Experimental Analysis of Resilient Characteristics of CRMB – 55 & 60 Grade with Grade-II Aggregates on Pavement

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Abstract

An evaluation of the physical and engineering properties of modified binders was conducted in this paper, namely Crumb Rubber Modified Bitumen (CRMB - 55 grade & CRMB - 60 grade) containing cement as a mineral filler of 2 % and varying binder contents between 4% and 6% for determining the Optimum Binder Content (OBC) for aggregates of nominal size 13.2 mm in Grade-II.

As a result of varying stress levels from 10% to 40%, the specimens have been cast for indirect tensile strength (ITS), moisture susceptibility, and fatigue cycles' estimation.

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

I. INTRODUCTION

Resilient modulus

For flexible pavements, the resilient modulus, M R, measures how well a material recovers from external shocks and disturbances. Basically it is described as the ratio of applied deviator stress to the recoverable or resilient strain.
Using this property to estimate the modulus of elasticity of the material is actually measuring the slope of the stress-strain curve, which in the case of slowly moving vehicular wheel loads will be linear elastic, while for rapidly applied wheel loads would yield M_R. By determining the resilient modulus of the pavement material, we can determine the structural behaviour of the pavement against traffic loads. However, obtaining M R requires laboratory and field testing of bituminous pavement materials. It is important to note that the temperature-induced pavement responses were significantly greater than traffic-induced responses & may have serious implications for pavement design.
A relationship between single-axle and tandem-axle loading is established for several types of pavement, where deflections are directly proportional to load, although not always.
The influence of aggregate density, aggregate gradation and degree of saturation on the resilient modulus is increased considerably with an increase in confining pressure and slightly increases in axial stress. There is also an increase in Poisson's ratio with decrease in confining pressure & increase in repeated stresses.

Aggregates:

Coarse aggregate morphology, quantified by angularity and surface texture properties, affects the elastic modulus of asphalt mixtures. Although the changes in aggregate size did not significantly affect the relationship between coarse aggregate morphology and elastic modulus, the reduction in the maximum nominal aggregate size from 19 mm (layer thickness of 50 mm) to 9.5 mm indicated an increasing positive influence of aggregate morphology on the elastic modulus of asphalt mixtures. The aggregates larger than a certain size behave linearly elastic, resulting in efficient elastic properties.

Modified binders:

Modified binders have beneficial properties such as increased rutting resistance at high temperatures and improved resistance to cracking at medium and low temperatures. Modified asphalt binders are typically used in high traffic applications. They are also used at intersections with stop-and-go traffic, on heavily traveled truck routes and on heavily traveled highways. Modifiers are also used in extreme climatic conditions to reduce bitumen aging in desert areas, and also for applications in extremely low temperatures such as -34 degrees and -40 degrees. Modified bitumen, when used properly and in the right place, can be a very cost-effective way to minimize pavement damage and failure due to climate variability.

Analysis of elastic modulus characteristics:

Modulus of elasticity is used to characterise pavement materials under various loading conditions that do not result in pavement system failure. Granular material is a stress-hardening material that exhibits less deformation with increasing stress and thus a higher stiffness or modulus of elasticity, while fine-grained or subgrade soils are referred to as stress-softening, meaning that as stress increases, the stiffness or modulus of elasticity decreases.

As the asphalt content increases, the percentage of air voids decreases. During the mixing and compaction process, some of the asphalt is absorbed by the mineral aggregates. This absorption has less influence on the physical behaviour of the mix than the properties at the interface between asphaltand aggregate and the asphalt film. If the modulus is above the upper limit of this range, the mix is too stiff and fatigue and/or thermal cracking may be a problem. If the mix is too soft and the relationship between modulus of elasticity and temperature runs below the lower limit, the mix is considered too soft and therefore does not adequately protect the underlying layers or may be susceptible to deformation. In addition, the modulus of elasticity at low temperatures has been found to be somewhat related to cracking, as stiffer mixtures (higher MR) are more prone to cracking at low temperatures than more flexible mixtures (lower MR). In addition, the modulus of elasticity decreases rapidly with increasing temperature, which is due to the softening of the asphalt binder with increasing temperature.

II. LITERATURE REVIEW

D.N. Little, E.tal In this study, several approaches to measuring the modulus of asphalt concrete were developed to enable the Department to perform this testing both to support design activities and to confirm non-destructive field testing. Efforts were made to develop a productive testing technique, as well as techniques that can be readily modified to incorporate new research and procedures focused on mechanistic design methods. Two test configurations were selected for development & the uniaxial compression test with sinusoidal loading can be used with a variety of materials and stress conditions. A method was developed that can be used for relatively short field cores. The diametrical indirect tensile test can be performed very quickly on short (two-inch) specimens of dense, graded asphalt concrete. For both test configurations, the ability to measure Poisson's ratio in addition to modulus of elasticity was created (1).

Amir Modarres, E.tal The modulus of elasticity of bituminous mix, determined by the ASTM D4123-04 method, is one of the stress-strain measurements used to evaluate the elastic properties of this mix. It is well known that most road construction materials are not elastic, but undergo some permanent deformation after each load. However, if the load is small compared to the strength of the material and is repeated frequently, the deformation at each load repetition is almost completely recoverable and proportional to the load and can be considered 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).

