IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 20, Issue 3 Ser. III (May. – June. 2023), PP 12-20
www.iosrjournals.org

Laboratory Investigation On Performance Of Densed Bituminous Macadam (Grade 2) Containing Rap Material With Different Mineral Fillers

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Abstract :
Over the time , recycling has become one of the most adoptable pavement rehabilitation alternatives, and different recycling Procedures are now available to address specific pavement distresses and structural needs . Recently, Industrial wastes have been widely used to improve the properties of asphalt binders due to their unique properties. Cracking and degradation is common mode of failure in asphalt pavements that occurs due to increasing traffic loads or even due to variation in environmental conditions. To overcome these damages, some solutions are proposed including corrections, quality improvement and increasing the asphalt resistance. This research aims to evaluate the performance of Dense bitumen macadam mix of grade 2 which is mixed By adding different percentage of RAP Material (10% to 30% by weight of virgin aggregate) with 3 different industrial wastes such as stone dust , fly-ash and GGBS . Each of them was added to a VG-30 grade bitumen at the concentration of 2% of asphalt binder weight. A number of basic tests will be carried out on the binders and aggregate. Mineral fillers and RAP material in the asphalt mixtures and conducted Marshall test, indirect tensile strength and fatigue test and found optimum value of RAP that can be added to Asphalt mix and found the mineral filler with better performance.

Keywords : *Densed Bituminous Macadam (DBM) , Reclaimed Asphalt Pavement (RAP), VG -30,GGBS, Indirect Tensile Strength (ITS)***.***

Date of Submission: 09-06-2023 Date of Acceptance: 19-06-2023

I. INTRODUCTION

Transportation contributes very important role in terms of social, cultural and economic development of a country. For any developing country such as India, roads and highways are majorly adopted as primary modes of transportation . It is known that bituminous material such as bitumen is mainly used on a large scale and in huge quantities for construction and maintenance of roads. These results in degradation of environment and leads to scarcity of natural resources like raw materials etc., so it is necessary to adopt the use of modifiers and mineral fillers for asphalt pavements for analyzing mechanical and physical properties and also durability of asphalt pavement.

In a flexible pavement the main role of bituminous mix is to Provide structural strength, Facilitate subsurface drainage and Provides surface friction especially when pavement is in wet condition.

Dense bituminous macadam is mainly used as binder course for the roads which carry much higher number of heavy commercial vehicles. Normally Marshall Mix design method is adopted for the mix design of Dense Graded Bituminous Macadam (DBM). DBM is also used as base material in construction of roads and highways.

The use of Reclaimed asphalt pavement (RAP) material has become a practice in many areas around the world. The recycling of existing asphalt pavement materials gives new pavement with considerable savings in material, energy and money. Aggregate and binder of old asphalt pavements are still perform well even though these pavements reached end of their service lives. RAP materials are used from many years by adding it with virgin aggregates and binders to make a new pavement which proves to be both economical and effective in protecting the environment. Furthermore, mixtures which consist of RAP material have been found to perform as same as of the virgin mixtures. However, although it is helpful in reduce the utilization of virgin asphalt binder and improving rut resistance, the aged binder in RAP is assumed to give factor responsible for thermal and fatigue cracking failures of the asphalt pavements .

