STUDIES ON LABORATORY PERFORMANCES OF BITUMINOUS CONCRETE MIXES USING DIFFERENT FILLERS

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Abstract: *Over the past twenty years road traffic has grown significantly. So, the good design of bituminous concrete mix is expected to result in a mix which is adequately strong, durable and resistive to fatigue and at the same time environment friendly and economical. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions of material combinations and finalizes the best one. The Modification of bitumen is one of the alternate solutions to improve the deficiencies of conventional bitumen. Use of modified bitumen and fillers affects the Marshall properties, strength and also increases the fatigue life. From the literature review, it was found that modified binder stiffens the mixes to reduce the thermal cracking and rutting. Fillers act as anti-stripping agents to mixes, fills the voids and help in bonding of the aggregates and binder strongly. In the present study, an attempt is made to design the bituminous concrete mixes by Marshall Method using Bituminous concrete(Grading-II) mix of VG 30 and PMB-40 with two different fillers i.e., BAGHOUSE and STONE DUST In this study, conventional bitumen was obtained locally and aggregates from single source are used to design bituminous mix. From literature, it is evident that the performance of bituminous mix is affected by the use of different fillers and it is also observed that the performance varies with varying stress level and temperature. In the present study the observation was made that the BC mix prepared using PMB-40 with Bag house dust is superior when compared to BC mix of VG-30 with Bag house dust and stone dust, PMB-40 with Stone dust as filler material.*

Keywords: Marshall Properties, ITS, TSR, BH, Stone Dust, VG-30, PMB-40.

1. INTRODUCTION

Bituminous concrete mix consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through the fine filler that is smaller than 0.075mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical.

1.1 Conventional Paving Bitumen

Paving grade bitumen which is obtained from the distillation process of petroleum crude is extensively used in the construction of flexible pavement layers, particularly in surface and binder course. At normal range of atmospheric temperature, bitumen is in semi-solid state and remains highly viscous and sticky. When the paving grade bitumen is heated, it softens at a rapid rate and attains fluid consistency and the viscosity decreases with further increase in temperature. For the construction of bituminous pavements, the paving grade bitumen is heated to temperatures in the range of 130 to 175°C or even higher, depending upon the type and grade of bitumen selected and the type of the construction work. Mixing of bitumen with the aggregates is done in a hot mix plant to obtain 'hot bituminous mix'.

1.2 Polymer Modified Bitumen (IRC SP 53-2010)

The properties of bitumen and bituminous mixes can be modified with the incorporation of certain additives or blend of additives. And these additives are called "Modifiers" and the bitumen which are blended with the modifiers are known as "Modified Bitumen". Use of modified bitumen in the top layers of the flexible pavement is expected to significantly improve the life of the surfacing and extend the time of the next renewal of the surfacing. Full-scale performance studies on overlay carried out by the various research institutions, Indian Institutes of Technology under the agency of Ministry of Road Transport and Highways, Central Road Research Institute, Highways Research Station, Chennai, Rubber Board, Kerala, Gujarat Engineering Research Institute, and various state Public Works Departments showed that the use of Modified Bitumen in construction or maintenance of bituminous roads significantly enhance the pavement performance and is cost effective.

1.3 Application of Polymer Modified Bitumen

Since a bituminous mix prepared with modified bitumen has a higher stiffness modulus, enhanced fatigue life, better resistance to creep and higher indirect tensile strength, it is suitable as a wearing course, a binder course and overlay material on surfaces which are cracked and subjected to heavy traffic. Modified binders are also used for application like stress absorbing membrane (SAM) for sealing of cracks, stress absorbing membrane interlayer (SAMI) for delaying reflection cracking. Modified bitumen performs better than conventional bitumen in situations, where the aggregates are prone to stripping. Due to their better creep resistance properties, they can also be used at busy intersections, bridge decks and roundabouts for increased life of the surfacing.