A. Patel, E.tal has described the elastic properties of in which the experimental studies of dense asphalt concrete and semi-dense asphalt concrete were carried out by taking core samples from the pavements. The complete characterization of these cores was carried out as part of the proposed method for determining MR. Cores were taken from the surface and binder courses of the pavements of these runways. Density-space analysis, Marshall stability, and yield value tests were performed on these cores in accordance with ASTM D6927 [14], and the results are presented. The Marshall stability value of the DAC and SDAC samples was determined to be 765 kg and 725 kg, respectively, at 60°C. The yield value of the SDAC samples was higher compared to that of the DAC samples. The average bulk densities of the DAC and SDAC samples were 2.36 and 2.33 g/cm3, respectively. The stiffness modulus of the mix was determined based on the parameters of the mix (density, air voids, aggregate voids filled with bitumen and bitumen content), the properties of the bitumen (penetration, softening point, temperature susceptibility, penetration index and specific gravity) and the properties of the aggregate (specific gravity) using the shell nomograms (3).

Kalhan Mitra, E.tal The binder mixture specimens are tested in an indirect tensile test where the load is applied at a constant deformation rate. The experimental results of the binder mixture are used to calibrate the proposed numerical model of the binder mixture. The properties of the binder and aggregate are used as input to develop the numerical model for the asphalt mixture. The asphalt mixture specimens are also tested in indirect tensile test at constant deformation. An asphalt mix containing 5% (by weight) asphalt binder relative to the total weight of the mix is commonly referred to as a "5% asphalt mix'. Indirect tensile tests are performed on asphalt and binder mix samples on an Instron machine. It is found that the experimental force-time curves (for all binder contents from 5.5% to 6.5%) show considerable variability from sample to sample(4).

H. Di Benedetto E.tal These properties can be introduced only if the behaviour of the material can be considered linear. An evaluation of the linear viscoelastic range of bituminous mixtures considering the axes logarithm (base 10) of the strain amplitude - logarithm (base 10) of the number of cycles applied. From the results of the inter laboratory tests of 15 laboratories, conclusions were drawn on test equipment, sample preparation, testing and calibration procedures for testing the stiffness properties of bituminous mixtures under cyclic (rather than dynamic, as explained below) loading, in order to improve the repeatability and reproducibility of this type of testing(5).

David H. Timm describes the individual pavement layers in terms of material composition and mechanistic material properties. Triaxial elasticity and dynamic modulus tests were performed in the laboratory and described. Laboratory and field data were statistically analyzed, and models were developed to describe the relationships between relevant pavement parameters and mechanistic material properties. The analysis showed that factors such as air voids, binder grade, gradation, and asphalt content were not significant. The effects of cracking on modulus values were most evident in the HMA layer (6)**.**

Ramprasad.D.S, E.tal In India, specifications for bituminous binders are based on various empirical tests, which are almost inconclusive about their performance characteristics, it is reported. In this paper, the physical and rheological properties of bituminous binders commonly used in India at high and medium field temperatures are described in terms of their performance characteristics. Considering various factors affecting the behaviour of bituminous binders, the effects of temperature variation, loading rate and loading amount are considered. Changes in the properties of commonly used bitumen's (60-70) are reported, both in the unmodified state and modified with rubber crumb. Marshall Properties and indirect tensile strength ratio are compared for the specimens prepared at optimum binder content (OBC) for bituminous concrete (BC) of grain size 2. Bitumen modified with crumb rubber exhibits higher Marshall Stability, lower flow, higher ITS, and improved rheological properties related to rutting. Although the optimum binder content for CRMB is slightly higher than that of normal bitumen, it exhibits higher strength in the form of increased Marshall Stability and decreased yield value(7).

Moe Aung Lwin E.tal, Recycling tyres in the form of crumb rubber tyres and mixing them with bituminous pavement can increase the recycling rate and minimise the cost of the incineration process. Five (5) different variations of open-graded pavement (OGW) samples were prepared using the dry-mixing process, each representing 1.15 kg. Each OGW mix contained 4% to 6% Bitumen Pen 60/70 and 1% rubber tyres, resulting in 14% to 20% rubber tyres of the bituminous samples. Bitumen Pen 60/70 blended with 20% crumb rubber tyres met the PG 76 bitumen properties. The physical properties of OGW made from crumb rubber modified bitumen (CRMB) were better than those of standard bitumen. In this study, the OGW (Open Graded Wearing) mix was selected because it offers a wider range of applications for different types of roads and has many advantages(8).

Nabin Rana Magar, The rheology of CRMB depends on internal factors such as quantity, type, particle size, source and composition of pure bitumen as well as external factors such as mixing time, temperature and also mixing method (dry or wet). The present study aims to investigate the experimental performance of the bitumen modified with 15 wt% crumb rubber, varying its size. Four different size categories of crumb rubber are used, namely coarse (1 mm - 600 µm), medium (600 µm -300 µm), fine (300 µm-150 µm) and superfine (150 µm -75 µm). Standard laboratory tests are performed on the modified bitumen with different sizes of crumb rubber and analyzed in this way. The Marshall stability method is used for the mix design. Crumb rubber modified bitumen (CRMB) is produced(9).

Ambika Kuity, E.tal The aggregates, asphalt binders and fillers used in this study are all collected locally. In the present study, bituminous concrete (BC) is selected as the asphalt mix as per Indian specifications. A medium gradation is used in the production of the BC samples. A comprehensive study on the performance of five different fillers namely brick dust, fly ash, lime dust, recycled concrete waste dust and conventional stone dust used in asphalt mix has been presented in this paper. The asphalt content was set at 5.66% by weight of the aggregates excluding fillers. Since the fillers have different densities, a volume proportioning scheme was applied in this paper, replacing the stone dust fillers with the new type of fillers(10).

