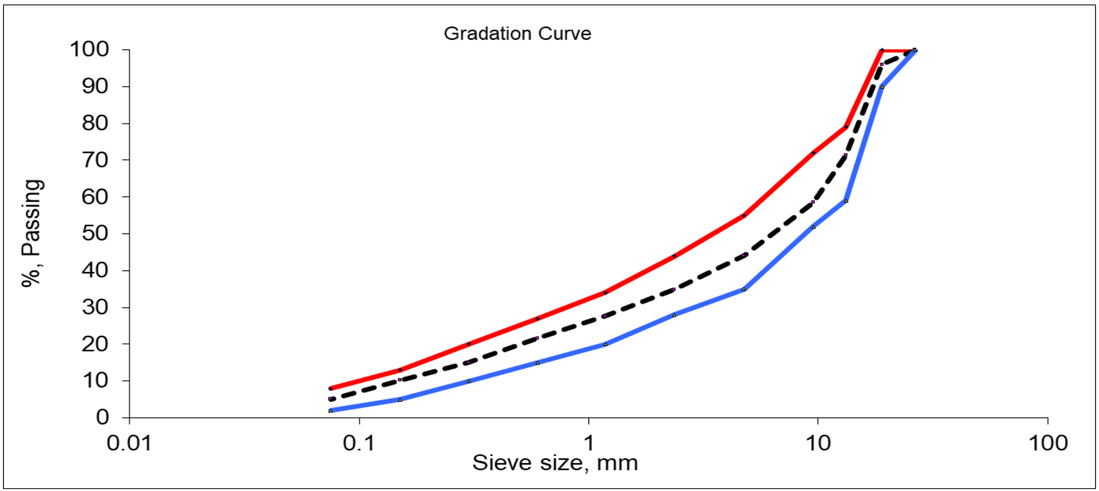


FIG 1 – OBTAINED GRADATION CURVE

TABLE – 7 GRADING REQUIREMENT OF MINERAL FILLER

Is sieve (mm)	Cumulative % passing by weight of total aggregate	% Passing of filler material
0.6	100	100
0.3	95-100	100
0.075	85-100	99.0

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Marshal stability Formulaes for estimation of OBC-

Theoretical specific gravity for 4 % bitumen -

$G_t = [\{(W_1+W_2+W_3+W_b) / \{(W_1/G_1) +(W_2/G_2) +(W_3/G_3) +(W_b/G_b)\}]$

Bulk specific gravity, $G_m = W_m / (W_m - W_w)$

Air voids percent $V_v = \{(G_t - G_m) / G_t\} * 100$

Percent volume of bitumen $V_b = [\{(W_b / G_b)\} / \{(W_1 +W_2 +W_3 +W_b) / G_m\}]$

Voids in mineral aggregate VMA

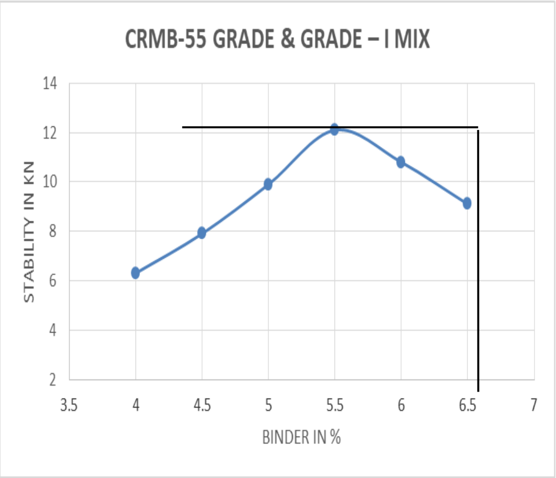
$VMA = V_v + V_b$

Voids filled with bitumen VFB

$VFB = (V_b * 100) / VMA$

TABLE – 8 STABILITY & FLOW ANALYSIS OF CRMB - 55 GRADE & GRADE – 1 MIX –

Bitumen content in %	Stability in KN	Flow in mm units	V_V in %	VFB in %	VMA in %	G_m
4	6.3	2.3	5.34	60	12.4	2.353
4.5	7.9	2.7	4.86	70.0	13.3	2.362
5	9.9	2.9	4.23	71.5	14.4	2.381
5.5	12.1	3.2	3.86	72.9	15.9	2.413
6	10.8	3.5	3.56	73.7	16.3	2.395
6.5	9.1	3.7	3.28	74.1	17.1	2.376



