COMPARATIVE EVALUATION OF BITUMINOUS MIXES CONTAINING WASTE PLASTIC WASTE AS AN ADMIXTURE SUBJECTED TO COLD WEATHERED ENVIRONMENT

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Abstract

This research was aimed at modifyingand improving the performance of bitumen mixes in low temperatures region using waste plastic bags (WPB) as an additive. Mixes with 6% WPB and 7% WPB show good results can replace aggregate in virgin mixes. The optimum amount of WPB for mix in bituminous concrete (BC)was found to be 6% at a bitumen content of 5.66%. The retained stability of control mix was found to be about 75% from the standard value, whereas for the mix with both anti-stripping and WPB and for mix with WPB only, it was above 85%. This shows that mixes with 6% WPB have greater durability and strength as compared to the mixes with anti-stripping chemical and control mix. Also WPB mixes are cheaper due to the availability of waste plastic, it was observed that control mix after being subjected to repeated freeze thaw cycles canlose more than 50% of its original strength. Hence modification to the mix can be done by addition of 6% WPB which gives the required strength.

Keyword: Performance, Mixes, Bituminous, Stability, Strength

1.0: Introduction

Use of plastic in bituminous mixes can be of importance in curbing the excess damage to roads in cold weather conditions. Waste plastic roads have been used in some parts of the country with a varying degree of success. Waste plastic roads have various advantages over normal roads which can be of great importance in these parts of the country. Despite the fact that a large amount of work has been carried out by addition of waste plastic to the bitumen mixes, little knowledge about the performance of such mixes in harsh climatic and snowy conditions presents a broader scope to precisely obtain results in this regard and thus understand the benefits and de merits of the use, if any. some relevant studies and research done on usage of waste plastic for cold weather regions are as follows:

(Awwad and Shbeeb 2007)claimed that the modified mixture considered to have higher stability and VMA rate in comparison with the non-modified blends and hasimpact directly to the rutting protection of mixtures. It was added by their finding that modifying the asphalt blend with HDPE polyethylene enhances its properties more when compared with LDPE polyethylene. (Herndon, 2009) examined dampness vulnerability of asphalt blend utilizing phosphorylated reused polythene. They demonstrated that there is a huge decrease in dampness susceptibility by addition of reused unmodified polyethylene to asphalt concrete mixtures in both the Wet Procedure and the Dry Process. According the work of (Chavan, 2013) Plastic waste was replaced in place of aggregate for better performance of pavement. This was attributes in providing an enhanced amount of bitumen containing plastic as an admixture. The polymer added decreases the voids present in the mix, which prevents the dampness absorption and oxidation of bitumen by captured air. They concluded that, utilizing plastic waste in blend will reduce amount of bitumen by 10%, as well as increase the quality, performance and eventually build up an eco-friendly innovation. The review work of (Gawande et, al., 2012) on waste plastic utilization in pavement in both wet and dry technique. It was concluded by them that modified bitumen with a content of waste plastic addition of 5-10% by weight of bitumen provides a longer life span and performance of pavement. (Ghorpade, 2018) revealed that the concurrent movement and high traffic volume of commercial vehicles, over-burdening of trucks and varieties in daily temperature of the pavement have been considered as the main factors causing rutting, cracking, bleeding, shoving and potholing on the bituminous surfacing.(Ahmadinia, et, al., 2012) conducted a series of laboratory test to utilize large amount of waste plastic containers as an admixture to stone mastic asphalt (SMA). Wheel tracking, dampness weakness, bulk modulus and drain down tests were conducted with the different percentage of these at 0%, 2%, 4%, 6%, 8% and 10% by weight of bitumen content. Their result indicates that in cooperating such waste into the blend has resulted in favourable outcome on the properties of SMA which could enhance the blend's protection against perpetual misshaping (rutting), increment the strength of the blend, give low binder drain down as well as recycling the waste product as an advantage.

