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ANALYSIS OF POLYMER MODIFIED BITUMINOUS CONCRETE

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ABSTRACT

This topic presents a laboratory study of modified bitumen containing polymer (plastic). Presently conventional bitumen and polymer modified bitumen (PMB) are widely available in the market for road and highway construction. Traditional bituminous binders exhibit various limitations with the overloading of vehicles, increasing service requirements and climatic conditions which lead to important stress-related problems. In addition to this, traffic frequency is increasing rapidly as a consequence of a tremendous increase in the number of vehicles. The bituminous surface on a road should have temperature characteristics that can resist plastic deformation at high temperatures and brittleness at low temperatures. Binder modification is a major break-through and the continuous research in this area aiming to produce new binders with better mechanical characteristics allows the manufacturing and application of road bituminous mixtures with higher performance. Plastic can be added to a bituminous mix either by dry or wet mixing process to get a modified mix. In dry mixing, the plastic is added to heated aggregates before adding a binder. In wet mixing, the plastic is added to plain bitumen producing modified bituminous binder, which is then mixed with aggregates. In this study plastic modified bituminous concrete was prepared by both dry and wet processes and the tests were compared with plain bituminous concrete. In the dry-mix process, the plastic was taken by weight of total mix and for wet mix, the plastic content was taken by weight of bitumen. Materials used for the study included coarse and fine aggregates,

bitumen and plastic. Plastic is in the form of small pieces cut out of carrying bags and such others. As a first step, aggregates and binders, both plain and modified bitumen, were tested for different properties as per the Bureau of Indian Standards procedures and the materials were found to satisfy the specifications. Marshall Method of mix design was adopted to find out the optimum binder content.

KEYWORDS: Bituminous Concrete, Marshall Stability, ANOVA, Tensile Strength, Number of cycles to failure, Resilient modulus, Initial tensile strain.

INTRODUCTION

Traditional bituminous binders exhibit many limitations with overcapacity, increasing service and climatic circumstances which leads to significant stress associated difficulties. In addition, the traffic frequency is increasing rapidly as a consequence of the tremendous worldwide increase in the number of vehicles. The bituminous surface on a road should have such temperature characteristics top resist plastic deformation at high temperatures and brittle failure at low temperatures. Binder change is a leap forward and the continuous research on this location aiming to supply new binders with better mechanical characteristics which allow the producing and alertness of avenue bituminous combos with higher performance.

1.1 BACKGROUND

Bituminous concrete combos are used to resist the expanded traffic volumes, truck visitors and higher tire pressures. The principal failure modes of bituminous concrete (BC) are cracking, distortion and disintegration. Cracking occurs for some of the reasons; however, this thesis makes a specialty of fatigue cracking, that is cracking because of repetitive loading until the fatigue life of the pavement is reached. every other issue blanketed is damage accumulation across temperatures and a way to evaluate equivalent harm at one of a kind temperature. Failure due to fatigue cracking of flexible pavements decreases the burden spreading characteristics of bituminous layers. They permit the rainwater to percolate the bottom, sub-base and the sub-grade. in the end, the entire destruction of pavements takes place. If timely preservation isn't taken up with the growth in vehicular extent, there can be a boom inside the value of production and the renovation of the pavements. This arises the need for a brand-new notion of using waste plastic in concrete pavements. those pavements are less prone to rutting, minimum fatigue cracking, and occasional stripping because of moisture. It gives extra durability, very little effect on processing and produces environmentally friendly roads that final longer and value much less.

1.2 Characteristics of Plastic

Learning of the thermal behavior of the plastic materials showed that plastic gets softened simply without any development of gas around 130-1400C. At around 3500C it gets decomposed releasing gases like methane, ethane, etc. and at 7000C it undergoes burning, producing gases like CO, etc.

2. OBJECTIVES AND SCOPE

The main objective of the project is to evaluate the effects of adding waste plastic on the presentation of bituminous concrete mixtures. The specific objectives of the study are

- To study the different concert evaluation methods used for modified bitumen through literature review.
- To estimate the performance of plastic modified bituminous concrete mix.
- To determine the optimum dosage of plastic.
- The scope of this study is to study the various characteristics of the bituminous concrete mixture when different amounts of plastic are being added into the mixture by laboratory analysis.

3. MATERIALS

- **Fine aggregates:** Fills the voids in the coarse aggregate and stiffens the binder. Material passing through IS sieve 4. 75 mm is taken as fine aggregate.
- **Filler:** Rock dust, cement are used as filler material. Fills the voids, stiffens the binder and offers permeability. Quarry dust passing through IS sieve 150 microns and cement were used as filler material.
- **Binder:** Bitumen fills the voids, cause particle adhesion and gluing. Plain bitumen of grade 80/100 is used to study the bituminous mix performance.