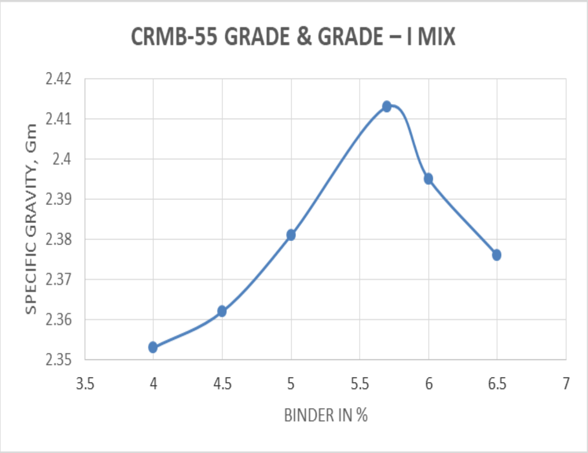


FIG – 2 CRMB 55 GRADE Vs STABILITY ANALYSIS FIG – 3 CRMB 55 GRADE Vs SPECIFIC GRAVITY G_M

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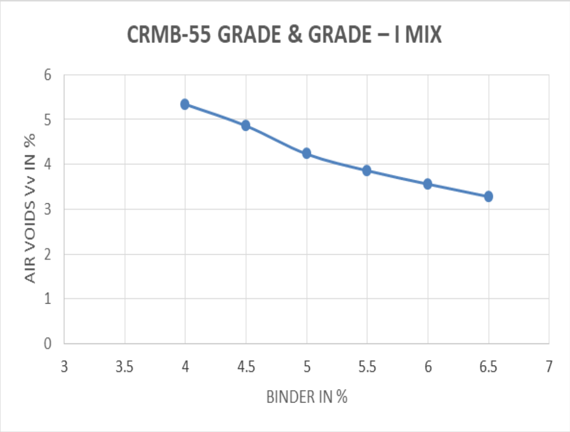

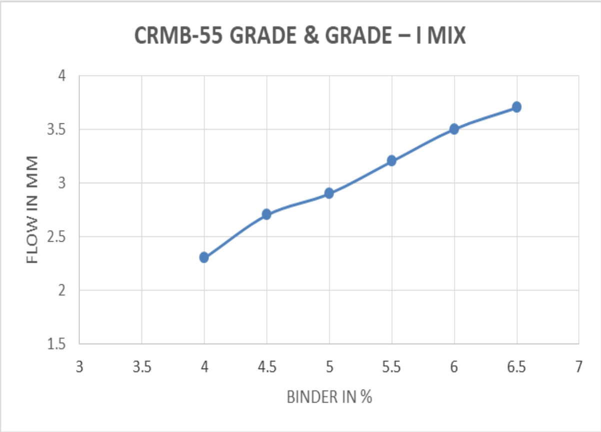

FIG – 4 CRMB 55 GRADE Vs PERCENTAGE VALUE OF VOIDS

FIG – 5 CRMB 55 GRADE Vs FLOW

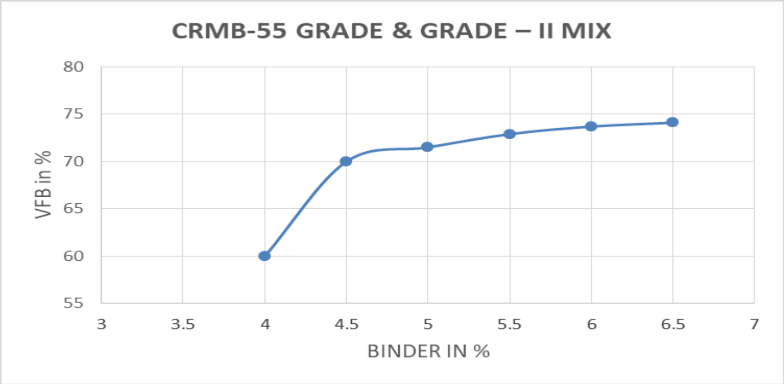

FIG – 6 CRMB 55 GRADE Vs VOIDS FILLED BY BITUMEN

Conclusion:

It has been found from the analysis that the Optimum Binder Content for Crumb Rubber Modified Bitumen – 55 Grade & Grade-I (19 mm nominal size) aggregates is 5.5% with the flow value of 3.2 mm where in the minimum Binder content specified by MORTH specifications 5th Revision is 5.4%.

Optimum binder content: The optimum bitumen content is computed as the average bitumen content selected corresponding to:

Maximum Marshall Stability.

Maximum Bulk Density.

4% Air voids.