Georges A.J. Mturi, E.tal Better characterization is made possible by rheological analyses with a dynamic shear rheometer (DSR). However, the heterogeneous morphology of CRM bitumens makes testing challenging with current methods and equipment. DSR Testing of CRM bitumens requires adjustment of the plate gap to avoid any interference from the rubber particles. To this end, the effect of changing the DSR plate gap setting on the measured linear visco-elastic properties of the binder was monitored. A matched gap was selected for the rheological measurements to characterise the properties of CRM bitumen with ageing. The heterogeneous nature of CRM bitumen makes it impossible to obtain the binder as a single component from surface sealants or asphalt mixes. It is recovered in two separate units, the rubber crumb and the solvent-soluble fraction containing the base binder. The solvent extraction process also destroys the chemical equilibrium of the CRM bitumen mixture(11).

Bashar Tarawneh E.tal The MR should be determined by repeated triaxial loading (RTL) tests in the laboratory. However, this test requires well-trained personnel and expensive laboratory equipment. It is also considered to be relatively time consuming. Therefore, MR is estimated using correlations with various in-situ test results as well as material index properties. The results of the regression analyses showed that using linear elastic software to back-calculate the FWD module gave a better prediction of the laboratory-measured elastic modulus than using the AASHTO or Florida equations (12).

Jorge B. Sousa, Etal Permanent deformation (rutting) of asphalt pavements has a significant impact on pavement performance. Ruts reduce the useful life of the pavement and create serious hazards for road users by impairing driving characteristics. Highway engineers have been hampered in their efforts to provide rut-resistant materials by the fact that existing methods for testing and evaluating asphalt-aggregate mixtures are empirical and do not provide a reliable indication of in-service performance. Although mix compaction (volume change) has some influence, rutting is primarily caused by repeated shear deformation under traffic loading. Factors that influence the extent of rutting include tire load level and pressure, traffic volume, thermal environment, and various mix properties. Among the influential mix properties, aggregate characteristics (especially rough surface texture, angularity, and dense aggregate) are particularly important in resisting permanent deformation. The amount and stiffness of the asphalt or modified asphalt binder are also important, with lower asphalt contents and stiffer binders providing better resistance to permanent deformation.(13)

III. 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-II aggregates.
- Evaluation of fatigue test of specimens casted with grade – II aggregates with CRMB – 55 & CRMB – 60 grade as a modified binders.
- Conduction of Indirect tensile strength (ITS) &moisture susceptibility tests of grade –II aggregate specimen

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	21.9%	< 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 CRMB

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:

1. Sufficient bitumen to ensure a durable pavement.
2. Sufficient strength to resist shear deformation under traffic at higher temperature.
3. Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic.
4. Sufficient workability to permit easy placement without segregation.
5. Sufficient flexibility to avoid premature cracking due to repeated bending by traffic.
6. 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			Obtained Gradation	Gradation Requirement as per MORTH Specifications (Grading – 2)
	13.20 mm down Size	4.75 mm down size	2.36 mm down size		
19	100	100	100	**100**	**100**
13.2	67	100	100	**97**	**90—100**
9.5	54	100	100	**80**	**70—88**
4.75	20	58	100	**59**	**53—71**
2.36	16	36	98	**45**	**42—58**
1.18	14	38	78	**38**	**34—48**
0.6	10	24	61	**29**	**26—38**
0.3	8	22	53	**25**	**18—28**
0.15	0	9	39	**14**	**12—20**
0.075	0	8	16	**7**	**04—10**

TABLE – 5- PROPORTION OF AGGREGATES FOR THE MIX

Sl. No.	Materials	* Proportion	Remark
1	13.20 mm down size aggregates, %	**39.0**	------------
2	4.75 mm down size aggregates, %	**31.0**	
3	2.36 mm down size aggregates, %	**28.0**	
4	Cement, as filler, %	**2.0**	

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

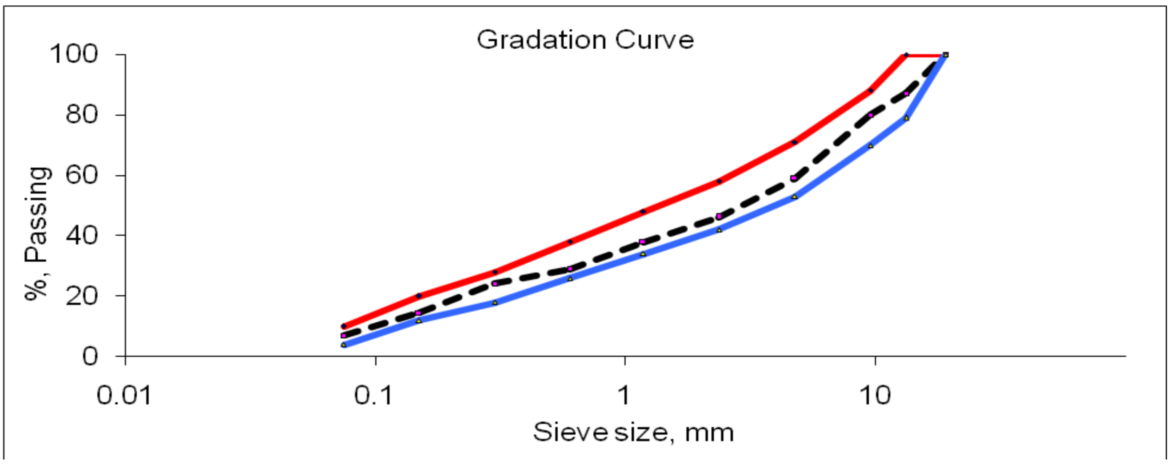

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FIG 1 – OBTAINED GRADATION CURVE