(Gundaliya, 2012) shows that the procedure of modifying of bitumen with waste polythene provide better ways in protecting the pavement from protection from splitting, pothole arrangement and rutting by improving softening point, hardness and diminishing stripping because of water, in this manner enhancing the general execution and performance of roads over a drawn out stretch of time. As indicated by them the waste polythene used in the blend shapes covering over aggregates of the blend which lessens porosity, ingestion of dampness and enhances binding property.

(Karim et, al., 2013) investigate the performance of bituminous blend with polyethylene admixture and revealed that bitumen blends with polyethylene performs better when compared with conventionalbituminous blend whensubmerged under water. Also protecting the earth from contamination will be a special reward. (Soni and Punjabi 2013), discovered that with the usage of waste plastic aiming at enhancing the performance of bituminous concrete mixture, this waste plastic modified bitumen mixture gives better binding property, stability, stiffness, thickness and impermeability to water. Their result indicates that the waste polythene used in the blend will give lessens porosity, retention of moisture and enhances binding property of the blend. The bitumen adjusted with 4.5 % Polythene waste is considered to be optimum indicating better performance when compared with conventional blends.

(Moghaddam et, al., 2013) confirmed that the use of waste material in asphalt pavement would be promising for the benefit life of asphalt pavement and reduces ecological contamination. Their result indicates that Polyethylene Terephthalate (PET) fortified blends have higher stability value, flow, and weariness life when compared with the mixtures without PET. (Rajasekaran et, al., 2013) revealedthat the reuse of waste Plastics Coated Aggregates-Bitumen Mix Composite for Road Application by Green Method. The sample showed higher Marshall Stability values ranges between 18 to 20KN and the load bearing capacity of the road is increased as well.(Sangita and Verinder, 2011) proposed a method for dealing with enhancing the quality of pavement by using plastic waste. As it was indicated by them India spends Rs 35,000 crores a year on road development and repairs, including Rs 100,000 crores every year only to upkeep serviceability and only by bitumen roads keeps going 2-3 times longer, which will spare us Rs 33,000 crores a year in repairs. (Bindu and Beana 2014) presented the result of their research on how the waste plastic behaves when added as a stabilizer in Stone Mastic Asphalt, the blends were subjected to tests which include Marshall Stability, rigidity, compressive strength tests and Tri-axial tests. The result indicated that that flexible pavement of high durability and greater performance can be attained with the optimum addition of 10% shredded plastic. (Sabina, et, al., 2009) evaluated the comparative performance of properties of bituminous mixes containing plastic/polymer (PP) (8% and 15% by the weight of bitumen) with conventional bituminous mix. remarkable improvement in properties such as Marshall Stability, Retained Stability, Indirect Tensile Strength and Rutting was observed in PP modified bituminous concrete mixes. Thus waste PP modified bituminous concrete mixes are expected to be more durable, less susceptible to moisture.

It was revealed from the studied conducted by (Sreedevi and saline, 2013) on roads surface using bituminous mix with plastic coated aggregates. Laboratory studies indicates that the Marshall Stability value of bituminous mixes increase by 1.5 to 2 times by using Plastic Coated Aggregates. Also amount of bitumen can be reduced by more than 10% by weight. (Thakur and Duggal 2017) concluded that replacing the reused material in pavement production will enhance the performance of the road and lower the construction cost of the road. (Verma, 2008) considered that plastic expands the point of melting of the bitumen and makes the road flexible amid winters bringing about its long life.

The amount of waste plastic available provides one of the best to be adopted for modifying the content of bitumen mixes. this can lead to a significant reduction in the maintenance and repair costs and even the construction cost of pavement. Hence the present study deals with enhancing the properties of modified mixes with waste plastic bags (WPB).

2.0: Materials

For this study various materials utilized are:

VG10 binder, Plastic waste, and aggregates. Waste plastic was used in shredded form.

i. Waste plastic: the waste plastic was obtained from Chandigarh industrial estate.
ii. Cement: Ordinary Portland cement was used for addition to the mixes. Aggregates:
iii. Aggregate: The size of aggregate utilized was 13.2 mm and stone dust was used.