The Optimum bitumen content = (5.50+5.56+5.50)/3

= **5.53 %.** (By weight of aggregates)

= **5.50%.** (By weight of total Mix)

Bulk Density: *Bulk density* of the mix determined for the above aggregate proportion and at optimum binder content is found to be **2.413 gm/cc.**

TABLE – 9 TABULATION OF VALUES -

Sl. No.	Test Property	*Test results obtained by Marshall method	Requirements of Bituminous Concrete mix as per MoRTH –V revision & IRC-SP-53-2010
1	Optimum binder content, % (by weight of total mix).	**5.50**	Min 5.40
2	Bulk density G_m, gm/cc.	**2.413**	2.34 to 2.42 g/cc
3	Voids in Compacted Mix, %.	**3.86**	3.0 – 5.0
4	Marshall Stability (75 blows) (At 60°C), kgs.	**1210**	Min 1200
5	Marshall Flow at 60°C, mm.	**3.20**	2.5 - 4.0
6	Percentage void filled with bitumen, %	**72.90**	65 - 75
7	Voids in Mineral Aggregates, %.	**15.90**	Min 13.00
8	Marshal Quotient, stability/ flow, kg/mm	**378**	250-500

TABLE – 10 STABILITY & FLOW ANALYSIS OF CRMB 60 GRADE & GRADE – 1 MIX -

Bitumen content in %	Stability in KN	Flow in mm units	V_V in %	VFB in %	VMA in %	G_m
4	6.6	2.58	3.9	58	14.3	2.359
4.5	7.8	2.78	3.53	64.5	15.7	2.368
5	10.9	2.93	3.3	65.9	16.1	2.392
5.4	13.6	3.12	3.13	68.5	16.5	2.410
6.0	11.4	3.34	2.93	71.3	17.1	2.397
6.5	9.1	3.45	2.67	74.1	17.5	2.376

Conclusion:

It has been found from the analysis that the Optimum Binder Content for Crumb Rubber Modified Bitumen – 60 Grade & Grade-I (19 mm nominal size) aggregates is 5.4% with the flow value of 3.12 mm where in the minimum Binder content specified by MORTH specifications 5th Revision is 5.4%.

Optimum binder content: The optimum bitumen content is computed as the average bitumen content selected corresponding to:

Maximum Marshall Stability.

Maximum Bulk Density.

4% Air voids.

The Optimum bitumen content = (5.4+5.5+4.0)/3

= **5.0 %.** (By weight of aggregates)

= **5.40%.** (By weight of total Mix)

Bulk Density: *Bulk density* of the mix determined for the above aggregate proportion and at optimum binder content is found to be **2.410 gm/cc.**

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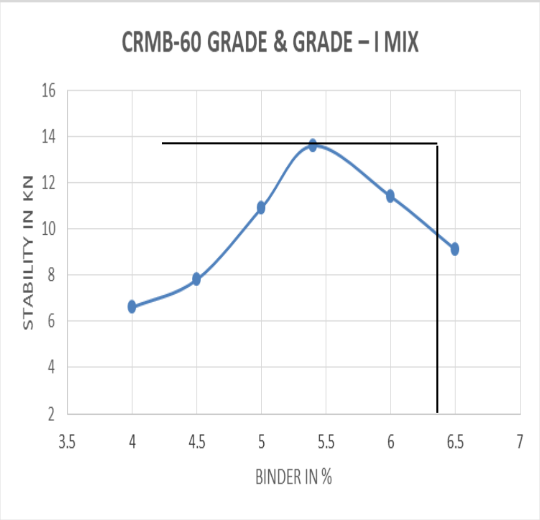