4. METHODOLOGY

In methodology, we have collected the literature review on the analysis of polymer modified bituminous concrete. Later on, we had gone to the material section. After that, we had conducted tests on aggregates. In testing aggregates, we had examined up to five trials and after conducting a test on aggregates we conduct the test on the binder. Now we conducted the test on bituminous mixes (Marshall Stability Test). At last, we had tabulated our results as per recommendations. Aggregates have an effect on, to an amazing quantity, the load transfer capability of pavements. subsequently, it's far critical that they should be very well tested earlier than the usage of for construction. now not best that aggregates have to be strong and durable, they need to additionally own right shape and length to make the pavement act monolithically. Aggregates are examined for energy, sturdiness, hardness, form, and water absorption. Various physical properties of aggregates were determined and the results are shown in Table 1.

Table 1: Physical properties of aggregates and the results.

Test	Test result					Average	Specification	Is code
	Trail 1	Trail 2	Trail 3	Trial 4	Trial 5			
Crushing value	29.23	28.42	28.56	27.84	27.63	28.33	Max 30%	IS:2386 Part-IV
Impact value	26.24	24.25	24.26	22.32	23.12	24.03	Max 30%	IS:2386 part - IV
Los angles and abrasion value	27.26	30.08	27.18	26.66	27.38	27.71	Max 30%	IS:2386 Part–IV
Specific value of coarse aggregate	2.75	2.72	2.77	2.62	2.67	2.7	2.6 – 2.8	IS:2386 Part III
Specific gravity of fine aggregate	2.59	2.71	2.68	2.56	2.73	2.65	2.6 – 2.8	IS:2386 Part III
Combined elongation and flakiness	18	16	20	22	23	19.8	Max 25	IS 2386 Part –I

Crushing value is tabulated as per IS: 2386 Part-IV. The maximum value is 30%. The test on crushing value is conducted up to five trails. The impact value is also tabulated as per IS: 2386 part -IV. The test on Los angles and abrasion value is shown as per IS:2386 Part –IV and the maximum value is 30%.

4.1 Characterization of Binder

The bitumen used in the present study was 80/100 penetration bitumen which was characterized by various physical properties. This bitumen was used for the development of formulations with waste plastic by the weight of bitumen and subsequently for the preparation of bituminous mixes. Standard tests were conducted on plain bitumen and the following experiments have been carried out to study the characteristics of the modified bitumen: Penetration, Softening Point, Ductility, Specific Gravity**,** Separation, Loss on the heating test, Elastic recovery.

4.2 Discussion on Experimental Results

From the above check, effects changed bitumen is displaying reducing penetration and growing softening factor in evaluation with everyday bitumen. The increase in softening because of the addition of plastic is favorable due to the fact that bitumen with higher softening points may be less susceptible to permanent deformation. The ductility cost of simple bitumen is enjoyable for the specifications.

Table 2: Standard tests for bituminous mixes.

Test	Plain Bitumen		Bitumen + 4% PM (polymer modified)		Bitumen + 6% PM		Bitumen + 8% PM		Bitumen + 10% PM		Speci-fication
Test	S1	Avg	S1	Avg	S1	Avg	S1	Avg	S1	Avg	Specification
Test	S2	Avg	S2	Avg	S2	Avg	S2	Avg	S2	Avg	Specification
Test	S3	Avg	S3	Avg	S3	Avg	S3	Avg	S3	Avg	Specification
Penetration Test IS:1203-1978	85	85.33	72	72.00	51	51	43	45.00	41	42.00	80-100
Penetration Test IS:1203-1978	89	85.33	75	72.00	53	51	44	45.00	43	42.00	80-100
Penetration Test IS:1203-1978	82	85.33	69	72.00	48	51	48	45.00	85	42.00	80-100
Ductility test IS: 1208-1978	97	92.00	42	44.67	48		52		55		Min 75
Ductility test IS: 1208-1978	92	92.00	47	44.67	51	49.66	55	53.33	58	56.33	Min 75
Ductility test IS: 1208-1978	87	92.00	45	44.67	50		53		56		Min 75
Softening point test IS:1205-1978	42	40.67	52	50.33	61	59	70	68.33	73	71.67	45-55
Softening point test IS:1205-1978	41	40.67	49	50.33	59	59	67	68.33	72	71.67	45-55
Softening point test IS:1205-1978	39	40.67	50	50.33	58	59	68	68.33	70	71.67	45-55
Loss on heating IS: 1208-1978	0.28	0.33	0.30	0.36	0.36	0.44	0.44	0.45	0.46	0.45	Max 1.0
Loss on heating IS: 1208-1978	0.33	0.33	0.36	0.36	0.41	0.44	0.48	0.45	0.48	0.45	Max 1.0
Loss on heating IS: 1208-1978	0.38	0.33	0.42	0.36	0.55	0.44	0.43	0.45	0.42	0.45	Max 1.0
% Elastic recovery IS: 1202-1979	63.5	62.73	62.5	60.97	48	45.7	39	37.27	34.8	35.53	min 35
% Elastic recovery IS: 1202-1979	60.5	62.73	61.0	60.97	44	45.7	37	37.27	35.6	35.53	min 35
% Elastic recovery IS: 1202-1979	64.2	62.73	59.4	60.97	45.7	45.7	35.8	37.27	36.2	35.53	min 35
Specific Gravity test IS: 1202-1978	1.04	1.08	1.14	1.15	1.18	1.19	1.21	1.21	1.236	1.23	Min 0.99

