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A Comparative Study on Effects of SBR & PP Polymer Blends with Conventional Performance of Asphalt Mixture.

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Abstract: *Bituminous mixes are most commonly used throughout the world in flexible pavement construction. It consists of asphalt or bitumen (used as binder) and mineral aggregate which are mixed together, spread in layers and then compacted. Research has shown the mixing of Styrene Butadiene Rubber and Poly Propylene to asphalt binder's helps in increasing the interfacial cohesiveness of the bond between the aggregate and the binder which can improve many properties of the asphalt pavement to cope up with this increased demand.*

Styrene Butadiene Styrene has been found to be good modifier of bitumen. In the present study, an attempt has been made to use Styrene Butadiene Rubber and Poly Propylene along with sulphur as a stabilizer. Detailed study on the effects of this polymer blend in the engineering properties of Bituminous Concrete has been made in the study.

Optimum binder content (OBC) has been derived by using Marshall Procedure. In total 12 samples were prepared of various % Polymer Bitumen Content (4.5 %, 5.0 %, and 5.5 %) along with 3 Conventional samples. The test includes the evaluation of Bulk Density, Stability, Flow Value, % Air Voids (Vv), Voids in Mineral Aggregates (VMA) and Voids Filled with bitumen (VFB). The OBC have been found to be 5.5% with Polymer blend 5.0% for Bituminous Concrete. This research also deals with the conclusion of various test performed on aggregate, bitumen and methodology of using Polymer Blend Styrene Butadiene Rubber and Poly Propylene in Bituminous Mixture.

Index Terms – Hot mix Asphalt, Polymer Blend, strength, SBR, PP.

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I. INTRODUCTION

Road construction with bitumen is gaining popularity now a day because of its good flexibility and price is lower than that of concrete. However when the roads are constructed with bitumen they show great variation on temperature such that as the increase of temperature bitumen softens and as the decrease of temperature bitumen shows cracks. Heavy traffic also causes damage to pavement which in turn requires regular maintenance. Therefore, it is necessary to improve the quality of bitumen by mixing some material which is useful in enhancing its properties (Seyed Ali Mojabi et al., 2020). Many studies have been done to find other material to use as modifiers in bitumen mixes on the improvement of highway quality. Various methods are continuously executed and out of these bitumen modified with polymer blend is very popular.

Polymer modified bitumen can be used as an environment-friendly modification process to decrease the deterioration of pavement due to increase in axle loading, high traffic density and low maintenances which has subjected flexible pavement to fail more quickly. It is very effective to use Polymer blend in bitumen because of low periodic maintenance, driving comfort and increased road life. Polymer modified asphalt made by mixing Styrene Butadiene Rubber & Polypropylene into bitumen at various percentages. The Polymer blend mixed with bitumen enhances the engineering properties of asphalt mixtures. It also improves the rutting resistance & cracking resistance characteristics, enhances the quality of pavement while riding and decrease the traffic noise of bituminous pavements (Ana Jimenez del et al., 2020).

II. LITERATURE REVIEW

Seyed Ali Mojabi et al (2020) studied; solid C25 composite fibres and SBS polymer were added to SMA mixture at a specific ratio and with different percentages to improve the performance of asphalt mixture. C25 fibres are composed of 75% wt. Arbocel cellulose fibre and 25% wt. The best enhanced indirect tensile strength is resulted by addition of 0.4% C25, which improves the parameter by 38% compared to the unmodified specimen in dry mode and by 116% compared to unmodified specimen in saturated mode.

Ana Jiménez Del Barco Carrion et al (2020) studied Cost effective optimization of modified bitumen with liquid rubber for pavements and roofing membranes is presented. Design optimization technique allowed producing superior bituminous binders. LR improves the flexibility at low in service temperatures (using up to 50% contents), while EBS improves stiffness at high in-service temperatures. The Response Surface Methodology was successfully used to optimize the final blends also in terms of cost. Analytical functions amongst the design parameters have been derived and here provided for future design exercises.