1.4 Objective of the mix design

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

- Sufficient bitumen to ensure a durable pavement

- 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 resistance to avoid premature cracking due to repeated bending by traffic
- Sufficient resistance at low temperature to prevent shrinkage cracks

2. OBJECTIVE OF THE PRESENT STUDY

1. To design bituminous concrete mixes using VG-30 and PMB-40 as binders with grade II aggregate gradation by Marshall Mix design method using stone dust and Bag House dust as fillers.
2. To compare the Marshall properties of conventional (VG-30) bituminous concrete (BC) mix and polymer modified bituminous concrete (PMBC) mix.
3. To determine the Indirect tensile strength (ITS) of bituminous concrete mix with VG-30 and PMB-40 as binders at four different stress level viz., 10, 20, 30 and 40% respectively.

3. LITERATURE REVIEW

Amol sharma et al [1] carried out research to analysis and determine the effects of "Baghouse Fines" in the asphaltic concrete mixes. The analysis includes carrying out Marshall Tests on asphaltic mixes having various filler/baghouse fines ratios. Sieve analysis and hydrometer analysis were used to produce gradations for aggregate mixtures with baghouse fines. Chemical properties of baghouse fines were determined using X-ray fluorescence machine. The results of the study indicate that indicate that baghouse fines can greatly affect the properties of the design mix, such as the stability values, the flow values and the optimum asphalt content. The chemical properties of baghouse fines indicate the absence of any harmful heavy metal in the baghouse fines. It is anticipated that the results of this study will be of great help in the improvement of local mix properties. Mixes which utilize approximately 50/50 ratio of fines to baghouse fines are optimum design mixes because of their satisfactory Marshall properties and are recommended to be used during the construction of asphaltic concrete layers in the roads. Due to the inclusion of baghouse fines in design mix the problem of pollution due to baghouse fines can be resolved and the cost of dumping of baghouse fines in landfills can also be reduced.

Jaroslaw Wilanowics et al [2] The paper presents the study results of the structural features and functional properties of the limestone filler as well as the basalt and amphibolite dusts from a dust extractor of a Hot-Mix Asphalt plant in Poland. Additionally, the selected physical and mechanical properties of asphalt concrete 0–16 mm in laboratory conditions were evaluated. The principal purpose of the study is to understand the structural and functional properties of baghouse dusts and "fillers mixed" from the perspective of their use as fillers for Hot-Mix Asphalt (HMA). The analysis of the results of grain-size distribution, specific surface, air voids of dry compacted fillers, increase in the softening point using the Ring & Ball method, as well as selected properties of the AC 16, all have shown that the studied baghouse dusts meet the requirements of fillers for HMA. Research results have also shown that these dusts as "fillers mixed" with limestone filler optimally meet the requirements of fillers for HMA. Presented results contribute substantially to expending the knowledge in the field of the quality, structure and functional properties of fillers. Therefore, it can be conceded that the analysed mineral dusts as a basis filler, and the dust-lime mixtures as mixed filler, can be used effectively in HMA.

Bassam A et al[3] The objective of this study was to determine the effects of baghouse fines on asphalt mixes. The analysis included Marshall tests on mixes that had various ratios of filler to baghouse fines. Other tests to study these effects included stability loss, viscosity, penetration, shear-modulus, and softening point. The results of the study indicated that baghouse fines can greatly affect the properties of the mix, such as the optimum asphalt content, stability, and stability loss. Asphalt mortars that used different ratios of filler to baghouse fines exhibited varied viscosity and penetration. Stability loss, which is a main factor in the design of local mixes, was decreased drastically by the inclusion of baghouse fines. One factor that controls the effect of baghouse fines on asphalt mixes was the percentage. of carbon. It is anticipated that the results of this study will be of great help in the improvement of mix properties by incorporating baghouse fines. Baghouse fines, if properly blended with filler, should reduce stability loss and affect the optimum asphalt content of the mix. Mixes that use approximately a 50/50 ratio of filler to baghouse fines are the optimum mixes.

4. MATERIALS USED

4.1 Aggregates

Generally, aggregate particles are divided to fine and coarse aggregate. Coarse aggregate can be defined as particles larger than 2.36mmIS sieve and fine aggregate as smaller particles passing 2.36mm IS sieve.

All aggregate particles should satisfy some specified standard test level to be suitable for applying in bituminous mixture. Some of the important tests carried out are Los Angeles abrasion test, Aggregate impact test, Flakiness and Elongation index test, Water absorption test and Aggregate Specific gravity test.