Specific Gravity test IS: 1202-1978	1.08	1.08	1.18	1.15	1.2	1.19	1.21	1.21	1.228	1.23	Min 0.99
Specific Gravity test IS: 1202-1978	1.12	1.08	1.14	1.15	1.21	1.19	1.21	1.21	1.234	1.23	Min 0.99
Separation (°C) IS: 15462-2004	2.2	2.4	2.14	2.06	2.7	2.90	3.1	3.10	2.9	3.17	Max 3
Separation (°C) IS : 15462-2004	2.4	2.4	1.96	2.06	3.1	2.90	3.3	3.10	3.2	3.17	Max 3
Separation (°C) IS : 15462-2004	2.6	2.4	2.08	2.06	2.9	2.90	2.9	3.10	3.4	3.17	Max 3

4.3 Experimental Evaluation of Modified Bituminous Concrete Mixes

The test values obtained are plotted in graphically as shown in fig 4.2 to determine the optimum binder content (OBC) for plain and modified bitumen. The bulk specific gravity of plain 80/100 grade of bitumen is maximum at 5% binder content indicated in fig a). Corresponding to 4% air voids both the mix types are showing 5% binder content. Marshall Stability values corresponding to varying binder contents are given in Fig (b). It can be observed that the stability value increases with an increase in waste plastic content up to 0.5% of waste plastic and then reduces. Hence, 0.5% of waste plastic by weight of the total mix is considered as the optimum value. Marshall Stability value of the modified bituminous mix (dry process) is 22.28 kN at the optimum binder content of 5%. The increase in the Marshall stability value for modified bituminous concrete (wet mix) is 13.37% compared to bituminous concrete with plain bitumen. Modified bituminous concrete (dry mix) showed an increase of 46% over that of bituminous concrete with plain bitumen. In its simplest form Analysis of Variance (ANOVA) provides a statistical test of whether the means of several groups are all equal. ANOVA test was conducted to know whether the increase in stability value is real or by chance. The results are tabulated are given below. At 5%, 5.5% of binder contents F critical values are less than F values calculated, and the null hypothesis is accepted. For 4%, 4.5%, 6% & 6.5% binder contents null hypothesis is rejected which means variation in Marshall Stability values of PB 80/100, modified bitumen is not significant. At optimum binder content, the improvement in the Marshall Stability value is significant.

Table 3: Comparison of volumetric properties of the mixes.

Properties	PMB-WM with plastic content					PMB-DM with plastic content				
	0%	4%	6%	8%	10%	0. 1%	0. 3%	0. 5%	0. 7%	1%
Marshall stability(KN)	15.25	15.96	18.26	17.14	15.73	16.4	18.32	22.282	18.08	17.08
Flow(mm)	3.5	3.58	3.787	3.95	4.15	3.62	4.16	4.327	4.56	4.45
Density(g/cc)	2.433	2.44	2.438	2.447	2.437	2.435	2.437	2.438	2.439	2.442
Air voids(%)	2.051	1.91	1.871	1.5	1.91	1985	1.891	1.876	1.819	1.7
VMA (%)	14.073	13.95	13.915	13.59	13.95	14.915	13.932	13.92	13.869	13.77
VFB (%)	85.516	86.33	86.625	88.98	86.31	85.84	86.43	86.533	86.88	87.62

Table 4: ANOVA for Marshall Stability Values for PB & PMB-WM-6.