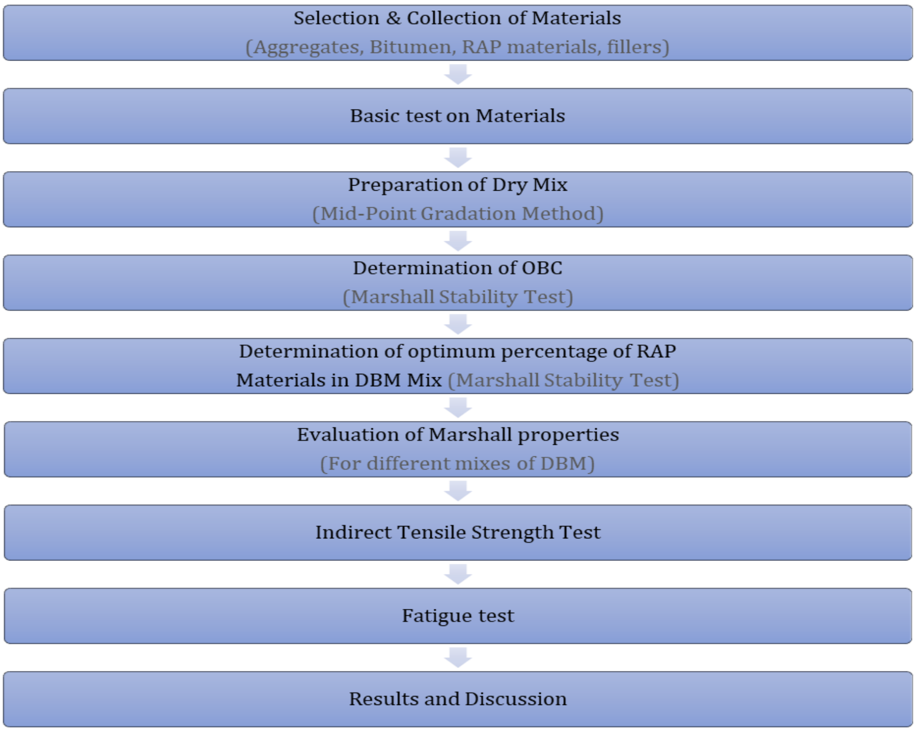
II. OBJECTIVES OF THE STUDY

- To determine the optimum bitumen content for DBM mix (Grade-2) prepared using VG-30 as a binder material.
- To determine the optimum Reclaimed Asphalt Pavement (RAP) material percentage to be used with virgin aggregates for maximum strength of DBM.
- To determine the Marshall characteristics of Dense Bituminous Macadam mix mixed with RAP Material and different Mineral fillers .
- To evaluate the Indirect Tensile Strength and Fatigue characteristics of bituminous mix with Optimum RAP Material for different fillers.

III. MATERIALS AND METHODOLOGY

In the present study the aggregate gradation (Grading-II) was adopted for Dense Bituminous Macadam as per Table 500-18 recommended by MORT&H (Vth revision) specifications. Marshall Method bituminous mix design is adopted for dense bituminous macadam mix prepared using Viscosity Grade (VG-30) by using RAP with Stone dust, GGBS and Fly-ash as fillers.

FLOW CHART OF THE WORK



Materials

a) Aggregate

The Aggregates required for the work such as coarse aggregates, fine aggregates is collected from a Kempanna and Son's crusher and Mix Plant located in Bidadi, Bengaluru.

The aggregates are processed by washing, drying and sieving. All the aggregates are sieved to the appropriate size according to different tests as per BIS guidelines and selected gradation for mix as mentioned in MoRT&H.

Table 1 : Test results of Coarse aggregates

Physical properties	Results	IS Code for test method	Required values as per MoRTH (V revision) Specifications, Table:500-18
Impact value	16.19	IS:2386 (Part-4)	Max 24%
Abrasion value	23.00	IS:2386 (Part-5)	Max 30%
Combined Flakiness and Elongation index	22.98	IS:2386 (Part-1)	Max 35%
Water Absorption	0.13	IS:2386 (Part-3)	Max 2%

b) bitumen

Bitumen acts as a binding agent to the aggregates in bituminous mixtures. Binder provides durability to the mix. The characteristics of bitumen which affects the bituminous mixture behaviour are temperature susceptibility, visco-elasticity and aging.

The Bitumen of grade VG-30 is used for the project and the binder is collected from a Kempanna and Son's crusher and Mix Plant located in Bidadi, Bengaluru.

Table 2 : Test results of Coarse aggregates

Type of test	Results	IS Code for test method	Required values For VG-30 as per IS:73 (2013)
Penetration test	51	IS: 1203 - 1978	Min-45 division
Ductility test	77	IS: 1208 - 1978	Min 40 cm
Softening point test	61.5	IS: 1216	Min 47°C
Specific gravity test	1.01	IS: 1202 - 1978	---

c) Reclaimed asphalt pavement material

Reclaimed asphalt pavement material is the material that obtained after removal of existing pavement which are aggregates and bitumen of the pavement.