Aggregates constitute of approximately 88 % to 96 % by weight and volume of the total mix. Aggregates are divided into coarse aggregates and fine aggregates materials. Aggregates smaller than 25 mm in size and larger than 2.36 mm in size are regarded as coarse aggregates and aggregates smaller than 2.36 mm in size and larger than 75 μ in size are taken as fine aggregates.

For the present study aggregates are collected from M/s Kaveri asphalts, Bengaluru, Karnataka.The test results are presented in Table 1.

Table -1: Test results of aggregates

Aggregate Test	Test result	Requirement as per MoRT&H (V Revision) 2013 specification
Aggregate impact value (%)	22.40%	Max 24%
Los Angeles Abrasion value (%)	21.60%	Max 30%
Aggregate crushing value (%)	22.83%	Max
Flakiness and Elongation Index (Combined) (%)	28.03%	Max 35%
Water absorption (%)	0.2	Max 2%
Aggregate specific Gravity		
Coarse aggregates	2.64	--
Fine aggregates	2.67	--

4.2 Mineral Fillers

Aggregate passing through 0.075 mm IS sieve is called as filler. It fills the voids, stiffens the binder and offers permeability. Filler acts as one of the major constituents in bituminous concrete mixture. Rock dust, Portland cement, lime, fly ash etc. are commonly used as fillers. Fillers not only fill voids in the coarse and fine aggregates but also affect the ageing characteristics of the mix. In the present study **Bag house dust and stone dust** is used as a filler material.

Stone dust is one of the conventional filler is used in bituminous concrete mix. Stone dust is obtained from the quarry whose size varies from 300 microns to 75 microns passing. In the study material passing 75 microns is considered as filler.

Baghouse fines are the airborne particles separated from the gas streams on a bag like filters. When using a baghouse collector, dust is collected on the outer surfaces of filter bags. The bags are automatically cleaned at regular intervals by forced air (Figure 3.4) causing them to expand and break free the dust caked on their outer surfaces The bags are normally constructed of aramid fibers which are felted onto a screen. The felt is then made into a sock-type bag. Each bag fits over a wire cage for support. The bags and cages fit into a tube sheet, which is the top wall of the baghouse.

The Specific gravity of stone dust & GGBS are shown in Table 2

Table-2: Specific Gravity

Filler	Specific gravity
Stone dust	2.60
Bag House Dust	2.58

4.3 Bitumen Binder

Bituminous binders are very commonly used in surface course of pavements they are also used in the base course of flexible pavements to withstand relatively adverse conditions of traffic and climate. In the present study, VG-30 and PMB 40 grade is used as binder. VG-30 binder is locally available, Bengaluru and PMB 40 binder is collected from M/S HINCOL, Mangalore.

The test results for VG-30 grade binder satisfy requirements as per IS 73-2013.

The test results for PMB 40 grade binder satisfy requirements as per IRC SP 53-2010.

The test results of VG-30 and PMB 40 binder are presented in Table 3.

Table -3: Test results of Bitumen VG-30 & PMB-40

Tests on Bitumen	Results of VG-30	Results of PMB-40	Requirement as per Table- 1 IS 73- 2013 & SP 53-2010 Specifications
Penetratio n at 25^{0}C	65	39	Min-45(VG-30) 30-50(PMB-40)
Softening point , ^{0}C	54	68	Min 47(VG-30) Min 60(PMB-40)
Flash point , ^{0}C	248	256	Min 220
Fire point , ^{0}C	276	280	Min 240
Ductility @27^{0}C, cm	84	90	Min 40
Specific Gravity	1.01	1.03	---

4.4 Gradation of Aggregate

Aggregate size and gradation is one of the important factors in pavements and can influence most properties of bituminous mixture. Gradation or distribution of particle sizes can be achieved by passing the aggregate particles through the standard sieve stacked and calculating the percent of retained aggregate on each sieve. Control the material and select desirable size, minimize cost, and optimize use of local available aggregate are some main aims of the gradation.

In the present investigation aggregate gradation for bituminous concrete mix (Grade-II) as per MORT&H (VTH Revision) specifications using mid limit gradation is adopted. The details are shown in Table 4 and in Figure 1.