Mahmoud Enieb et al (2020) studied elastomer [commercially available styrene-butadiene-styrene (SBS) and a plastomer (functionally modified olefin commercially known as Eastman EE-2)], blended separately with two penetration-grade binders (60=70 and 80=100) at polymer/binder ratios of 2%, 4%, and 6% (by mass). The rheological properties of the polymer-modified binders (PMBs) were tested using a rotational viscometer, dynamic shear rheometer, and bending beam rheometer. The effect of the polymers on the rheological properties of the asphalt binders was investigated before and following standardized short- and long-term oxidative aging. Hot-mix asphalt mixes were prepared and evaluated in terms of the number of performance tests, which included indirect tensile strength, moisture susceptibility, resilient modulus, creep-recovery strain properties, and indirect tension fatigue.

Mohammed Belmokaddem et al (2020) study we evaluated and compared the impact of substituting both fine and coarse aggregates with three plastic wastes. The wastes were; polypropylene PP, high-density polyethylene HDPE, and polyvinylchloride PVC based. Different amounts (25, 50 and 75%) of natural aggregates were substituted with the same volume of plastic aggregates. In addition to morphology, thermo-mechanical and acoustic properties, their environmental impact were evaluated. The results show, that plastic waste has a positive effect by decreasing the density. Moreover, the concrete with 75% of PE aggregate presents the lowest dynamic elastic modulus; which correspond more ductile composite. Incorporating 75% of PVC aggregates into concrete caused the thermal conductivity to decrease until 0.61 W/mk. The use of plastic wastes in concrete allows developing a composite material with interesting acoustic insulation characteristics.

III. MATERIAL REQUIRED

1. Aggregate :

The aggregate forms the major part of the pavement structure as they primarily bear high magnitude of load stresses occurring on the pavement. The physical properties of aggregate ware studied to determine its performance under the severe conditions [18: 2386- l963 (part1- 6)].

2. Binder :

Bitumen is a common binder used in flexible pavement construction. When the higher fractions of diesel, kerosene, petrol, gas etc. are removed from product of petroleum refineries, the residual obtained is known as bitumen. Bitumen is a dark brown or black non- crystalline viscous material derived from petroleum crude having adhesive properties. The bitumen is used as a binder material in the bituminous mix.

3. Styrene Butadiene Rubber :

The copolymerization of Styrene and Butadiene Produces the SBR polymer. The Butadiene soft monomer changes the elasticity of the binder and makes it more flexible, while the Styrene hardener monomer makes the binder hardener and increases its softening point.

4. Poly Propylene :

Poly Propylene can be synthesized by propylene polymerization in a mild pressure and temperature by considering a catalyst. Thermoplastic polymer increases the strength against the load induced deformation by creating asphalt rigidity.

Fig.No.1 Appearance of SBR/PP Polymer Blends

5. Sulphur :

One of the most important issues in polymer application in asphalt is storage stability, in this study, 1.5 % Sulphur (weight of the binder) was used to improve the storage capacity of the polymer in modified binders.

Fig.No.2 Appearance of Sulphur

IV. OBJECTIVES OF THE STUDY

- To evaluate the suitability of Styrene Butadiene Rubber and Poly Propylene in Bituminous Concrete using Sulphur as a Stabilizer.
- To evaluate the strength characteristics of Hot Mix Bituminous Concrete modified using Styrene Butadiene Rubber and Poly Propylene.

V. NEED OF THE STUDY

- Today's bituminous concrete pavements are expected to perform much better as they are experiencing very large increased volume of traffic, increased loads and increased variations in daily and seasonal temperature over what they has experienced in the past.
- Researchers suggest that water does not have adverse effects on Styrene Butadiene Rubber & Polypropylene and use of Styrene Butadiene Rubber & Polypropylene increases strength of bituminous concrete by some extent. The utilization of Styrene Butadiene Rubber & Polypropylene in bituminous concrete will definitely give a new dimension to the bituminous construction.
- Study is required to analyze the effects of Styrene Butadiene Rubber & Polypropylene in strength characteristics of bituminous concrete.