The RAP material is collected from kerala rock crystals, near Sri Venkateshwara engineering college of engineering , chikkajala , Bangalore and it was of 8-10 years old pavement.

The binder content was found out to be 2.25%.

Table 3: Test results of RAP aggregates

Physical properties	Results	IS Code for test method	Required values as per MoRTH (V revision) Specifications, Table:500-18
Impact value	19.24	IS: 2386 (Part-4)	Max 24%
Specific gravity	2.55	IS: 2386 (Part-3)	2.5 to 3.0
Retained biumen content	2.25%	ASTM D 2172	-

d) Mineral filler

Mineral Filler Mineral filler consists of very fine, inert mineral matter that is added to the dense bituminous mix, to increase the density and enhance strength of the mixture. The Mineral filler is available which are free from organic impurities. The Mineral fillers may be cement, stone dust, fly ash or hydrated lime. In this study stone dust, fly-ash and GGBS is used as Filler content of about 2% by weight of bitumen is added in the preparation of dense bituminous mix.

1)Stone dust:

Stone dust, also known as stone screenings, is a by product of crushing stone. It is formed when the stones are crushed into different sizes, and dust is produced.

For our study stone dust was collected from Kempanna and sons stone crusher, Ramanagara.

2) Flyash:

Fly ash is a heterogeneous by-product material produced in the combustion process of coal which are used in power stations. It is a fine grey coloured powder which has spherical glassy texture that rise with the flue gases. As fly ash contains pozzolanic materials components this will react with lime to form cementitious materials. Thus Fly ash is used in concrete, mines, landfills and dams etc.

3) GROUND GRANULATED BLAST FURNANCE SLAG:

Slag is a by-product from steel plants obtained from blast furnaces, during the separation of iron from iron ore. This process involves cooling of the slag through high-pressure water jets, which enables the formation of granular particles. Then the granulated slag is further dried and then grinding is done in a vertical roller mill or rotating ball mill or roller press to form very fine powder, which is called as GGBS.

Table 4: Specific Gravity of Mineral Filler

Filler	Specific gravity
Stone dust	2.67
Fly-ash	2.7
GGBS	2.85

Table 5 : Sieve analysis of mineral fillers

Sieve size	Cumulative (%) passing by weight of total Aggregate			
	Obtained results, %passing			Requirements as per MORT&H (V revision), Table 500-9
	Stone dust	Fly-ash	GGBS	
600mm	100	100	100	100
300mm	100	100	100	95-100
0.075mm	91.20	93.2	95.50	85-100

IV. TEST ON BITUMINOUS MIXTURE

Marshall Stability Test

This test is conducted to determining the optimum bitumen substance bearing a maximum stability and other Marshall parameters.

Sample preparation for DBM mix:

The various size of aggregates were mixed in proportion obtained from the gradation and Marshall Samples were prepared at varying binder contents of 4%, 4.5%, 5%, 5.5% at increments of 0.5%. Around 1200gms aggregate is taken in combination of different sizes required for the mix and filler heated to a temperature of around 170℃ -180℃ for the preparation of specimen. Then the bitumen is heated up to a flowing state of around 125℃. The aggregates and bitumen are mixed well in the mixer or container at a temperature of around 165℃-185℃. The mix is now transferred to the preheated spicimen making mould and compacted with 75 blows on both side of specimen at a temperature of around 130℃-150℃. Once the mix is compacted the specimen is allowed to cool down for 24hrs and demould the specimen . The demoulded specimen is kept in water bath for 30 minutes which is maintained at a temperature of 60℃ . The specimen is placed in the Marshall Test setup, the load is applied at the constant deformation rate of 51mm per minute and load deformation readings are closely observed. The maximum load reading corresponding deformation of the specimen at failure load are noted. The maximum load value expressed in kg is recorded as the 'Marshall Stability' value of the specimen. The vertical deformation of the specimen corresponding to the maximum load is expressed in mm which is recorded as the 'Flow Value'. The specimen is removed from the test head and test is repeated on other specimen. Three specimens were casted for each binder content and average value is considered.