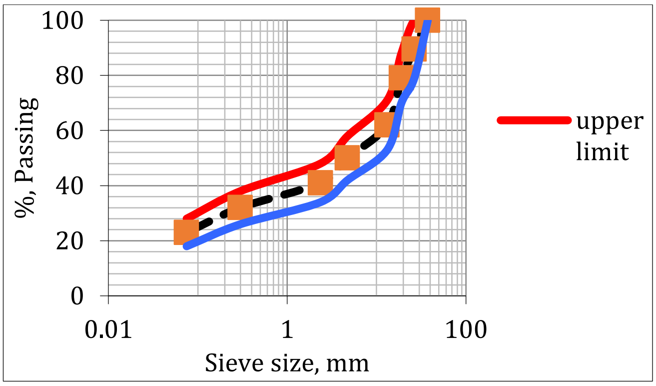

Fig-1: Aggregate Gradation of BC-II Mix

Table -4: Gradation of aggregates of DBM mix (Grade II)

Sieve Size, mm	Gradation of aggregates as per MORT&H (V^TH Revision) specifications	
	% Passing (Specified)	% Passing (Mid Limit)
19	100	100
13.2	90-100	89.5
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.60	26-38	32
0.30	18-28	23
0.15	12-20	16
0.075	4-10	7

5. ANALYSIS OF THE DATA

5.1 Binder optimization by Marshall Method

In order to determine the optimum binder content for this type of mixture four different percentages of bitumen content are used (4.5, 5.0, 5.5, 6.0) % respectively by weight of aggregate. The optimum binder content is determined by the ability of a mix to satisfy the Mechanical properties and volumetric properties. The data obtained from Marshall stability-flow test are used to plot the Marshall properties versus bitumen content, from these plots optimum bitumen contents are determined corresponding to maximum stability, maximum bulk density and 4% air voids in total mix. The optimum bitumen content of the mix is the numerical average of the three values for bitumen contents determined as above.
Marshall properties of bituminous mix with baghouse and stone dust as fillers. The relationship between Marshall properties and bitumen content is shown and the test results are in Table 5 and Table 6.

Table -5: Results of Marshall Properties of Binder VG-30.

Sl No.	Marshall Properties	Test Results of VG-30 with stone Dust	Test Results of VG-30 with BH	Requirements as per Table-500-10 of MORT&H (V Revision)
1	Optimum Bitumen Content, %	5.46	5.43	5.40 (Min.)
2	Marshall Stability, kg	1208	1318	900 (Min.)
3	Flow, mm	3.12	3.09	2.0 - 4.0
4	Air voids(Vv), %	3.58	3.42	3.0 - 5.0
5	Voids filled with Bitumen (VFB), %	77.20	77.45	65-75

Table -6: Results of Marshall Properties of Binder PMB-40

Sl No.	Marshall Properties	Test Results of PMB-40 with stone Dust	Test Results of PMB-40 with BH	Requirements as per Table-500-10 of MORT&H (V Revision)
1	Optimum Bitumen Content, %	5.48	5.45	5.40 (Min.)
2	Marshall Stability, kg	1260	1390	1200 (Min.)
3	Flow, mm	3.13	3.20	2.0 - 4.0
4	Air voids(Vv), %	3.74	3.60	3.0 - 5.0
5	Voids filled with Bitumen (VFB), %	76.52	76.85	65-75

The comparative graphs are plotted for Marshall Properties of Bituminous Concrete (Grading II)Mix prepared using VG-30 & PMB- 40 with 2% Baghouse & 2% Stone Dust as mineral fillers are shown below in the Figures 2, 3, 4 & 5.