3.0:Methodology

For this purpose of this study, bitumen mixes were made using Marshall Method of Design. Various materials viz: aggregates, binder, polythene, anti- stripping chemicals. Also optimum binder content was selected. The work performed for this study was carried out in various stages. Determination of Bituminous Concrete control mix andutilizing Waste

Plastic Bags with varying percentages (6%, 7%). As well as for Bituminous Concrete by utilizing anti-stripping chemical with varying percentages (0.5%, 0.75%, and 1%) by using Marshall Method while Repetitive Freezing and Thawing of samples with plastic having both plastic and anti- stripping chemical of varying percentages (0.5%, 0.75%), and control mix for 3, and 7 days was also determined.

4.0: Results and Analysis

4.1: Properties of Various Materials Utilized in the Study

In order to meet the requirements as per MORTH (revision 5th), various types of tests were performed on the materials. The results obtained as a result of these tests are indicated in the following table:

Table 1.0: Physical Properties of Aggregates

S/No.	Physical Properties	Values	Requirements as per MORTH
1	Specific Gravity	2.70	2.6-2.8
2	Elongation Index (%)	10.50	Max 30% (combined)
3	Flakiness Index (%)	10.80	
4	Impact Value (%)	18.4	Max 24%
5	Water Absorption (%)	0.70	Max 2%
6	Stripping Value (%)	3.50	<5%

Table 2.0 Physical Properties of Binder

Binder: The bitumen used was VG 10 grade. The results of the tests performed are given in the following table

S/No.	Properties	VG-10 Grade		Test Method
		Determined	Required	
1	Penetration	93	80-100	IS: 1203-1978
2	Softening point	43.50	40 min.	IS : 1205-1978
3	Specific gravity	1.10	0.99 min.	IS: 1202-1978

4.2 The Aggregate Grading

The Grading of different aggregates was done for obtaining virgin mix. The results are as shown in following table:

Table 3.0: Grading of Aggregates for Control Mix

IS Sieve Size	% passing (required)	% passing 19mm	% passing 13.2mm	% passing Stone dust	% passing Cement	Grading
19mm	90-100	89.75	100	100	100	97.54
13.2mm	59-79	13.05	99.5	100	100	78.979
9.5mm	52-72	1.85	78.7	100	100	69.2
4.75mm	35-55	0.05	5.05	96.8	100	45.665
2.36mm	28-44	0	0.05	75.05	100	32.037
1.18mm	20-34	0	0	62.35	100	26.94

600mm	15-27	0	0	47.95	100	21.18
300mm	10-20	0	0	34.1	99.2	15.62
150mm	5-13	0	0	20.05	98.5	9.99
75mm	2-8	0	0	34.6	99	7.8

After grading of aggregates, ratio of the blend is calculated. It was done by hit and trial method and the ratio used was 58:40:2

4.3: Marshall Stability

Table 4.0: Marshall Stability Test results for Control Mix

Bitumen Content	5.43%	5.70%	5.86%	6.5%
Specific Gravity of Bitumen	1.10	1.10	1.10	1.10
Density (g/cc)	2.50	2.32	2.31	2.32
Specific Gravity of Aggregate Blend	2.36	2.36	2.36	2.36
Volume of Bitumen, Vb(%)	11.86	11.93	12.46	14.34
Volume of Aggregate, V_a(%)	80.03	79.40	78.74	78.50
Voids in Mineral Aggregate, VMA (%)	16.86	16.93	17.43	1794.
Voids Filled with Bitumen, VFB (%)	62.35	68.43	70.35	72.00
Air Voids, %	5.23	4.67	4.40	4.20
Stability, kg	1769	1890	1890	1935
Flow Value, mm	3.54	3.80	4.10	3.90.