Figure 1: Specimen arrangement for marshall stability test

Indirect Tensile Strength Test

The effect of traffic load for a long period of time may affect the strength of an asphalt mixture which shows fatigue cracks or rutting.To determine and analyse this damage the Indirect Tensile Strength (ITS) is commonly used. To evaluate the ITS, the cylindrical specimen must be placed in the compression testing machine between the loading strips and the load is applied diametrically along the direction of the cylinder axis with a constant speed of displacement until it fails.The indirect tensile strength is the maximum tensile stress which is obtained from the maximum load applied at the failure of specimen and the dimensions of the specimen and calculated by the following eqn: ITS = $\frac{2P}{\pi DH}$

where ITS is indirect tensile strength,
expressed in Kg/cm2
P is the peak load, expressed in Kg
D is diameter of the specimen (in cm).
and H is height of the specimen(in cm).

Besides the strength of mixture is also compromised by water effect thus to evaluate its behavior and durability the ITS value was determinate after maintaining 0 degree temperature for 24 hour followed by 10,20,30,40,50 and 60 degrees in a water bath for 1 hour. we need to compare the ITS Values of specimen for different temperature with the standard room temperature of 28 degree Therefore, the following eqn has been adopted:

ITSR $=\frac{ITS\ (conditioned)}{ITS\ (standard)} \times 100$

where $ITSR$ is the indirect tensile strength ratio (%) is the ratio of average indirect tensile strength of the conditioned Kg/cm2 and ITS is the indirect tensile strength of the standard room temperature Kg/cm2.

Figure 2: Specimen arrangement for Indirect Tensile Strength test

Fatigue test

Fatigue cracking is the major distress in bituminous concrete pavements. This type of distress results from the application of repeated traffic loading which causes the failure in flexible pavements. The fatigue life of bituminous concrete pavements depends on the stiffness of the mix, bitumen content, viscosity of bitumen, softening point of bitumen, grading of aggregate, construction practice, traffic, and climate. Aggregate shape also indirectly influence the fatigue performance on applied strain.

Test procedure for conducting Fatigue test:

1. The prepared Marshall specimens were kept in water bath maintained at the desired temperature 25°C for about 2 hours before testing.
2. The specimen was placed in the testing mould on the bottom-loading strip. The holding bolts were tightened so that the specimen was held properly. The linear bearing was placed over the specimen.
3. LVDT's were fixed to measure horizontal and vertical deformation of the specimen under loading.
4. The load cell of the repeated loading machine was brought in contact with the linear bearing by operating the offset knob.
5. The visual basic program was opened and details of the test and specimen dimensions were entered and it was run.
6. The fatigue tests were carried out on VG 30 grade mix at 10%, 20%, 30% and 40% stress level at test temperature of 25°C for a frequency of 2 Hz and a rest period of 0.25 seconds by using half sine waveform to evaluate the fatigue characteristics of mixes.

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
(@ 25^0C, μ = 0.35 as per TRL)

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

Figure 3: Specimen arrangement for Indirect Tensile Fatigue test

V. Result and discussion

Optimum Bitumen Content

• The optimum Bitumen content for Dense Bituminous Macadam Mix prepared using Viscosity Grade (VG-30) with 30% RAP by varying mineral fillers such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 4.64%, 4.61% and 4.54% respectively.

Marshall Stability

• The Marshall Stability for Dense Bituminous Macadam Mix prepared at different RAP percentage such as 10% , 20% and 30% is 10.86 kN and 11.22 kN and 11.72 kN respectively.

• The Marshall Stability for Dense Bituminous Macadam Mix prepared at OBC using Viscosity Grade (VG-30) and RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 11.72 kN , 12.61 kN and 13.16 kN respectively.

Marshall Flow

• The Flow for Dense Bituminous Macadam Mix prepared at OBC using VG30 binder at different RAP percentage such as 10% , 20% and 30% is 3.21mm, 3.27, 3.3mm respectively.

• The Flow for Dense Bituminous Macadam Mix prepared at OBC using Viscosity Grade (VG-30) and 30% RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 3.3mm ,3.4mm and 2.9mm respectively.