VI. RESEARCH METHODOLOGY

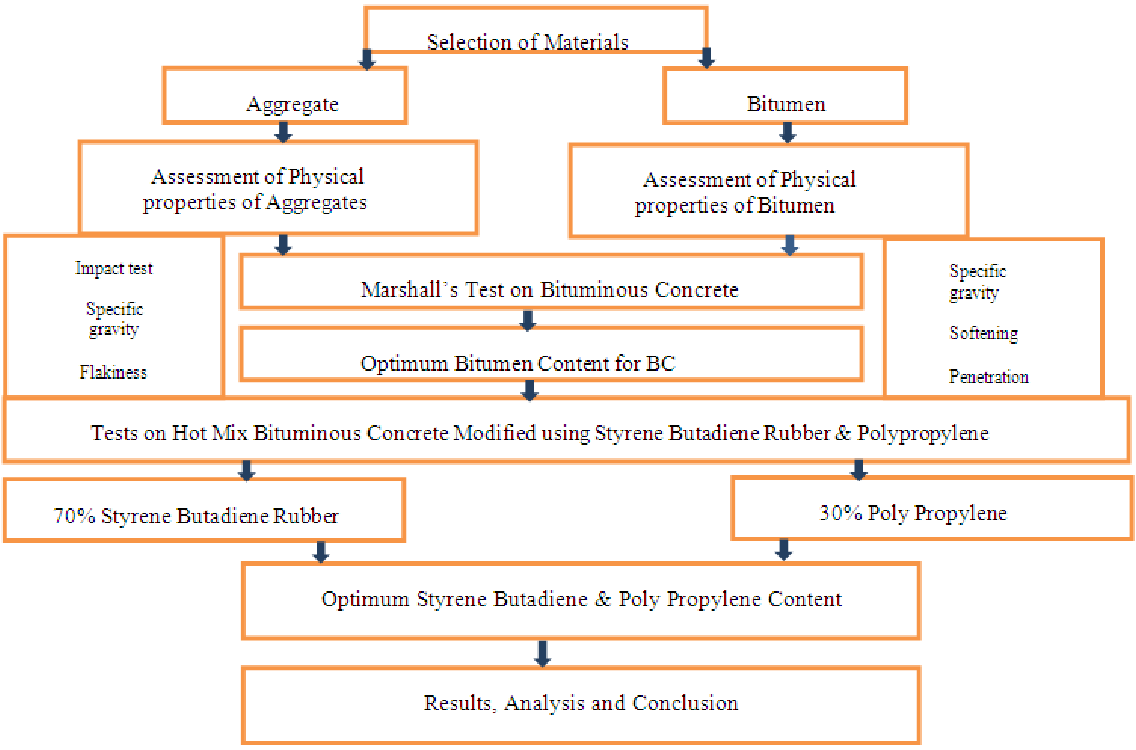


Fig No. 3 Methodology for the Evaluation of Strength Characteristics of Hot Mix BC using Styrene Butadiene Rubber & Poly Propylene

VII. EXPERIMENTAL INVESTIGATION

Aggregate: The aggregate forms the major part of the pavement structure as they primarily bear high magnitude of load stresses occurring on the pavement. Table no.1 list of tests performed on the aggregates.