FIG – 7 CRMB 60 GRADE Vs STABILITY ANALYSIS

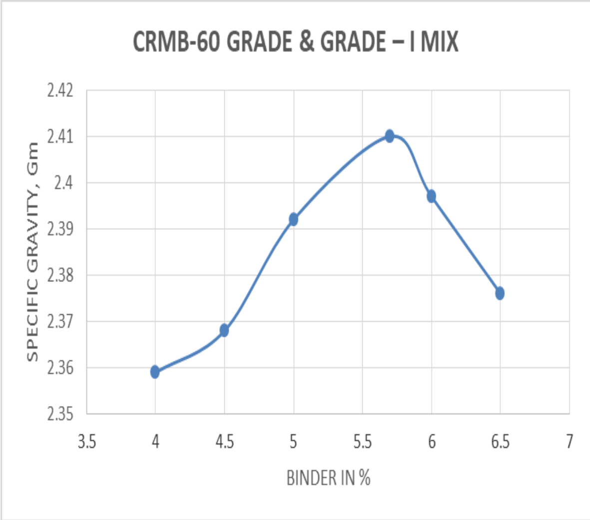

FIG – 8 CRMB 60 GRADE Vs SPECIFIC GRAVITY G_M

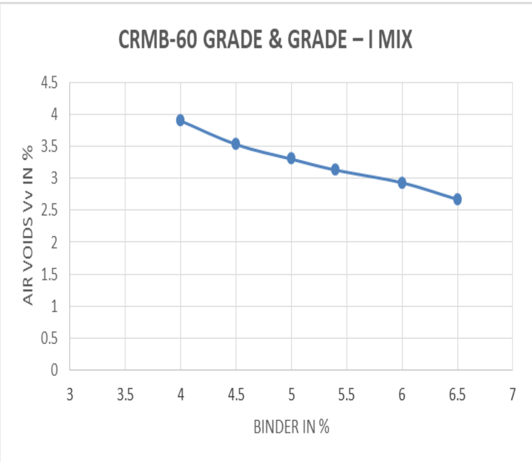

FIG – 9 CRMB 60 GRADE Vs PERCENTAGE VALUE OF VOIDS

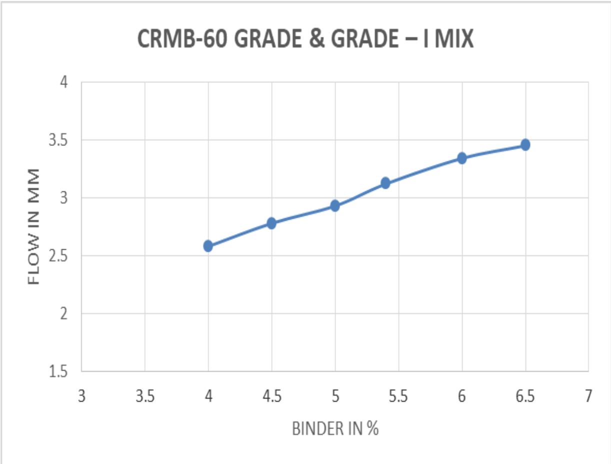

FIG – 10 CRMB 60 GRADE Vs FLOW

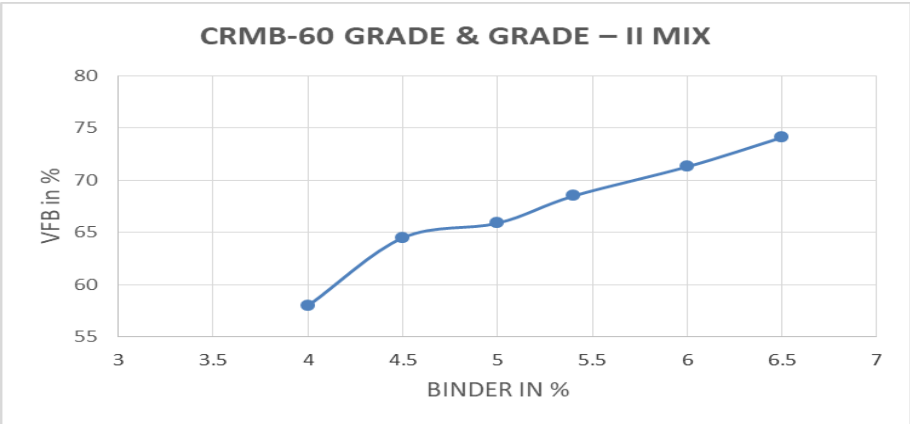

FIG – 11 CRMB 60 GRADE Vs VOIDS FILLED BY BITUMEN

TABLE – 11-TABULATION OF VALUES -

Sl. No.	Test Property	*Test results obtained by Marshall method	Requirements of Bituminous Concrete mix as per MoRTH – V revision & IRC-SP-53-2010
1	Optimum binder content, % (by weight of total mix).	**5.40**	Min 5.40
2	Bulk density G_m, gm/cc.	**2.410**	2.34 to 2.42 g/cc
3	Voids in Compacted Mix, %.	**3.13**	3.0 – 5.0
4	Marshall Stability (75 blows) (At 60°C), kgs.	**1360**	Min 1200
5	Marshall Flow at 60°C, mm.	**3.12**	2.5 - 4.0
6	Percentage void filled with bitumen, %	**68.5**	65 – 75
7	Voids in Mineral Aggregates, %.	**16.50**	Min 13.00
8	Marshal Quotient, stability/ flow, kg/mm	**436**	250-500

Indirect Tensile Strength (ITS)

Test Procedure for Indirect Tensile Strength test

The indirect tensile strength test is carried out as per ASTM D-4123-1995 to study the behaviour of paving mixes.