Total Air Voids

• The Total Air Voids for Dense Bituminous Macadam Mix prepared at OBC using VG30 binder at different RAP percentage such as 10% , 20% and 30% is 4.52%, 4.75% and 3.45%respectively.

• The Total Air Voids for Dense Bituminous Macadam Mix prepared at OBC using Viscosity Grade (VG-30) and 30% RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 3.45%, 4.2% and 3.9% respectively.

Voids Filled with Bitumen

- The Voids Filled with Bitumen for Dense Bituminous Macadam Mix prepared at OBC using VG30 binder at different RAP percentage such as 10% , 20% and 30% is 71%, 69.84% and 76.65% respectively.
- The Voids Filled with Bitumen for Dense Bituminous Macadam Mix prepared at OBC using Viscosity Grade (VG-30) and 30% RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 76.65%, 68.12% and 69.23% respectively.

Indirect Tensile Strength Test

- The Indirect Tensile Strength (ITS) for Dense Bituminous Macadam Mix prepared at OBC for unconditioned specimen using VG30 binder at different RAP percentage such as 10% , 20% and 30% is 0.86Mpa, 0.86Mpa and 0.88Mpa respectively.
- The Indirect Tensile Strength (ITS) for Dense Bituminous Macadam Mix prepared at OBC for unconditioned specimen using Viscosity Grade (VG-30) and 30% RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 0.88Mpa, 0.84Mpa and 0.88Mpa respectively.
- The Indirect Tensile Strength (ITS) for Dense Bituminous Macadam Mix prepared at OBC for conditioned specimen using VG30 binder at different RAP percentage such as 10% , 20% and 30% is 0.71Mpa, 0.70Mpa and 0.72Mpa respectively.
- The Indirect Tensile Strength (ITS) for Dense Bituminous Macadam Mix prepared at OBC for conditioned specimen using Viscosity Grade (VG-30) and 30% RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 0.72Mpa, 0.75Mpa and 0.75Mpa respectively

Tensile Strength Ratio

- The Tensile Strength Ratio (TSR) for Dense Bituminous Macadam Mix prepared at OBC using VG30 binder at different RAP percentage such as 10% , 20% and 30% is 82.66%, 80.85% and 81.79% respectively.
- The Tensile Strength Ratio (TSR) for Dense Bituminous Macadam Mix prepared at OBC using Viscosity Grade (VG-30) and 30% RAP with different mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) is 81.79%, 89.15% and 87.64% respectively.

Fatigue Life

- The Fatigue life for Dense Bituminous Macadam Mix prepared using VG30 binder at 10% RAP are 7762 Cycles, 6459 Cycles,5147 Cycles and 4046 Cycles at 10%,20%,30%,40% stress level respectively.
- The Fatigue life for Dense Bituminous Macadam Mix prepared using VG30 binder at 20% RAP are 7704 Cycles, 6630 Cycles,5423 Cycles and 4369 Cycles at 10%,20%,30%,40% stress level respectively.
- The Fatigue life for Dense Bituminous Macadam Mix prepared using VG30 binder at 30% RAP with stone dust(2%) as filler are 7928 Cycles, 6685 Cycles,5486 Cycles and 4190 Cycles at 10%,20%,30%,40% stress level respectively.
- The Fatigue life for Dense Bituminous Macadam Mix prepared using Viscosity Grade (VG-30) and 30% RAP with fly-ash (2%) are 8322 Cycles, 4432 Cycles, 2393 Cycles and 1243 Cycles at 10%,20%,30%,40% stress level respectively.
- The Fatigue life for Dense Bituminous Macadam Mix prepared using Viscosity Grade (VG-30) and 30% RAP with GGBS (2%) are 8318 Cycles, 4461 Cycles, 2484 Cycles and1263 Cycles at 10%,20%,30%,40% stress level respectively.