Table No. 1 Test Methods of Aggregates

S. No.	Name of Test	Test Method
1	Aggregates Impact Value Test	IS: 2386 - Part 4
2	Specific Gravity Test Water absorption	IS: 2386 - Part 3
3	Los Angeles Abrasion Value Test	IS: 2386 - Part 4
4	Aggregates Crushing Value Test	IS: 2386 - Part 4
5	Combined Flakiness and Elongation Index	IS:2386 - Part 1
6	Water absorption Test	IS: 2386 - Part 3

Bitumen: It is a common binder used in flexible pavement construction. When the higher fractions of diesel, kerosene, petrol, gas etc. are removed from product of petroleum refineries, the residual obtained is known as bitumen. Table no.2 shows the list of tests performed on the Bitumen.

Table No. 2 Tests Performed on VG-30 Grade Bitumen and Test Methods

S. No.	Name of Test	Test Method
1	Specific gravity at 27^0C	IS: 1202
2	Ductility at 27^0C	IS: 1208
3	Softening Point	IS: 1205
4	Penetration at 25^0C	IS: 1203
5	Flash & Fire Point	IS: 1209

Styrene Butadiene Rubber: Styrene Butadiene rubber from the family of elastomers also can improve the elastic and flexible properties of asphalt. Table no.3 shows the properties of the Styrene Butadiene Rubber.

Table No. 3 Properties of Styrene Butadiene Rubber

S. No.	Property	Specification
1	Styrene Content %	22.5-24.5
2	Organic Acid %	2.8
3	Tensile Strength Mpa	24.5
4	Elongation at Break %	>350
5	Ash	0.20
6	Density	0.98

(Source: Mostafa Vamegh et al., 2020)

Poly Propylene: Poly propylene can be synthesized by propylene polymerization in a mild pressure and temperature by considering a catalyst. Thermoplastic polymers increase the strength against the load induced deformation by creating asphalt rigidity. Table no.4 shows the properties of Poly Propylene.

Table No. 4 Properties of Poly Propylene

S. No.	Property	Specification
1	Melt Flow Rate g/10 min.	25
2	Vicat Softening point 10N	152
3	Tensile Strength MPa	32
4	Elongation at Break %	13
5	Density gr/cm3	0.9

(Source: Mostafa Vamegh et al., 2020)

VIII. ANALYSIS AND RESULTS

With the combination of varying percentage of Styrene Butadiene Rubber and Poly Propylene in the bituminous concrete the bituminous concrete modified using Styrene Butadiene Rubber and Poly Propylene was prepared. The design of the mix was done as per the guidelines of MORT&H. VG-30 grade bitumen as a binder and Portland cement was used in the mix as filler during entire experimental work.

- Test Results on aggregate: To check that whether the aggregates used for study are suitable for the study or not physical tests on aggregate were conducted as per MoRT&H specification. The tests conducted are namely specific gravity test, impact tests, water absorption test and shape test. All the tests on aggregates were conducted as per Indian Standard Specification. Table 5 presents the results of tests conducted on aggregate.

Table No. 5 Results of Tests on Aggregates

S. No.	Name of the test		Results	MORT&H Specification
1	Aggregates Impact Value Test		21%	Max. 24%
2	Specific Gravity	12 mm	2.74	-
		10 mm	2.72	
		6 mm	2.67	
		Below 4.75 mm	2.76	
3	Combined Flakiness and	Elongation Index	28%	Max. 35%
4	Water absorption		1.2%	Max. 2%

- Test Results on Bitumen: The main objective of performing tests on bitumen was to check the trend of variation in physical

Properties of bitumen have a preliminary idea about the success or failure of modification of bituminous concrete. Table 6 presents the results of tests conducted on bitumen.

Table No. 6 Tests Results on Bitumen

S. No.	Name of Test	Results	MORT&H Specification
1	Specific gravity at 27^0C	1.00	Min. 0.99
2	Softening Point (^{0}C)	49	40^0C - 55^0C
3	Penetration at 25^0C (1/10^{th} mm)	63	60 – 70

- Test Results on Bituminous concrete: The variation was done in SBR & PP content from 4.5% to 5.5% to find out optimum bitumen content of SBR & PP in hot mix bituminous concrete. Table 7 presents the results of Marshall Test conducted on Bituminous concrete modified using SBR & PP and Conventional Bituminous Concrete.