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

Marshal stability Formulaes for estimation of OBC-

1. Theoretical specific gravity for 4 % bitumen -
   $G_t = [\{(W_1+W_2+W_3+W_b) / \{(W_1/G_1) + (W_2/G_2) + (W_3/G_3) + (W_b/G_b)\}]$
2. Bulk specific gravity, $G_m = W_m / (W_m - W_w)$
3. Air voids percent $V_v = \{(G_t - G_m) / G_t\} * 100$
4. Percent volume of bitumen $V_b = [\{(W_b / G_b)\} / \{(W_1 + W_2 + W_3 + W_b) / G_m\}]$
5. Voids in mineral aggregate VMA
   $VMA = V_v + V_b$
6. Voids filled with bitumen VFB
   $VFB = (V_b * 100) / VMA$

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

Bitumen content in %	Stability in KN	Flow in mm units	V_V in %	VFB in %	VMA in %	G_m
4	6	2.1	5.2	66	13.1	2.351
4.5	8.1	2.6	4.68	66.9	14.2	2.359
5	10.6	2.9	4.26	67.3	15.3	2.378
5.6	12.9	3.2	3.6	69.1	16.6	2.413
6	11.4	3.5	3.1	70.4	17.4	2.391
6.5	9.3	3.7	2.3	73.9	17.6	2.377