Resilient Modulus

- The Resilient Modulus for Dense Bituminous Macadam Mix prepared using VG30 binder at 10% RAP are 698.81 MPa, 909.32MPa,1097.22 MPa and 1271.08 MPa at 10%,20%,30%,40% stress level respectively.
- The Resilient Modulus for Dense Bituminous Macadam Mix prepared using VG30 binder at 20% RAP are 696.4MPa, 863.3MPa,1002 MPa and 1166 MPa at 10%,20%,30%,40% stress level respectively.
- The Resilient Modulus for Dense Bituminous Macadam Mix prepared using VG30 binder at 30% RAP with stone dust(2%) as filler are 669.1 MPa, 814.3 MPa,1019.3 MPa and 1264.35 MPa at 10%,20%,30%,40% stress level respectively.
- The Resilient Modulus for Dense Bituminous Macadam Mix prepared Viscosity Grade (VG-30) and 30% RAP with fly-ash (2%) are 750.38 MPa, 1299.04 MPa, 1683.47MPa and 2086.44MPa at 10%,20%,30%,40% stress level respectively.
- The Resilient Modulus for Dense Bituminous Macadam Mix prepared Viscosity Grade (VG-30) and 30% RAP with GGBS (2%) are 750.10 MPa, 1294.74 MPa, 1695.11 MPa and 2106.97 at 10%,20%,30%,40% stress level respectively.

Initial Tensile strain

- The Initial Tensile strain for Dense Bituminous Macadam Mix prepared using VG30 binder at 10% RAP are 257.03Micro Strain, 260.48 MicroStrain,270.16Micro Strain and 284.67 Micro Strain, at 10%,20%,30%,40% stress level respectively.
- The Initial Tensile strain for Dense Bituminous Macadam Mix prepared using VG30 binder at 20% RAP are 259.79Micro Strain, 273.62 MicroStrain,294.34Micro Strain and 307.47 Micro Strain, at 10%,20%,30%,40% stress level respectively.
- The Initial Tensile strain for Dense Bituminous Macadam Mix prepared using VG30 binder at 30% RAP are 259.49 Micro Strain, 273.61 MicroStrain,294.34 Micro Strain and 307.47 Micro Strain, at 10%,20%,30%,40% stress level respectively.
- The Initial Tensile strain for Dense Bituminous Macadam Mix prepared using Viscosity Grade (VG-30) and 30% RAP with fly-ash (2%) are 234.23Micro Strain, 268.08 Micro Strain,311.62 Micro strain and 338.56 Micro Strain at 10%,20%,30%,40% stress level respectively.
- The Initial Tensile strain for Dense Bituminous Macadam Mix prepared using Viscosity Grade (VG-30) and 30% RAP with GGBS (2%) are 239.07Micro Strain, 274.31 Micro Strain,315.765 Micro strain and 342.02 Micro Strain at 10%,20%,30%,40% stress level respectively.

Figure 4: Marshall stability for different mixes

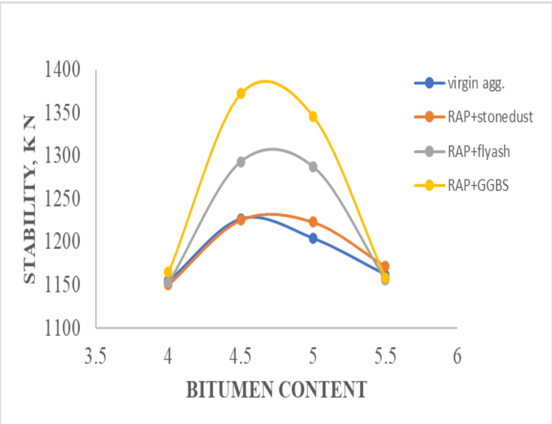
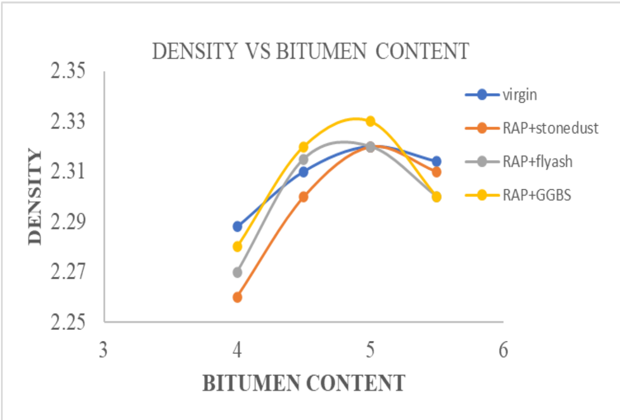