Table No. 7 Results of Marshall Tests on Polymer Modified BC and Conventional BC

S. No.	Properties	Polymer Bitumen Content (%)			Bitumen Content (%)
		PBS 1 4.5%	PBS 2 5.0%	PBS 3 5.5%	CS 1 5.5%
1	Bulk Density (gm/cc)	2.286	2.355	2.36	2.286
2	Stability value (KN)	17.60	19.17	18.62	13.19
3	Flow value (mm)	2.63	3.85	3.27	3.27
4	Air voids (%)	5.14	3.44	3.27	3.93
5	VMA (%)	17.58	16.128	15.58	16.47
6	VFB (%)	70.76	78.67	79.01	76.13
7	Marshall Quotient (kn/mm)	6.69	4.979	5.29	4.033

IX. GRAPHICAL REPRESENTATION OF MARSHALL PARAMETERS

I. Marshall Stability vs. Polymer Blend Content, Compared with Conventional Mixture.

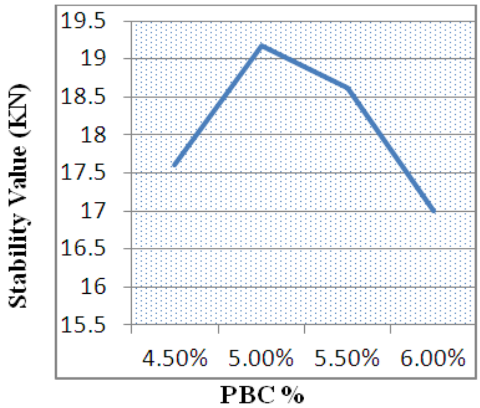


Fig.No.4 Stability of BC Modified using SBR/PP

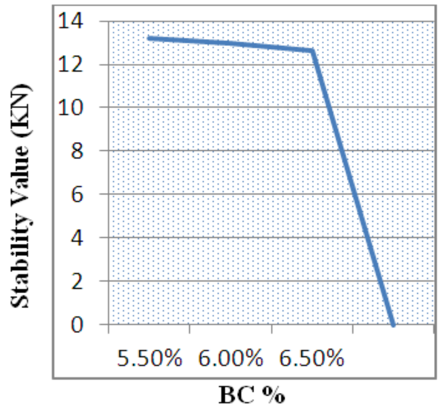


Fig.No.5 Stability of Conventional BC

From figure 4 and figure 5 it is clear that stability increase up to a certain content of Styrene Butadiene Rubber and Poly Propylene and then decreases. For maximum stability the optimum content of Styrene Butadiene Rubber and Poly Propylene was found out to be 5.0% by the weight of the bitumen.