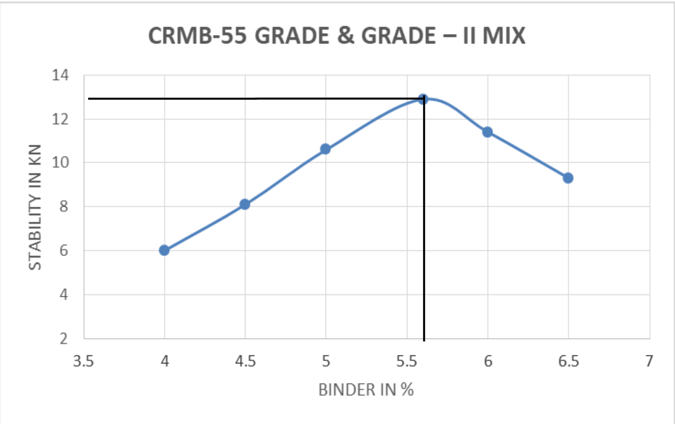

FIG – 2 CRMB 55 GRADE Vs STABILITY ANALYSIS

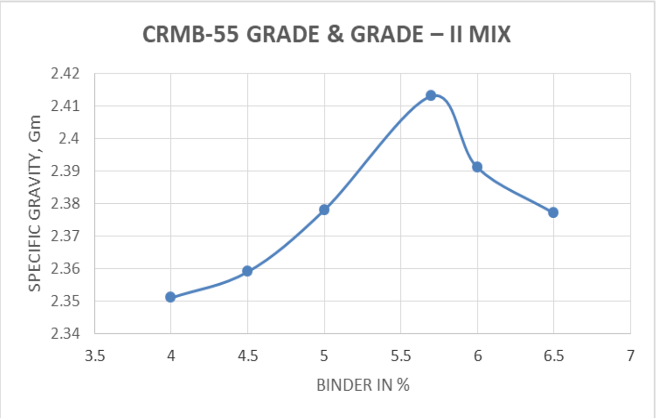

FIG – 3 CRMB 55 GRADE Vs SPECIFIC GRAVITY G_M

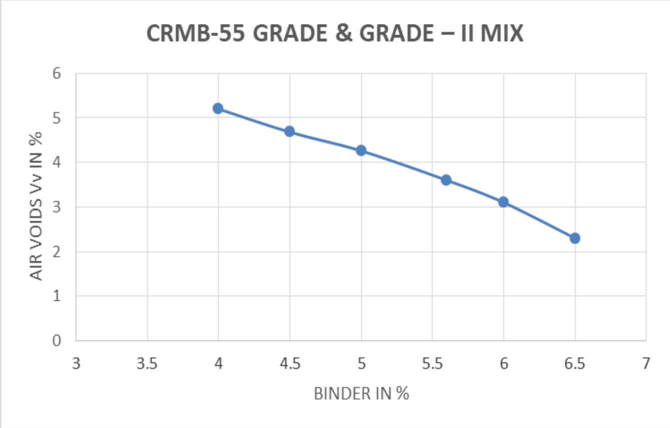

FIG – 4 CRMB 55 GRADE Vs PERCENTAGE OF VOIDS

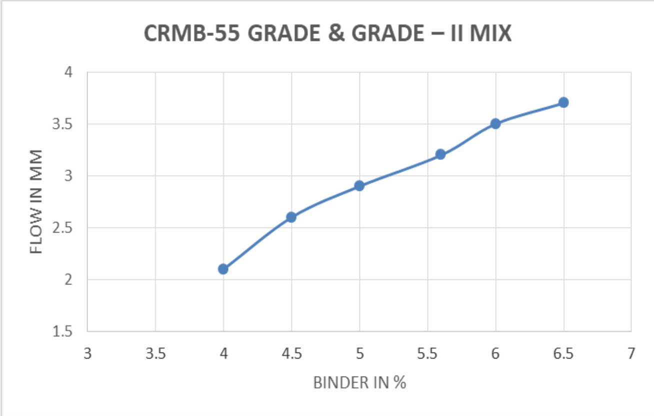

FIG – 5 CRMB 55 GRADE Vs FLOW VALUE

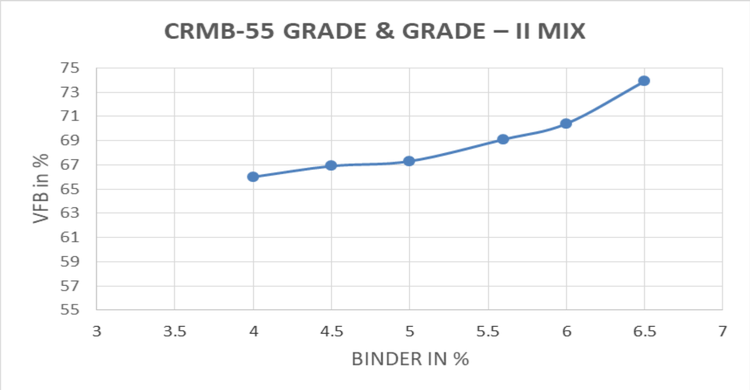

FIG – 6 CRMB 55 GRADE Vs VOIDS FILLED BY BITUMEN

Conclusion:

It has been found from the analysis that the Optimum Binder Content for Crumb Rubber Modified Bitumen – 55 Grade & Grade-II (13..2 mm nominal size) aggregates is 5.6% with the flow value of 3.2 mm where in the minimum Binder content specified by MORTH specifications 5th Revision is 5.6%.

1) **Optimum binder content:** The optimum bitumen content is computed as the average bitumen content selected corresponding to:
   - **a)** Maximum Marshall Stability.
   - **b)** Maximum Bulk Density.
   - **c)** 4% Air voids.

   The Optimum bitumen content = (5.60+5.56+5.50)/3

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

   = **5.60%.** (By weight of total Mix)

2) **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).	**5.60**	Min 5.60
2	Bulk density G_m, gm/cc.	**2.413**	2.34 to 2.42 g/cc
3	Voids in Compacted Mix, %.	**3.6**	3.0 – 5.0

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4	Marshall Stability (75 blows) (At 60ºC), kgs.	**1290**	1200
5	Marshall Flow at 60ºC, mm.	**3.20**	2.5 - 4.0
6	Percentage void filled with bitumen, %	**69.10**	65 - 75
7	Voids in Mineral Aggregates, %.	**16.60**	Min 13.00
8	Marshal Quotient, stability/ flow, kg/mm	**403**	250-500

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

Bitumen content in %	Stability in KN	Flow in mm units	V_V in %	VFB in %	VMA in %	G_m
4	6.8	2.32	4.62	66	13.6	2.362
4.5	8.1	2.65	4.28	66.9	14.2	2.369
5	10.4	2.94	3.9	67.3	15.8	2.395
5.7	14.8	3.28	3.4	69.1	17.1	2.417
6.0	12.3	3.51	2.9	70.4	17.6	2.391
6.5	10.1	3.78	2.3	73.9	18.1	2.376

Conclusion:

It has been found from the analysis that the Optimum Binder Content for Crumb Rubber Modified Bitumen – 60 Grade & Grade-II (13.2 mm nominal size) aggregates is 5.7% with the flow value of 3.12 mm where in the minimum Binder content specified by MORTH specifications 5^{th} Revision is 5.6%.

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

a) Maximum Marshall Stability.
b) Maximum Bulk Density.
c) 4% Air voids.

The Optimum bitumen content = (5.7+5.5+5.5)/3

= **5.7 %.** (By weight of aggregates) **& 5.60%.** (By weight of total Mix)

3) Bulk Density: *Bulk density* of the mix determined for the above aggregate proportion and at optimum binder content is found to be **2.417 gm/cc.**