Load at failure is recorded and the indirect tensile strength is computed using the relation given below:

$\sigma_x = \{(2*P) / (\pi t D)\}$, **MPA**

Where: σ_x= Horizontal tensile stress/tensile strength, in MPa

P= Failure load, N

D= Diameter of the specimen, mm

t = Height of the specimen, mm

Table 12 Results of ITS test of various Bitumen content on CRMB-55 Grade With Grade – I aggregates –

Unsoaked condition	
Bitumen content in %	**ITS, N/mm²**
4.0	1.51
4.5	1.58
5.0	1.63
5.5 (OBC)	1.65
6.0	1.53

Table 13 Results of ITS test of various bitumen content on CRMB- 60 Grade with Grade – I aggregates –

Unsoaked condition	
Bitumen content in %	**ITS, N/mm²**
4.0	1.68
4.5	1.73
5.0	1.76
5.4 (OBC)	1.79
6.0	1.67

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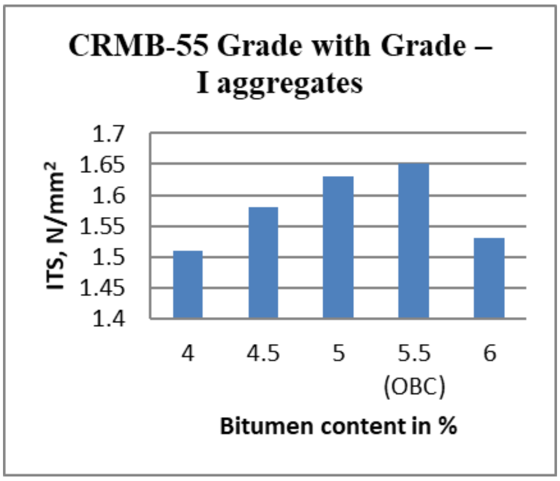

Fig 12 Variation in ITS value with different bitumen content of CRMB-55 & Grade-I aggregates at 25°C

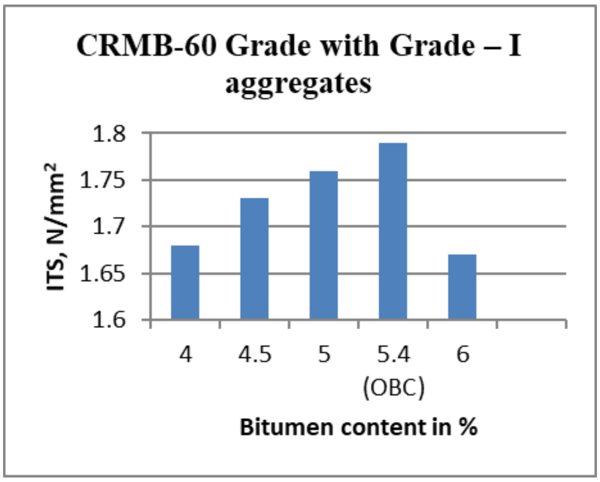

Fig 13 Variation in ITS value with different bitumen content of CRMB-60 & Grade-I aggregates at 25°C

Table 14 Results of ITS test of various bitumen content on CRMB- 55 Grade with Grade – I aggregates at varied temperatures –

Soaked condition -						
Temperature in °C	**10°C**	**20°C**	**30°C**	**40°C**	**50°C**	**60°C**
Bitumen content in %	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**	**5.5 (OBC value)**
ITS, N/mm²	1.403	1.395	1.372	1.369	1.250	1.369

Table 15 Results of ITS test of various bitumen content on CRMB- 60 Grade with Grade – I aggregates at varied temperatures –

Soaked condition -						
Temperature in °C	**10°C**	**20°C**	**30°C**	**40°C**	**50°C**	**60°C**
Bitumen content in %	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**	**5.4 (OBC value)**
ITS, N/mm²	1.55	1.53	1.50	1.48	1.38	1.49

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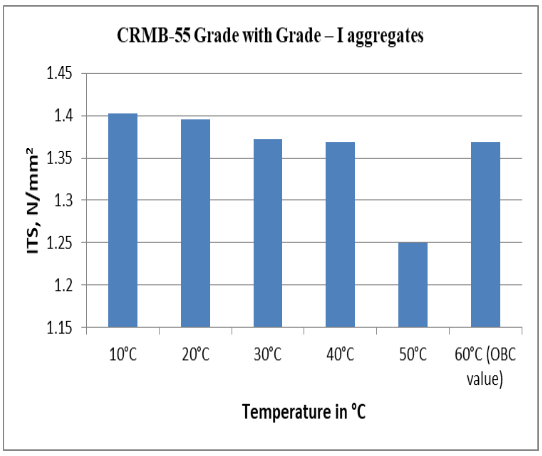