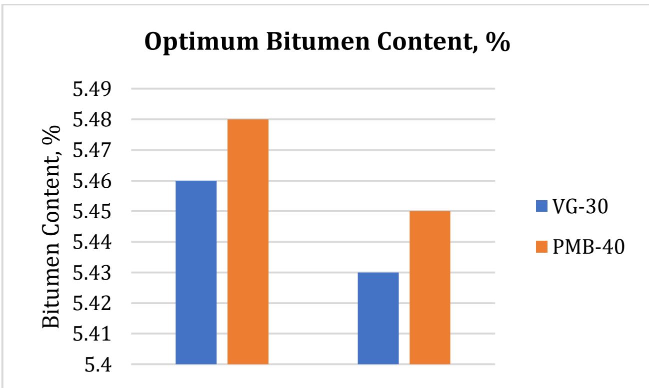

Figure -2: OBC for VG-30 & PMB-40 with Mineral Fillers

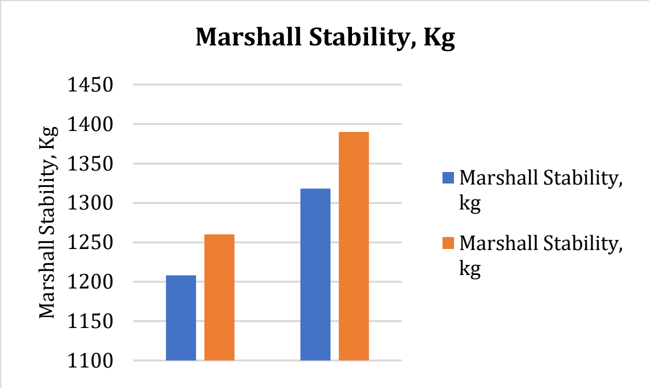

Figure -3: Marshall Stability for VG-30 & PMB-40 with Mineral Fillers

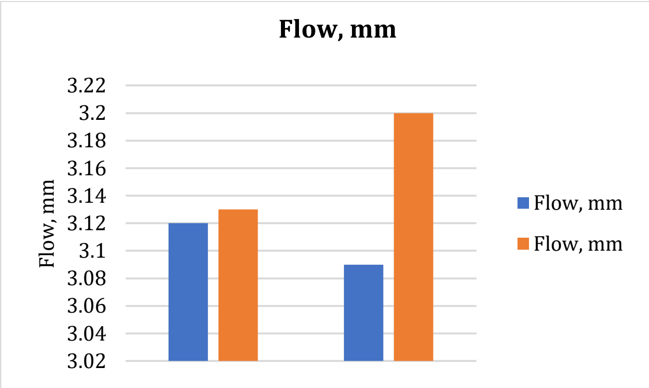

Figure -4: Flow Value for VG-30 & PMB-40 with Mineral Fillers

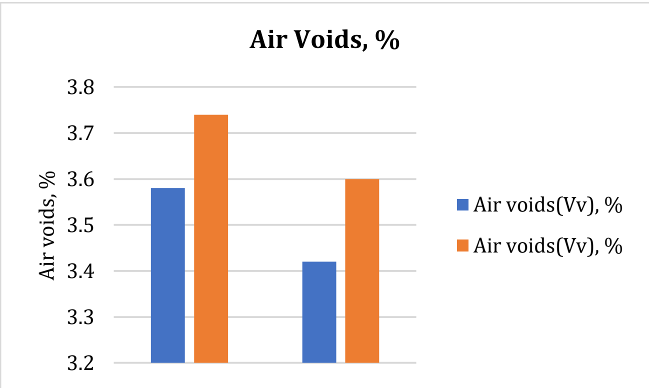

Figure -5: Air Voids, % for VG-30 & PMB-40 with Mineral Fillers

5.2 Indirect Tensile Strength

Indirect Tensile Strength test is conducted on Bituminous Concrete mix (Grading-II) prepared using stone dust (2%) and BH (2%) as mineral filler at optimum bitumen content of binders VG- 30 and PMB- 40. Specimens are conditioned at 25°C in water bath for duration of 2 hours.

5.3 Moisture susceptibility test: tensile strength ratio

Moisture damage in bituminous mixes refers to the loss of serviceability due to the percent of moisture. The extent of moisture damage is called the moisture susceptibility. The Indirect Tensile Strength test is a performance test which is often used to evaluate the moisture susceptibility of a bituminous mixes. Tensile Strength Ratio (TSR) is a measure of water sensitivity or to say moisture susceptibility. Tensile Strength Ratio is expressed as the percentage of ratio of average indirect tensile strength of the conditioned specimen to the average indirect tensile strength of the unconditioned specimens and the results are shown in table 8 with graph of Figure-6.

Table -8: ITS for binders VG-30 & PMB-40 with fillers.