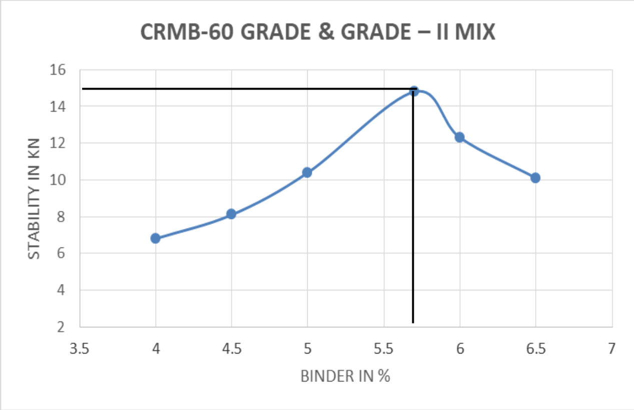

FIG – 7 CRMB 60 GRADE Vs STABILITY ANALYSIS

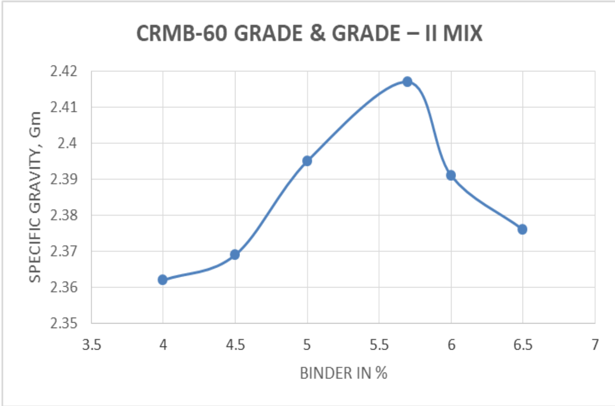

FIG – 8 CRMB 60 GRADE Vs SPECIFIC GRAVITY G_M

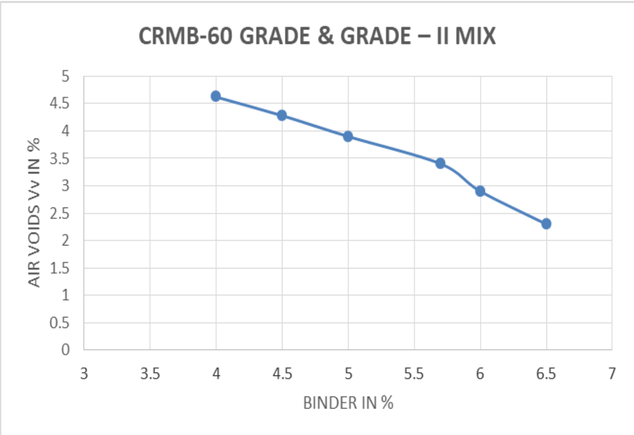

FIG – 9 CRMB 60 GRADE Vs PERCENTAGE OF VOIDS

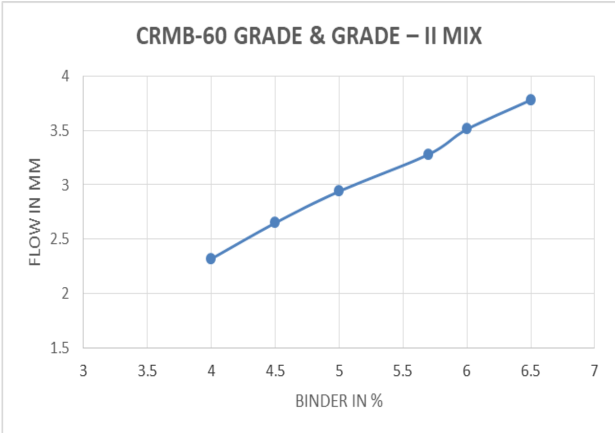

FIG – 10 CRMB 60 GRADE Vs FLOW VALUE

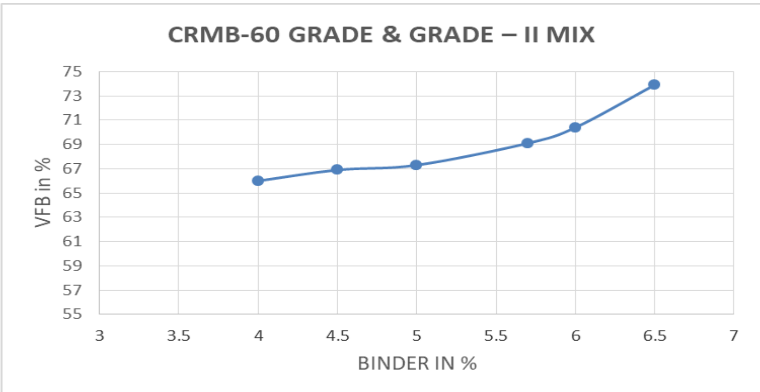

FIG – 11 CRMB 60 GRADE Vs VOIDS FILLED BY BITUMEN

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).	**5.70**	Min 5.60
2	Bulk density G_m, gm/cc.	**2.417**	2.34 to 2.42 g/cc
	Voids in Compacted Mix, %.	**3.4**	3.0 – 5.0

3			
4	Marshall Stability (75 blows) (At 60°C), kgs.	**1480**	1200
5	Marshall Flow at 60°C, mm.	**3.28**	2.5 - 4.0
6	Percentage void filled with bitumen, %	**69.1**	65 - 75
7	Voids in Mineral Aggregates, %.	**17.10**	Min 13.00
8	Marshal Quotient, stability/ flow, kg/mm	**445**	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:

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

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 – II aggregates –

Unsoaked condition	
Bitumen content in %	**ITS, N/mm^2**
4.0	1.56
4.5	1.59
5.0	1.62
5.6 (OBC)	1.63
6.0	1.59

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

Unsoaked condition	
Bitumen content in %	**ITS, N/mm^2**
4.0	1.67
4.5	1.69
5.0	1.70
5.7 (OBC)	1.74
6.0	1.58

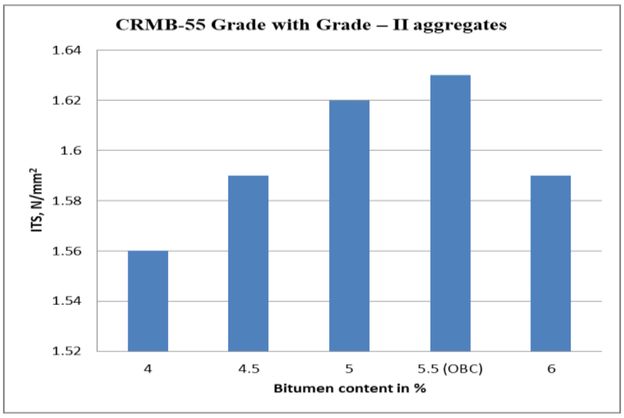

Fig 12 Variation in ITS value with different bitumen content of CRMB-55 & Grade-II aggregates at 25°C