Fig 14 Variation in ITS value with different temperatures of Grade-I aggregates (soaked condition)

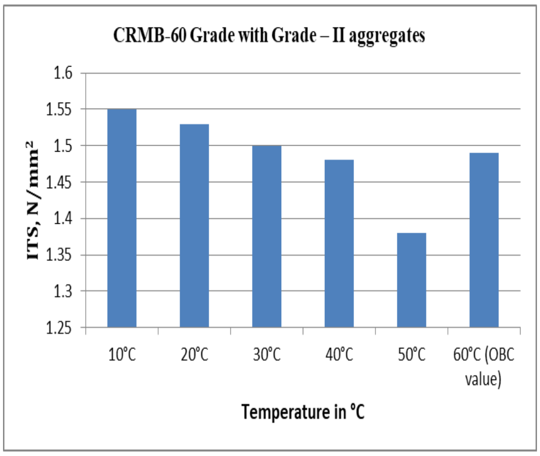

Fig 15 Variation in ITS value with different temperatures of Grade-I aggregates (soaked condition)

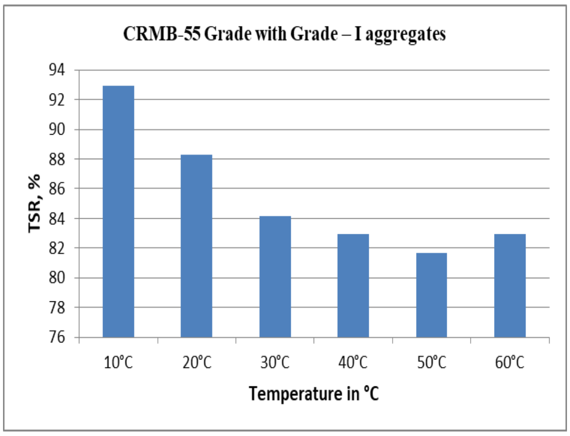

Fig 16 Variation in ITS value with different Test temperatures of CRMB-55 grade with Grade-I aggregates

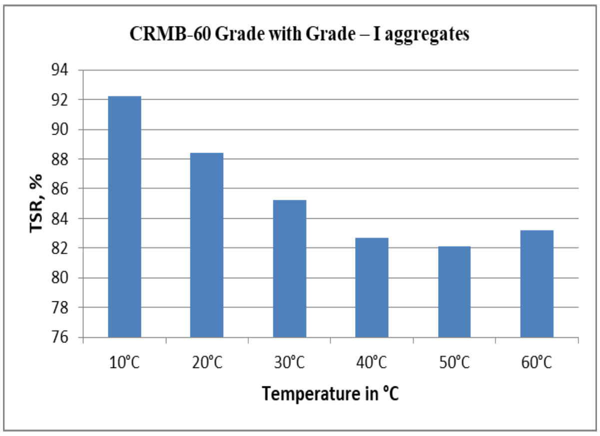

Fig 17 Variation in ITS value with different Test temperatures of CRMB-60 grade with Grade-I aggregates

Test Procedure for conducting Tensile Strength Ratio (TSR)

The indirect tensile strength ratio (TSR) can be determined using the following relation

$$TSR = \frac{Sn}{St}$$

Where, TSR: Indirect Tensile Strength Ratio

S_t: Average Indirect tensile strength of Group-1 (Unsoaked) specimens

S_n: Average Indirect tensile strength of Group-2 (Soaked) specimens

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Table 16 Results of TSR value at varied test temperatures for Grade-I aggregates-

Test Temperature, ^{0}C	TSR, %	
	CRMB-55 grade	CRMB-60 grade
10°C	92.91	92.26
20°C	88.29	88.43
30°C	84.17	85.22
40°C	82.97	82.68
50°C	81.69	82.13
60°C (OBC value)	82.96	83.22

Fatigue Test

Test procedure for conducting Fatigue test

The data provided by the software in an excel format was analysed to determine Resilient Modulus, Tensile stress, and Initial Tensile Strain for all the specimens tested using the following equations.