Mix Type	Indirect Tensile Strength, N/mm^2		TSR, %	Requirements as per Table 500-38 MORT&H (V Revision) Specifications
	Unconditioned at 25°C	Conditioned at 60°C		
VG-30+SD	1.053	0.946	89.81	Min 80%
VG-30+BH	1.005	0.909	90.49	
PMB+SD	1.087	0.981	90.27	
PMB+BH	1.054	0.974	92.41	

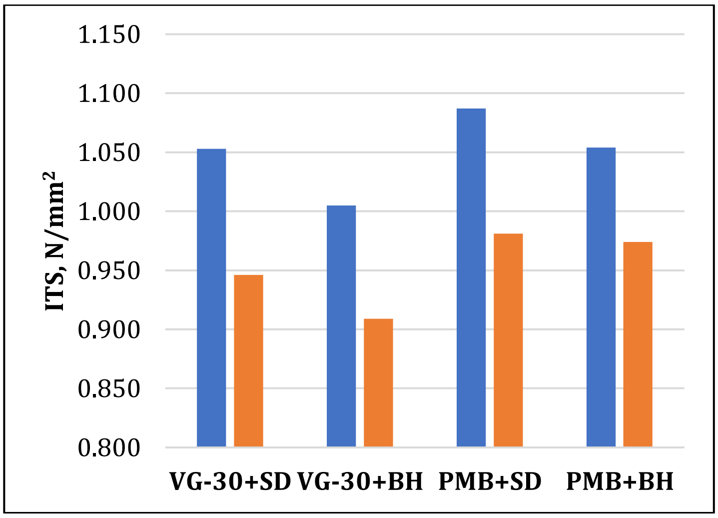

Figure -6: ITS for binders VG-30 & PMB-40 with fillers.

6. CONCLUSONS

1. The optimum bitumen content for BC mix of PMB-40 with stone dust and Bag House dust as filler is excessive when compared to BC mix of VG-30 with Stone dust and Bag House dust as fillers.
2. The Marshall properties of BC mix of PMB-40 is superior than BC mix of VG-30 with Stone dust and Bag House dust as filler.
3. The ITS values of BC mix of PMB-40 is higher than that of BC mix of VG-30 with Stone dust and Bag House dust as fillers, thus from ITS results it can be stated that PMB-40 mix performs better than conventional VG-30 mix.

4. BC mix of PMB-40 are less temperature susceptible than BC mix of VG-30 with Stone dust and Bag House dust as fillers.

REFERENCES

1. **Jaroslaw Wilanowics & Wojciech Grabowski** "Assessment of the suitability of baghouse dusts from a dust extractor as fillers for hot-mix asphalt". (ELSEEVIER)
2. **Bassam A ,Anani and Hamad I** "Effect of baghouse fines and mineral filler on properties of asphalt mixes".(Transportation research record 843)
3. **Amol Sharma and SK Singh** "Use of Baghouse fines from Hot Mix Plant in Ashaltic Concrete".
4. **IRC SP 53-2010** "Specifications for modified bitumen" Indian road congress, New-Delhi.
5. **IS 73-2013** "Specification for paving bitumen" Bureau of Indian Standards, New Delhi.
6. **MORT&H "**Specifications for Road and Bridge Works**"- 2013**, Fifth Revision, Indian Roads Congress, New Delhi.
7. **IRC 111-2009, "**Specification for Dense Graded Bituminous Mixes", Indian Road Congress, New-Delhi, India.
8. **IS 15462-2004** "Polymer and Rubber modified Bitumen Specifications" Indian Road Congress, New Delhi, India.
9. **ASTM D 6931 (2012), "**Indirect Tensile (IDT) Strength for bituminous mixtures" American Society for Testing and Materials, Philadelphia, USA
10. **ASTM D 4123-82 (1995),** "Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures", American Society for Testing and Materials, Philadelphia, USA.
11. **ASTM D 6926-10 (2010)**, "Standard Practice for Preparation of Bituminous Specimens using Marshall Apparatus", American society for testing materials, Philadelphia, USA
12. **Khanna S.K., Justo C.E.G. and Veeraragavan A**, A Text Book on "Highway Engineering", Revised 10th Edition, Nem Chand & Bros., Roorkee, India, ISBN 978-81-85240-80-0.