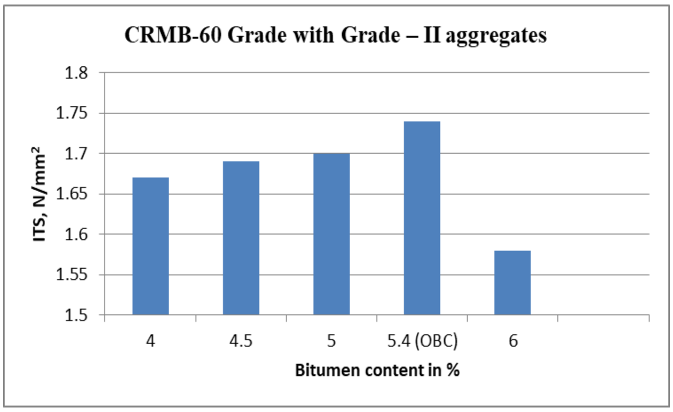

Fig 13 Variation in ITS value with different bitumen content of CRMB-60 & Grade-II aggregates at 25°C

Table 14 Results of ITS test of various bitumen content on CRMB- 55 Grade with Grade – II 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**	**5.6**	**6.0**	**5.6 (OBC value)**
ITS, N/mm^2	1.46	1.435	1.412	1.409	1.350	1.409

Table 15 Results of ITS test of various bitumen content on CRMB- 60 Grade with Grade – II 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**	**5.6**	**6.0**	**5.7 (OBC value)**
ITS, N/mm^2	1.58	1.55	1.52	1.49	1.45	1.47

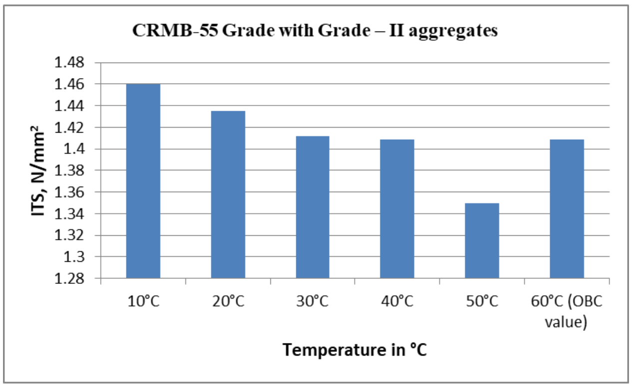

Fig 14 Variation in ITS value with different temperatures of Grade-II aggregates (soaked condition)

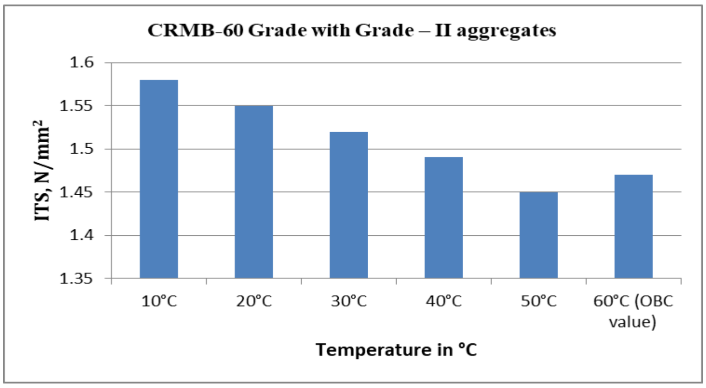

Fig15 Variation in ITS value with different temperatures of Grade-II aggregates (soaked condition)

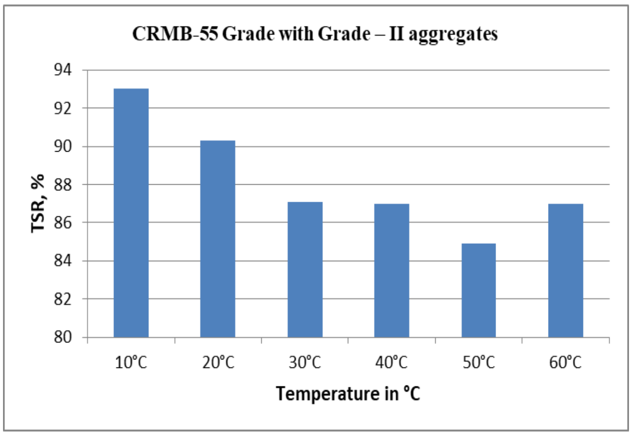

Fig 16 Variation in ITS value with different Test temperatures of CRMB-55 grade with Grade-II aggregates

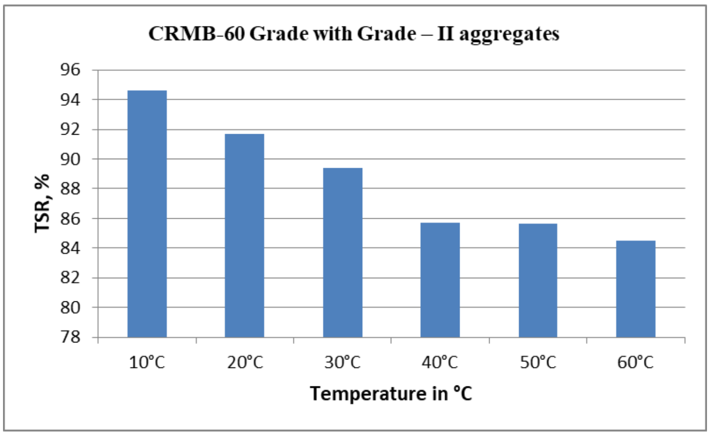

Fig 17 Variation in ITS value with different Test temperatures of CRMB-60 grade with Grade-II aggregates