Table 5.0: Marshall Stability Test results for 6% WPB

Bitumen Content	5.43%	5.70%	5.86%
Specific Gravity of Bitumen	1.10	1.10	1.10
Density (g/cc)	2.74	2.56	2.32
Specific Gravity of Aggregate Blend	2.30	2.30	2.30
Volume of Bitumen, Vb(%)	11.75	11.93	12.30
Volume of Aggregate, V_a(%)	79.70	79.86	80.43
Voids in Mineral Aggregate, VMA (%)	14.43	14.80	15.13
Voids Filled with Bitumen, VFB (%)	78.70	79.42	78.70
Air Voids, %	3.10	2.93	3.20
Stability, kg	2143	2321	2567
Flow Value, mm	4.12	4.75	4.31

Table 5.0: Marshall Stability Test results for 7% WPB

Bitumen Content	5.43%	5.70%	5.86%
Specific Gravity of Bitumen	1.0	1.0	1.0
Density (g/cc)	2.93	2.53	2.47
Specific Gravity of Aggregate Blend	2.30	2.30	2.30
Volume of Bitumen, Vb(%)	11.94	12.01	12.30
Volume of Aggregate, V_a(%)	80.37	81.00	82.35
Voids in Mineral Aggregate, VMA (%)	14.23	14.34	15.45
Voids Filled with Bitumen, VFB (%)	79.87	81.45	81.55
Air Voids, %	3.56	3.67	3.45
Stability, kg	2345	2458	3678
Flow Value, mm	4.21	4.34	4.41

Determination of optimum binder content After performing Marshall Stability Test, the optimum binder content was known to be 5.70%.The quantity of bitumen in accordance to its percentage was calculated as 72grams.

4.4: Various Relationship of Parameters Determined

4.4.1: Air Voids-Bitumen Content

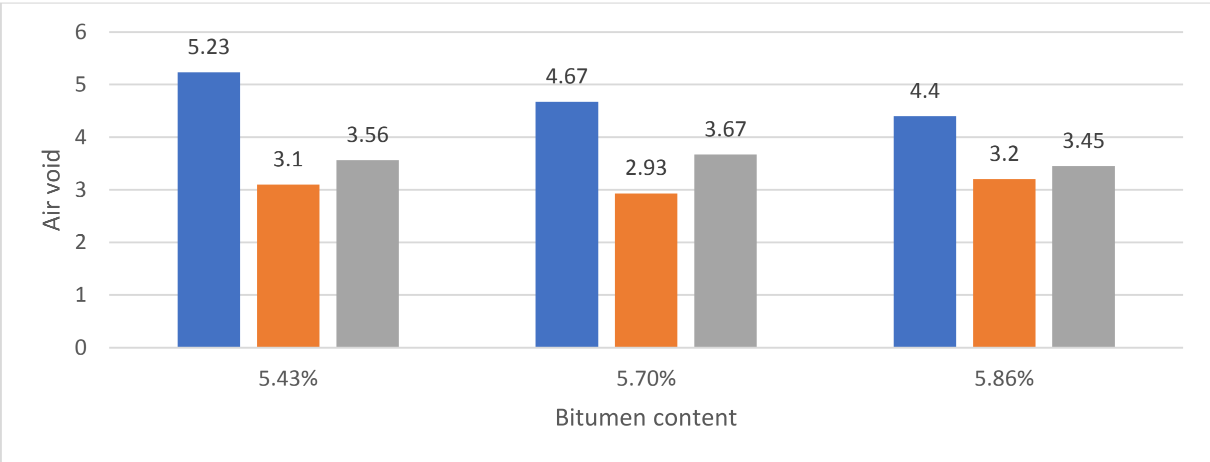

Figure 1.0: Relationship between Air voids and Bitumen content for WPB

From the above figure, it is observed that there is a decrease in the percentage of air voids with an increase in the percentage of bitumen content.