Tensile stress, $$\sigma_x = \frac{2 \times P}{(\pi \times d \times t)} Mpa$$

Where,

P = applied repeated load in Newton.

d = diameter of the specimen in mm.

t = thickness of the specimen in mm.

a) Resilient Modulus, MR $$= \frac{P(0.27 + \mu)}{(HR \times t)} Mpa$$

Where,

HR = Resilient Horizontal Deformation

μ = Resilient Poisson's Ratio (@ 25^{0}C μ = 0.35 as per TRL)

b) Initial tensile strain, $$\varepsilon = \frac{\sigma_x (1 + 3\mu)}{MR}$$

Table 17 Results of Indirect Tensile Fatigue Test with 25^{0}C temperature at 10%, 20%, 30%, and 40% stress level using CRMB-55 grade with Grade-I aggregates

Specimen Name	Stress Level, %	Load, N	Height of specimen, mm	Tensile Stress, MPa	Resilient Horizontal Deformation, mm	Resilient Modulus, MPa	Initial Tensile strain, Micro strain	Fatigue Life, No. of cycles
CRMB-55-1	10	900	65.3	0.0863	0.0121	2119.21	250.656	14044
CRMB-55-2	10	900	66.3	0.0851	0.0127	2130.51	263.085	14042

CRMB-55-3	10	1800	65.6	0.0869	0.0133	2129.11	265.514	14545
CRMB-55-4	20	1800	66.3	0.1712	0.0135	1677.33	281.678	12783
CRMB-55-5	20	1800	66.3	0.1701	0.0137	1788.66	283.823	12119
CRMB-55-6	20	1800	66.6	0.1748	0.0134	1732.15	290.016	12765
CRMB-55-7	30	2700	65.3	0.2583	0.0151	1217.72	312.802	10543
CRMB-55-8	30	2700	65.6	0.2438	0.0163	1297.39	337.661	10411
CRMB-55-9	30	2700	65.3	0.2454	0.0161	1263.03	333.517	10435
CRMB-55-10	40	3600	66.3	0.4123	0.0192	890.86	356.812	8356
CRMB-55-11	40	3600	66.6	0.4132	0.0181	899.33	342.986	8116
CRMB-55-12	40	3600	66.2	0.4189	0.0186	859.33	351.248	8215

Table 18 Results of Indirect Tensile Fatigue Test with 25^{0}C temperature at 10%, 20%, 30%, and 40% stress level using CRMB-60 grade with Grade-I aggregates

Specimen Name	**Stress Level, %**	**Load, N**	**Height of specimen, mm**	**Tensile Stress, MPa**	**Resilient Horizontal Deformation, mm**	**Resilient Modulus, MPa**	**Initial Tensile strain, Micro strain**	**Fatigue Life, No. of cycles**
CRMB-60-1	10	1050	65.3	0.0799	0.0101	3012.99	201.354	16765
CRMB-60-2	10	1050	65.3	0.0874	0.0119	3017.88	211.384	16168
CRMB-60-3	10	1050	63.5	0.0881	0.0114	3011.02	209.646	15987
CRMB-60-4	20	2100	66.6	0.1629	0.0145	2963.12	256.037	14324
CRMB-60-5	20	2100	66.3	0.1678	0.0134	2896.32	257.434	14765
CRMB-60-6	20	2100	63.5	0.1723	0.0149	2587.42	253.814	14210
CRMB-60-7	30	3150	66.6	0.2613	0.0156	1782.32	287.325	12222
CRMB-60-8	30	3150	66.3	0.2678	0.0149	1687.21	294.187	12123
CRMB-60-9	30	3150	65.3	0.2893	0.0153	1537.99	286.332	12976
CRMB-60-10	40	4200	65.3	0.3585	0.0167	985.729	306.587	9654
CRMB-60-11	40	4200	63.5	0.3422	0.0162	982.126	304.756	9987
CRMB-60-12	40	4200	66.6	0.3625	0.0169	980.35	307.819	9123

RESULTS AND DISCUSSION

Results of ITS Test-Un Soaked Condition-

The ITS value for CRMB- 55 grade & CRMB- 60 grade bituminous concrete mix are prepared using Cement as filler of 2% are tested at 25°C for both grade-I aggregates.

ITS of bituminous concrete mix prepared using CRMB-55 grade as binder with cement as filler material by 2% at 25^0C with grade – I with varied bitumen content are 1.51, 1.58, 1.63, 1.65, 1.53 N/mm^2 respectively.

ITS of bituminous concrete mix prepared using CRMB-60 grade as binder with cement as filler material by 2% at 25^0C with grade – I with varied bitumen content are 1.68, 1.73, 1.76, 1.79, 1.67 N/mm^2 respectively.

Soaked Condition-

ITS of bituminous concrete mix prepared using CRMB-55 grade as binder with cement as filler material by 2% at 25^0C with grade – I with varied bitumen content are 1.403, 1.395, 1.372, 1.369, 1.250, 1.369 N/mm^2 respectively.