Binder Content	Source of Variation	SS	D. O. F	MSS	F	F c	Result
4%	Between Groups	3.506	1	3.506	3.428	7.71	Variation is not significant
4%	Within Groups	4.091	4	1.023	3.428	7.71	Variation is not significant
4%	Total	7.597	5	-	3.428	7.71	Variation is not significant
4. 50%	Between Groups	5.198	1	5.198	3.855	7.71	Variation is not significant
4. 50%	Within Groups	5.394	4	1.348	3.855	7.71	Variation is not significant
4. 50%	Total	10.592	5	-	3.855	7.71	Variation is not significant
5%	Between Groups	13.230	1	13.230	13.619	7.71	Variation is significant
5%	Within Groups	3.886	4	0.971	13.619	7.71	Variation is significant
5%	Total	17.116	5	-	13.619	7.71	Variation is significant
5. 50%	Between Groups	7.765	1	7.765	11.753	7.71	Variation is significant
5. 50%	Within Groups	2.643	4	0.661	11.753	7.71	Variation is significant
5. 50%	Total	10.407	5	-	11.753	7.71	Variation is significant
6%	Between Groups	1.294	1	1.294	1.095	7.71	Variation is not significant
6%	With in Groups	4.724	4	1.181	1.095	7.71	Variation is not significant
6%	Total	6.017	5	-	1.095	7.71	Variation is not significant
6. 50%	Between Groups	3.268	1	3.268	4.174	7.71	Variation is not significant
6. 50%	With in Groups	3.132	4	0.783	4.174	7.71	Variation is not significant
6. 50%	Total	6.400	5	-	4.174	7.71	Variation is not significant

Table 5: ANOVA for Marshall Stability Values for PB & PMB-DM-0.5.

Binder Content	Source of Variation	SS	D. O. F	MSS	F	F c	Result
4%	Between Groups	9.132	1	9.132	7.254	7.71	Variation is not significant
4%	Within Groups	5.036	4	1.259	7.254	7.71	Variation is not significant
4%	Total	14.168	5		7.254	7.71	Variation is not significant
4. 50%	Between Groups	45.080	1	45.080	70.589	7.71	Variation is significant
4. 50%	Within Groups	2.554	4	0.639	70.589	7.71	Variation is significant
4. 50%	Total	47.634	5		70.589	7.71	Variation is significant
5%	Between Groups	79.571	1	79.571	57.080	7.71	Variation is significant
5%	Within Groups	5.576	4	1.394	57.080	7.71	Variation is significant
5%	Total	85.147	5		57.080	7.71	Variation is significant
5. 50%	Between Groups	17.212	1	17.212	23.133	7.71	Variation is significant
5. 50%	Within Groups	2.976	4	0.744	23.133	7.71	Variation is significant
5. 50%	Total	20.188	5		23.133	7.71	Variation is significant
6%	Between Groups	8.651	1	8.651	4.963	7.71	Variation is not significant
6%	Within Groups	6.972	4	1.743	4.963	7.71	Variation is not significant
6%	Total	15.622	5		4.963	7.71	Variation is not significant
6. 50%	Between Groups	3.447	1	3.447	2.307	7.71	Variation is not significant
6. 50%	Within Groups	5.977	4	1.494	2.307	7.71	Variation is not significant
6. 50%	Total	9.425	5		2.307	7.71	Variation is not significant

At 4%,6% and 6.5% of binder contents F critical value are greater than F values calculated and hence the null hypothesis is accepted, which means the difference in stability values is not significant. For all binder contents, the null hypothesis is rejected which means the difference in Marshall Stability values of PB 80/100 modified bitumen is significant. From table 6, at 4%, 6% and 6.5% of binder contents F critical value are greater than F value calculated and hence the null hypothesis is accepted. For all other binder contents, then the null hypothesis is rejected which means the difference in Marshall Stability values of wet mix and dry mix are significantly different. As stated earlier, the plastic modifier was varied from 4% to 10% by weight of bitumen in case of wet mix and 0.1 to 1% by weight of total mix in case of dry mix to study the effect on mechanical properties of mixes such as bulk density, stability, flow, indirect tensile strength, and tensile strength ratio. The coated aggregate bitumen mix performed better as it mixes showed higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics. Plastic material added with bitumen by weight of bitumen is also giving better results than plain bitumen but the dry mix is giving still better improvement. It was observed that the addition of the additives improves the tensile strength ratio of the mixes, and thus the moisture susceptibility.