4.4.2: Density-Bitumen content

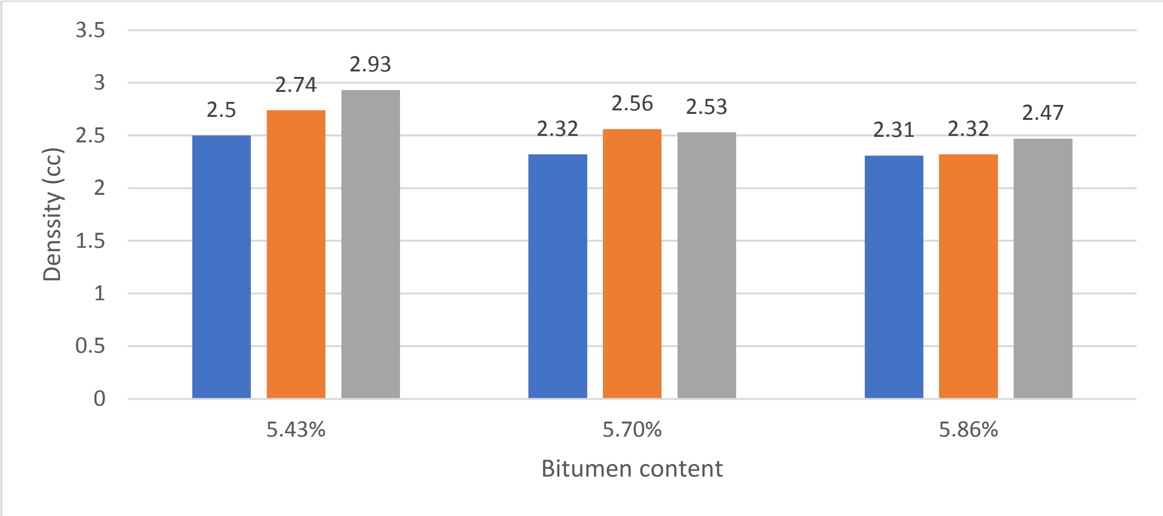

Figure 2.0: Relationship between Density and Bitumen content for WPB

The density results for all the mixes follow a similar pattern. As the Bitumen content increases, there is a decrease in density value of the mix. It is observed that the densities of mixes with WPB are less than that of Control Mix. The maximum values of densities for mixes with 6%WPB and 7%WPB are 2.56 & 2.47 respectively. The maximum density is shown by control mix as 2.93. After control mix, the mix with 6% WPB at 5.70% bitumen content shows maximum density.

4.4.3: Stability-Bitumen Content:

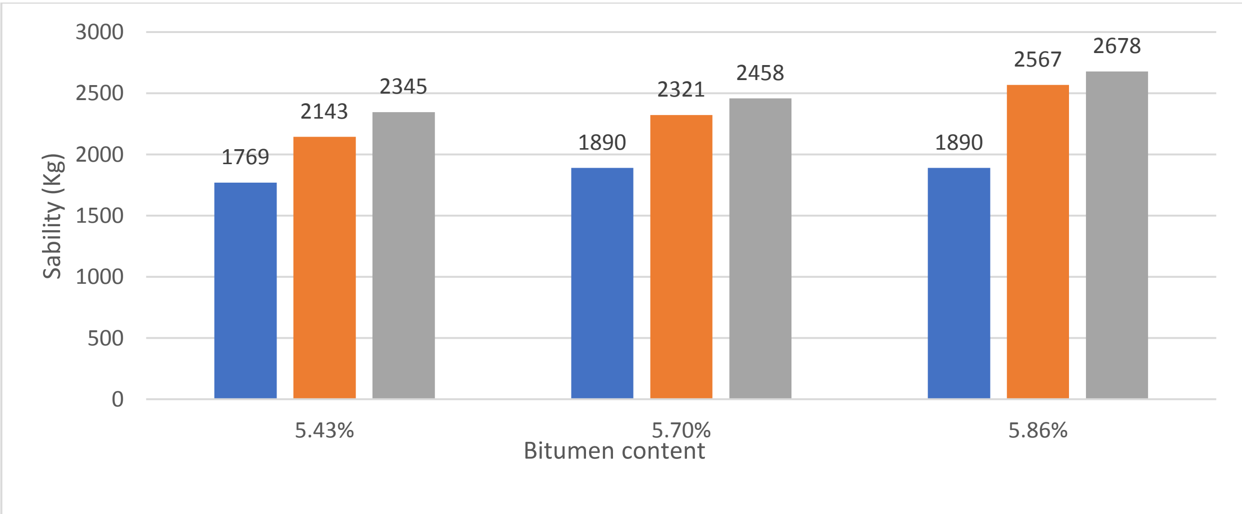

Figure 3.0 Relationship between Stability and Bitumen content for WPB

With increase in WPB content, the stability of the mix increases. The mix with 7% WPB exhibits maximum stability i.e. 2678 kg at 5.86% Bitumen content. At 5.70% Bitumen content, the least stability is exhibited by control mix i.e. 2345kg. The stability values of WPB 6%& WPB 7% at bitumen content 5.70% are 2458 kg and 2678 kg respectively.