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

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

Test Temperature, ^{0}C	TSR, %	
	CRMB-55 grade	CRMB-60 grade
10°C	93.01	94.61
20°C	90.29	91.71
30°C	87.10	89.41
40°C	86.97	85.68
50°C	84.90	85.63
60°C	86.97	84.48

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.

1. 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.

2. 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)

3. 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-II 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	1300	65.5	0.0763	0.0125	2419.21	270.656	16044
CRMB-55-2	10	1300	66.4	0.0751	0.0127	2430.51	273.085	16042
CRMB-55-3	10	1300	65.6	0.0769	0.0131	2429.11	275.514	16545
CRMB-55-4	20	2600	66.4	0.1812	0.0134	1777.33	291.678	13783
CRMB-55-5	20	2600	66.5	0.1801	0.0131	1758.66	293.823	13119
CRMB-55-6	20	2600	66.4	0.1848	0.0132	1742.15	290.016	13765

CRMB-55-7	30	3900	65.5	0.2383	0.0141	1247.72	332.802	11543
CRMB-55-8	30	3900	65.3	0.2338	0.0153	1267.39	337.661	11411
CRMB-55-9	30	3900	65.5	0.2354	0.0151	1273.03	333.517	11435
CRMB-55-10	40	5200	66.4	0.4323	0.0182	990.86	376.812	9356
CRMB-55-11	40	5200	66.4	0.4332	0.0181	999.33	372.986	9116
CRMB-55-12	40	5200	66.2	0.4389	0.0186	959.33	371.248	9215

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-II 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	1400	65.5	0.0899	0.0111	3112.99	211.354	16565
CRMB-60-2	10	1400	65.4	0.0874	0.0119	3117.88	221.384	16668
CRMB-60-3	10	1400	63.5	0.0881	0.0116	3111.02	219.646	15487
CRMB-60-4	20	2800	66.2	0.1729	0.0145	2763.12	276.037	14724
CRMB-60-5	20	2800	66.3	0.1778	0.0144	2796.32	277.434	14365
CRMB-60-6	20	2800	63.4	0.1723	0.0159	2787.42	273.814	14710
CRMB-60-7	30	4200	66.3	0.2513	0.0146	1582.32	297.325	12822
CRMB-60-8	30	4200	66.5	0.2578	0.0149	1587.21	294.187	12523
CRMB-60-9	30	4200	65.6	0.2693	0.0143	1537.99	296.332	12876
CRMB-60-10	40	5600	65.3	0.3485	0.0177	885.729	326.587	9634
CRMB-60-11	40	5600	63.2	0.3522	0.0172	882.126	324.756	9967
CRMB-60-12	40	5600	66.5	0.3525	0.0179	880.35	327.819	9173

IV. RESULTS AND DISCUSSION

Results of ITS Test-
Un Soaked Condition-

1. 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-II aggregates.

2. ITS of bituminous concrete mix prepared using CRMB-55 grade as binder with cement as filler material by 2% at 25^{0}C with grade – II with varied bitumen content are 1.56, 1.59, 1.62, 1.63, 1.59 N/mm^2 respectively.
3. ITS of bituminous concrete mix prepared using CRMB-60 grade as binder with cement as filler material by 2% at 25^{0}C with grade – II with varied bitumen content are 1.67, 1.69, 1.70, 1.74, 1.58 N/mm^2 respectively.

Soaked Condition-

1. ITS of bituminous concrete mix prepared using CRMB-55 grade as binder with cement as filler material by 2% at 25^{0}C with grade – II with varied bitumen content are 1.46, 1.435, 1.412, 1.409, 1.350, 1.409 N/mm^2 respectively.
2. ITS of bituminous concrete mix prepared using CRMB-60 grade as binder with cement as filler material by 2% at 25^{0}C with grade – II with varied bitumen content are 1.58, 1.55, 1.52, 1.49, 1.45, 1.47 N/mm^2 respectively.

Results of TSR

1. TSR values of bituminous concrete mix prepared using CRMB-55 grade as binder with cement as filler material by 2% for Grade-II aggregates for 10°C, 20°C, 30°C, 40°C, 50°C & 60°C is found to be 93.01%, 91.71%, 89.41%, 85.68%, 85.63%, 86.97% respectively.
2. TSR values of bituminous concrete mix prepared using CRMB-60 grade as binder with cement as filler material by 2% for Grade-II aggregates for 10°C, 20°C, 30°C, 40°C, 50°C & 60°C is found to be 94.61%, 88.43%, 85.22%, 82.68%, 80.13%, 84.48% respectively.

Results of Fatigue test

1. The Resilient Modulus of CRMB-55 grade with Grade-II aggregates are in the range of 2419.21 to 959.33 N/mm^2.
2. The Resilient Modulus of CRMB-60 grade with Grade-II aggregates are in the range of 3112.99 to 880.35N/mm^2

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