II. Marshall Flow vs. Polymer Blend Content, Compared with Conventional Mixture.

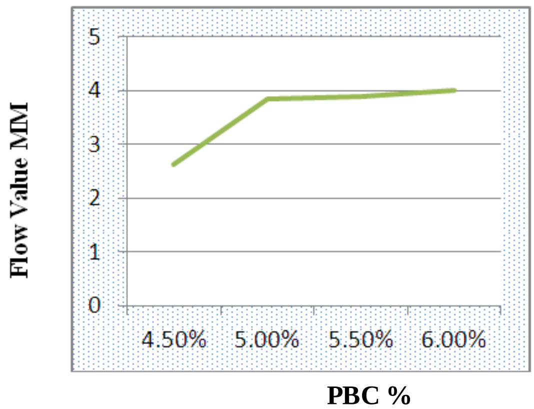


Fig.No.6 Flow of BC Modified using SBR/PP

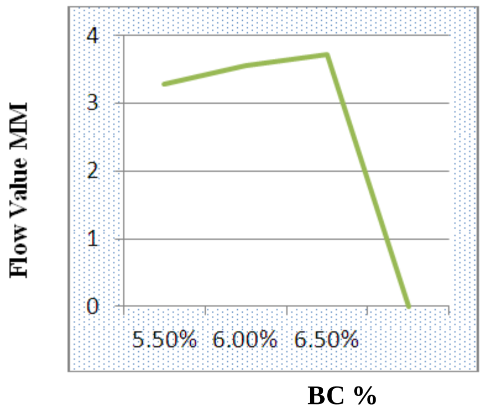


Fig.No.7 Flow of Conventional BC

From the figure 6 and figure 7 it can be seen that flow value increases with increase in Styrene Butadiene Rubber and Poly Propylene content. The flow value pattern was found out to be more in the case of Styrene Butadiene Rubber and Poly Propylene as compared to the Conventional Bituminous Concrete.

III. % Vv vs. Polymer Blend Content, Compared with Conventional Mixture.

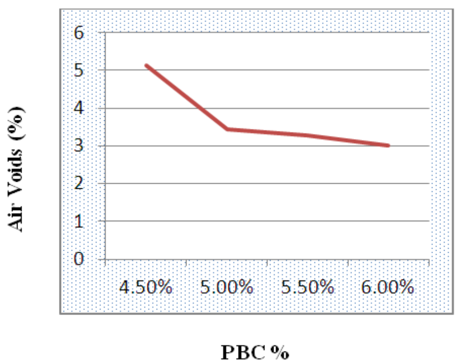


Fig.No.8 % Vv of BC Modified using SBR/PP

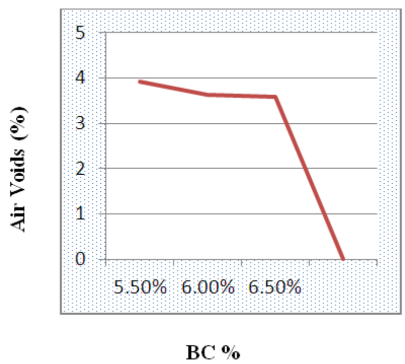
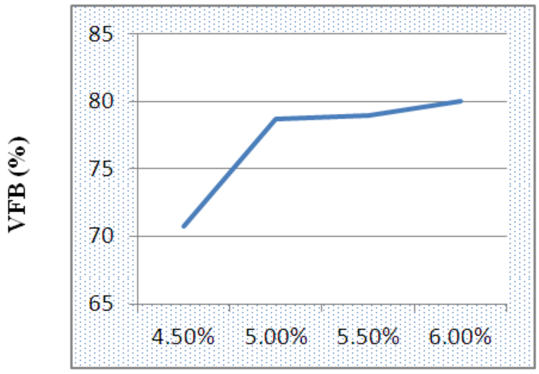


Fig.No.9 % Vv of Conventional BC

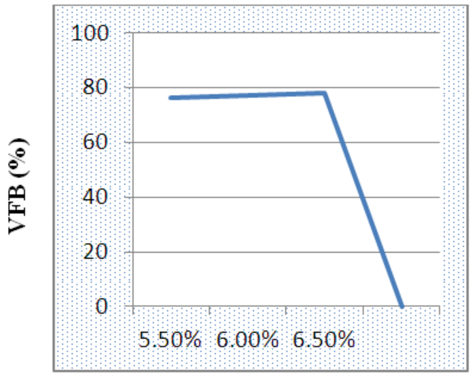
It is clearly visible form the figure 8 and figure 9 that air voids decreases as we add Styrene Butadiene Rubber and Poly Propylene to the bituminous concrete but rate of decrement of air voids shows that initially the decrement is more than it slows down, this is because initially all the Styrene Butadiene Rubber and Poly Propylene content get absorbed in the voids but as the content increases the voids gets reduced and hence there is decrement in the rate of decrement of air voids.