5. FATIGUE CHARACTERISTICS OF THE MIXES

A program is written in Macro in Microsoft Excel to get the peak value of deformations and load in each cycle and also to find the fatigue life of the specimen. The different fatigue characteristics that can be found from the repeated load test are discussed. The following parameters are used to evaluate the fatigue characteristics of the mixtures.

a) Number of cycles to failure (Nf)
b) Resilient modulus (Mr)
c) Initial tensile strain (ei)

The laboratory results obtained under this study clearly demonstrate that there is a significant improvement in the properties of the modified mixes such as fatigue. Based on fatigue test results regression equations were formulated, which establishes the relationship between various fatigue parameters like fatigue life, resilient modulus.

Table 6: ANOVA for Marshall Stability Values for PB & PMB.

Binder Content	Source of Variation	SS	DOF	MSS	F	F c	Result
4%	Between Groups	1.322	1	1.322	1.150	7.71	Variation is not significant
4%	Within Groups	4.597	4	1.149	1.150	7.71	Variation is not significant
4%	Total	5.918	5	-	1.150	7.71	Variation is not significant
4. 50%	Between Groups	19.662	1	19.662	10.135	7.71	Variation is significant
4. 50%	Within Groups	7.760	4	1.940	10.135	7.71	Variation is significant
4. 50%	Total	27.422	5	-	10.135	7.71	Variation is significant
5%	Between Groups	27.909	1	27.909	15.064	7.71	Variation is significant
5%	Within Groups	7.411	4	1.853	15.064	7.71	Variation is significant
5%	Total	35.320	5	-	15.064	7.71	Variation is significant
	Between Groups	1.856	1	1.856	13.137	7.71	

5. 50%							Variation is significant
5. 50%	Within Groups	.565	4	0.141	13.137	7.71	Variation is significant
5. 50%	Total	2.421	5	-	13.137	7.71	Variation is significant
6%	Between Groups	3.254	1	3.254	5.047	7.71	Variation is not significant
6%	Within Groups	2.579	4	0.645	5.047	7.71	Variation is not significant
6%	Total	5.833	5		5.047	7.71	Variation is not significant
6. 50%	Between Groups	0.002	1	0.002	0.003	7.71	Variation is not significant
6. 50%	Within Groups	3.794	4	0.948	.003	7.71	Variation is not significant
6. 50%	Total	3.796	5	-	.003	7.71	Variation is not significant

6. SUMMARY OF STUDY AND ITS CONCLUSIONS

The objectives of the study were to evaluate the performance of waste plastic modified bituminous mixes through laboratory investigations. Aggregate and binder tests were conducted to assess the suitability of the materials used in the study. The laboratory tests like the Marshall Stability test, and bituminous mixes. Based on the laboratory test results, the following conclusions were drawn.

1. Binder tests like penetration, softening point have proved that plastic modification of the bitumen increased the stiffness.
2. The plastic-coated aggregate bitumen mix and plastic modified bitumen forms better material for flexible pavement construction as the mixes showed higher Marshall Stability value. Hence the use of plastics for pavement is recommended.
3. The performance of the plastic-coated aggregate mix is better than the ordinary and modified bituminous (wet) mix in many aspects.
4. The optimum binder content was found to be 5% in all cases.
5. The indirect tensile strength of the modified bituminous mix (dry mix) was found to be higher compared with that of plain and modified bituminous mixes (wet mix).
6. The Tensile Strength Ratio of the modified bituminous mixes is better for plain bitumen which is an indication of better resistance to moisture damage.
7. Repeated load test on plain and plastic modified bituminous mixes has proved that the performance of dry mix under fatigue is better compared with conventional and modified wet bituminous mixes.
8. Maximum fatigue life for plain and modified bituminous mixes was observed at binder contents 5%.

9. Using the plastic in bituminous concrete now not only strengthens the road construction however additionally will increase the street lifestyles as well as will help to improve the surroundings. Plastic roads could be a boon for India's hot and extremely humid weather, wherein temperatures often go 50°C and torrential rains create havoc, leaving most of the roads with huge potholes. it is hoped that during close to the destiny we can have robust, long-lasting and eco-friendly roads in order to relieve the earth from all sorts of plastic-waste.

7. SCOPE FOR FURTHER STUDY

The generation of plastic is growing day by day. molten state Plastics will increase the melting point of the bitumen of the major polymers viz. polyethylene, polypropylene, polystyrene show adhesion property.

- Construction of some test tracks and field studies on the performance of pavements using the modified bitumen.
- In addition, laboratory evaluation, working out relative economics of using the modified bituminous mixes in road construction works, considering the enhanced performance and improved service life of the pavement.
- An analytic approach using finite element methods as well as field analysis can be done to understand the various properties of modified bituminous concrete mixtures.

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