4.4.4: Flow-Bitumen content:

The maximum flow is exhibited by the mix having 7% WPB at Bitumen content of 5.86% i.e. 4.41mm. The control mix also exhibits a flow value outside permissible limits at a Bitumen content of 5.86% i.e. 4.25. At a bitumen content of 5.70%, the control mix, mix with 6% WPB & mix with 7% WPB exhibit flow values as 4.21mm, 4.34mm, and 4.41mm respectively.

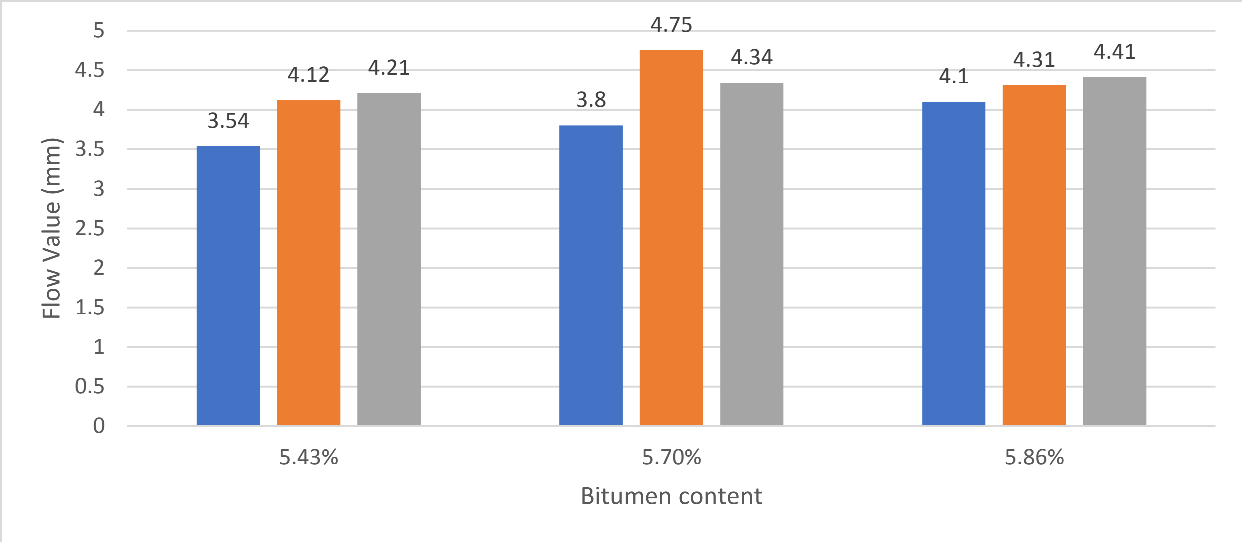

Figure 3.0 Relationship between flow and Bitumen content for WPB

4.5: Marshall Stability Test results for Control Mix, Mix with various percentages of Anti-stripping chemical, mix with 6% WPB of different Freeze Thaw cycles.

Table6.0: Retained Marshall Stability Test results for Control Mix, Mix with various percentages of Anti-stripping chemical, mix with 6% WPB at 5.66% Bitumen content

Parameters	Anti-stripping chemical			Control mix	WPB (6%)
	0.5%	0.75%	1%		
Specific Gravity of Bitumen	1.10	1.10	1.10	1.10	1.10
Density(g/cc)	2.309	2.310	2.314	2.348	2.287
Specific Gravity of Aggregate Blend	2.30	2.30	2.70	2.70	2.70
Volume of Bitumen, Vb(%)	11.93	11.73	12.30	12.30	12.43
Volume of Aggregate, V_a(%)	80.20	80.73	81.21	81.21	82.30
Voids in Mineral Aggregate, VMA (%)	12.31	12.18	12.62	12.86	14.34
Voids Filled with Bitumen, VFB (%)	82.21	81.42	84.21	78.21	83.34
Air Voids, %	1.23	1.81	1.52	4.21	2.63
Retained Marshall Stability, kg	2321	2339	2357	1781	2423
Flow Value, mm	4.34	4.97	4.82	3.4	3.71