IV. % VFB vs. Polymer Blend Content, Compared with Conventional Mixture.



PBC %

Fig.No.10 % VFB of BC Modified using SBR/PP

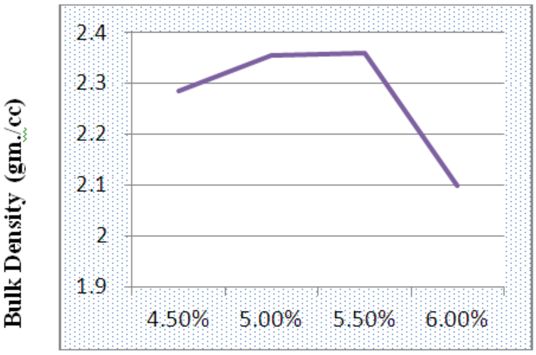


BC %

Fig.No.11 % VFB of Conventional BC

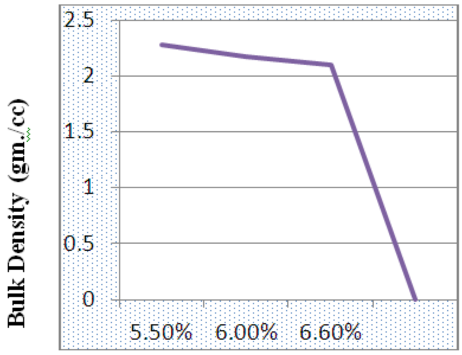
From the figure 10 and figure 11 it can be seen that addition of Styrene Butadiene Rubber and Poly Propylene increases the VFB, which means that addition of Styrene Butadiene Rubber and Poly Propylene increases the bonding between ingredients of bituminous concrete. As the increment of Styrene Butadiene Rubber and Poly Propylene more voids are filled with bitumen results in increased VFB.

V. Density (gm/cc) vs. Polymer Blend Content, Compared with Conventional Mixture.



PBC %

Fig.No.12 Density of BC Modified using SBR/PP



BC %

Fig.No.13 Density of Conventional BC

Figure 12 and figure 13 show trends that bulk density increases up to 3 % content of Styrene Butadiene Rubber and Poly Propylene then decreases. Bulk density at optimum Styrene Butadiene Rubber and Poly Propylene content gives maximum bulk density because of the voids filled by SBR/PP.

X. CONCLUSIONS

- The Marshall Stability of bituminous concrete modified using Styrene Butadiene Rubber & Polypropylene increased up to 44 % by the weight of bitumen then decreasing trend was observed. This gives the optimum dose of Polymer Blend Styrene Butadiene Rubber and Poly Propylene (5 %) by the weight of bitumen.
- Flow values increased with increment (17%) of Styrene Butadiene Rubber & Polypropylene content, which results in increment in elastic properties.
- Percentage air voids (V_V) decreased (29%) with increment of Styrene Butadiene Rubber & Polypropylene content.
- Marshall Quotient (MQ) value is indirect measure of toughness of bituminous concrete. MQ initially increased (23%) then started decreasing with increment in Styrene Butadiene Rubber & Polypropylene content.

XI. FUTURE RECOMMENDATION

- In the present study, VG 30 grade bitumen was used. Further studies may be carried out with other grades of bitumen like VG 10, VG20 and VG 40.
- In the present study, assessment of strength characteristics of wearing surface course of Bituminous Concrete was done. Studies may also be carried out on other types of bituminous mixes like SDBC, DBM etc.
- In present study, Styrene Butadiene Rubber and Poly Propylene were additives in Hot Mix Bituminous Concrete. Future studies may be carried out on some other additive like E- Wastes Polymers, glass and fiber etc.
- In the present study, Bituminous Concrete was prepared by using hot mix process in which Sulphur was used as a stabilizer. Further studies may be done on Warm Mix Asphalt (WMA), Half Warm Mix Asphalt (HWMA), Cold Mix Asphalt (CMA).

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