Figure 5: Flow value for different mixes



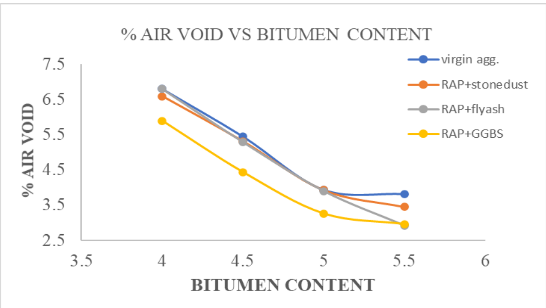


Figure 6: Percentage air void for different mixes

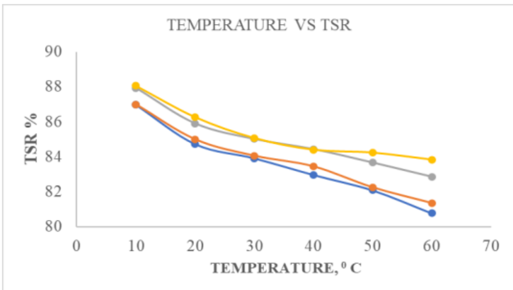


Figure 7: Density value for different mixes

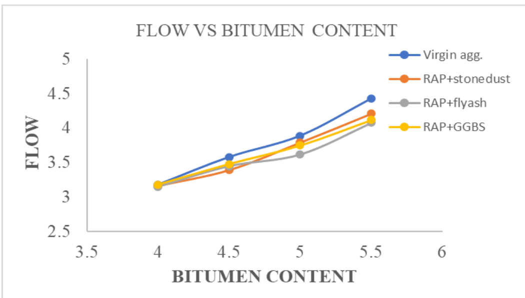


Figure 8: Tensile strength ratio for different mixes

VI. CONCLUSIONS

- Dense bituminous macadam mix prepared using VG-30 as binder with different percentage of RAP aggregate (10% to 30%) are satisfying the requirements as per MORT&H (Vth Revision) specification.
- Dense bituminous macadam mix prepared using VG-30 as binder with mineral filler such as stone dust (2%), fly-ash (2%) and GGBS (2%) are satisfying the requirements as per MORT&H (Vth Revision) specification.
- The optimum bitumen content for Dense bituminous macadam mix with stone dust (2%) as filler is found to be 4.64% and optimum RAP aggregate content is found to be 30% for the OBC.
- The optimum bitumen content for Dense bituminous macadam mix with optimum RAP and fly-ash (2%) and GGBS (2%) as mineral filler is found to be 4.61% and 4.54% respectively.
- The GGBS (2%) in the bituminous mix increases the stability of DBM . The result shows that the stability of DBM is more with GGBS as filler compare to the mix with other fillers that is fly-ash and stone dust of same percentage.
- The stability value, Air voids and Unit weight varies in the same pattern for the mix with different percentage of RAP and all are within the range for the mix with optimum bitumen.
- There is an increase in stability value, Air voids and Unit weight up to certain binder content value and then decrease on both conventional bituminous mixes and the mix with different mineral fillers and these found to be maximum for the mix with GGBS (2%) as filler.
- The Indirect Tensile Strength and Tensile Strength Ratio for Dense bituminous macadam mix prepared using VG-30 at OBC and 30% RAP with GGBS (2%) is performing better when compared to the mix, prepared using stone dust(2%) and fly-ash(2%) as mineral filler.
- Dense Bituminous Macadam mix prepared using VG-30 and RAP aggregate at OBC with GGBS (2%) as mineral filler showing better performance in terms of Fatigue behaviour when compared to VG-30 as binder with 30% RAP and stone dust (2%) and fly-ash (2%) as mineral filler.
- Based on the laboratory studies carried out, it can be concluded that the dense bituminous macadam mix can be prepared using 30% of RAP aggregate with GGBS (2%) as filler material is superior and its performance is better than the dense bituminous macadam mix prepared using stone dust (2%) and fly-ash (2%) as filler material.

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