Table 7.0: Marshall Stability Test results for Control Mix, Mix with various percentages of Anti-stripping chemical, mix with 6% WPBafter 3 and 7 repeated Freeze Thaw cycles.

Parameters	3 Repeated Freeze Thaw Cycles.				7 Repeated Freeze Thaw Cycles.			
	Anti-stripping chemical		Control mix	WPB 6%	Anti-stripping chemical		Control mix	WPB 6%
	0.5%	0.75%			0.5%	0.75%		
Specific Gravity of Bitumen	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Density (g/cc)	2.41	2.43	2.34	2.32	2.21	2.31	2.28	2.27
Specific Gravity of Aggregate Blend	2.30	2.30	2.70	2.30	2.30	2.30	2.70	2.30
Volume of Bitumen, Vb(%)	11.92	11.87	11.86	12.21	11.67	11.56	11.86	12.47
Volume of Aggregate, V_a(%)	81.62	81.96	82.91	82.30	81.96	82.60	82.46	82.23
Voids in Mineral Aggregate, VMA (%)	13.45	12.93	12.76	12.74	13.36	12.35	12.45	15.67
Voids Filled with Bitumen, VFB (%)	83.21	84.21	76.81	83.74	82.34	89.21	76.78	83.76
Air Voids, %	1.99	1.74	4.34	2.63	2.21	1.78	4.75	2.45
Stability, kg	1482	1658	1368	2342	1202.7	1368	1007	2003
Flow Value, mm	2.92	2.78	2.65	3.4	2.72	2.63	2.55	3.1

After being exposed to 3 Repetitive Freeze Thaw cycles, the control mix exhibited stability values around 72% of the Standard value, the mix with 0.5% & 0.75% anti-striping chemical showed stability values around 77% and 80% respectively, whereas the mix with 6%WPB showed stability values higher than 85% of the standard value. While being exposed to 7 Repetitive Freeze Thaw cycles, the control mix exhibited stability values around 53% of the Standard value, the mix with 0.5% & 0.75% anti-striping chemical showed stability values around 60% and 65% respectively, whereas the mix with 6%WPB showed stability values higher than 72% of the standard value. Also the mix with 6% WPB after 7 repetitive Freeze Thaw cycles exhibited similar stability values as shown by Control mix with 5.66% bitumen under ideal conditions.

5.0Conclusions

The following conclusions were made:

The mixes with 6% WPB have greater durability and Strength as compared to the mixes with both control and mixes containing anti-stripping chemical. Also WPB mixes are advantageous compared with the conventional bitumen materials due to the availability and abundanceof waste plastic bag. It was observed that control mix subjected to repeated Freeze Thaw cycles loses more than 50% of its original strength; hence modification to the mix should be done by addition of 6% WPB which contributed in enhancing the strength of the mix. The mixes with 6% WPB at 7 Freeze thaw cycles exhibits stability values similar to that of control mix under ideal conditions. Thus, it can be concluded that 6% WPB should be added to the mix for the application in low-temperature environment.

6.0: Recommendations

Further research can be done based on the limitations in the present study. The limitations area as:

i. The optimum value of WPB is found to be 6% based on trials with only 2 percentages of waste plastic bags i.e. 6% & 7%. Trials above and below this range can be used to reform the findings.

ii. This Study has been carried out by utilizing VG-10 grade binder. Different grades of binder can be used for performing similar study.

iii. Only WPB in shredded form has been used for performing the study. Various other forms of Plastic can be used to carry out this type of study.

iv. This study is limited for BC layer only. Similar studies can be done on various kinds of mixes such as SDBC, DBM.

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