ITS of bituminous concrete mix prepared using CRMB-60 grade as binder with cement as filler material by 2% at 25^0C with grade – I with varied bitumen content are 1.55, 1.53, 1.50, 1.48, 1.38, 1.49 N/mm^2 respectively.

Results of TSR

TSR values of bituminous concrete mix prepared using CRMB-55 grade as binder with cement as filler material by 2% for Grade-I aggregates for 10°C, 20°C, 30°C, 40°C, 50°C & 60°C is found to be 92.91%, 88.29%, 84.17%, 82.97%, 81.69%, 82.96% respectively.

TSR values of bituminous concrete mix prepared using CRMB-60 grade as binder with cement as filler material by 2% for Grade-I aggregates for 10°C, 20°C, 30°C, 40°C, 50°C & 60°C is found to be 92.26%, 88.43%, 85.22%, 82.68%, 82.13%, 83.22% respectively.

Results of Fatigue test

The Resilient Modulus of CRMB-55 grade with Grade-I aggregates are in the range of 2119.21 to 859.33 N/mm^2.

The Resilient Modulus of CRMB-60 grade with Grade-I aggregates are in the range of 3012.99 to 980.35N/mm^2

REFERENCES

1. D.N Little, E.tal, “Resilient modulus of asphalt concrete”, Texas transportation institute, Research Report, November, 1991.
2. Amir Modarres, Morteza Rahmanzadeh, Application of coal waste powder as filler in hot mix asphalt, Construction and Building Materials 66 (2014) 476–483, Elsevier publications.
3. Patel, E.tal, “A methodology for determination of Resilient modulus of asphaltic concrete”, Article ID 936395 Hindawi Publishing Corporation, Advances in Civil Engineering, Volume 2011.
4. Kalhan Mitra, Animesh Das, Sumit Basu, Mechanical behavior of asphalt mix: An experimental and numerical study, Construction and Building Materials 27 (2012) 545–552, Elsevier publications.
5. H. Di Benedetto, M. N. Partl, L. Francken and C. De La Roche Saint André, Stiffness testing for bituminous mixtures RILEM TC 182-PEB PERFORMANCE TESTING AND EVALUATION OF BITUMINOUS MATERIALS, *Materials and Structures/Matériaux et Constructions*, Vol. 34, March 2001, pp 66-70.
6. David H. Timm, Angela L. Priest, “Material Properties of the NCAT Test Track Structural Study”, National centre for asphalt technology NCAT Report 06-01, April 2006.

7. Ramprasad.D.S, Umesha.T.S, Dinesh.S.V, Dattatreya.J.K, COMPARISON OF PHYSICAL AND RHEOLOGICAL PROPERTIES OF PLAIN AND CRUMB RUBBER MODIFIED BITUMEN, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.
8. Moe Aung Lwin, Handojo Djati Utomo, Crumb Rubber Modified Bitumen in Open Graded Wearing Course of Flexible Pavement, ISSN Online: 2164-3172, Open Journal of Civil Engineering, 2017, 7, 165-176.
9. Nabin Rana Magar, A Study on the Performance of Crumb Rubber Modified Bitumen by Varying the Sizes of Crumb Rubber, International Journal of Engineering Trends and Technology (IJETT) – Volume 14 Number 2 – Aug 2014.
10. Ambika Kuity, Sandhya Jayaprakasan, Animesh Das, Laboratory investigation on volume proportioning scheme of mineral fillers in asphalt mixture, Construction and Building Materials 68 (2014) 637–643, Elsevier publications.
11. Georges A.J. Mturi, Johan O'Connell, Salah E. Zoorob and Morris De Beer, A study of crumb rubber modified bitumen used in South Africa, Article in Road Materials and Pavement Design · May 2014.
12. Bashar Tarawneh/ Munir D.Nazzal, Optimization of resilient modulus prediction from FWD results using artificial neural network, periodica polytechnic Civil Engineering 58/2 (2014) 143–154 doi: 10.3311/PPci.2201 http://periodicapolytechnica.org/ci Creative Commons Attribution.
13. Jorge B. Sousa, Joseph Craus, Carl L. Monismith, Summary Report on Permanent Deformation in Asphalt Concrete, Institute of Transportation Studies University of California Berkeley, California, SHRP-A/IR-91-104.
14. Jean-Pascal Bilodeau, Estimation of resilient modulus for compacted unbound granular materials used as base and subbase layers in Canada, Paper prepared for presentation at the Success through the use of geo-synthetics of the 2011 Annual Conference of the Transportation Association of Canada Edmonton, Alberta.
15. AASHTO guide for design of pavement structures, American Association of Transport Officials, Washington.D.C, 1993.

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