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Improvement of Bituminous Pavement by Adding Waste Plastic

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Md. Imran Khan

***Abstract:** The present paper reports the results of a study undertaken to determine the physical properties of aggregates, 80/100 grade bitumen, optimum bitumen content by using Marshall mix design, optimum plastic content and also to compare the results with plain mix.*

***Keywords:** Bitumen, Concrete, Aggregates, Cement, Sand Etc.*

I. INTRODUCTION

Disposal of waste materials including waste plastic bags is a menace and has become a serious problem, especially in urban areas, in terms of its misuse, its dumping in the dustbins, clogging of drains, reduced soil fertility and aesthetic problem etc. Waste plastics [13] are also burnt for apparent disposal, causing environmental pollution. The laboratory studies conducted by CRRI in utilization of waste plastic bags in bituminous concrete mixes have proved that these enhance the properties of mix in addition to solving disposal problems. The results indicated that there was an improvement in strength properties when compared to a conventional mix [1][6][7]. Therefore, the life of pavement surfacing using the waste plastic is expected to increase substantially in comparison to the use of conventional bituminous mix. There are two different processes, namely dry and wet process, to incorporate waste plastic bags into the bituminous mixes. The performance test proved that

- The fatigue life was doubled and
- Increased resistance to rutting and water damages when plastic waste was used.

II. EXPERIMENTAL INVESTIGATION

A. Materials:

- Crushed basalt type of coarse aggregates 20mm and down
- Crushed basalt type of fine aggregate 2.36mm and down
- Basalt stone dust& cement as a mineral filler
- 80/100 penetration grade bitumen
- Waste plastic in shredded form

B. Physical Properties of Aggregates:

The following tests have been conducted in order to determine the physical properties of the aggregates: [2]

- Abrasion test
- Aggregate impact test
- Specific gravity
- Water absorption test
- Shape test

Table 2. 1: Results of Los Angles Abrasion Test

Sl. No.	Grade of Aggregate	Type of Aggregate	Total Wt of Aggregate (W_1)	Wt Retained on 1.7mm Sieve (W_2)	Los Angles Abrasion Value	Weighted Average Value	Requirements as per MORT & H 2001
1.	A	Basalt	5000	4128	17.44%	21.92%	Max. value 35%
2.	B	Basalt	5000	4110	18%		
3.	C	Basalt	5000	3900	22%		
4.	D	Basalt	5000	3488	30.24%		

Table 2. 2: Aggregates Impact Values [1]

Sl. No.	% Passing	Conclusion
1	<10%	Exceptionally strong:
2	10-20%	strong
3	10-30%	satisfactorily for road surfacing
4	>35%	weak for road surfacing

Table 2. 3: Observation for Basalt

Sl. No.	Description	Weights in gm
1	Empty weight of measuring cylinder	750
2	Empty weight + aggregates	1100
3	Weight of sample = W_1	350
4	Weight of sample passing 2.36mm sieve = W_2	75
5	Weight of sample retained on 2.36mm sieve = W_3	275
6	Aggregate impact value	21.42%

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* *Correspondence Author (s)*

Dr. Md. Imran Khan*, Department of Civil Engineering, Technocrats Institute of Technology Bhopal (M.P), India. E-mail: mdimran_stru@yahoo.com, ORCID ID: 0009-0009-4606-8602

Table 2. 4: Observation of Specific Gravity Coarse Aggregate

Sl. No.	Description	Weights in gms
1	Weight of saturated aggregate suspended in water with the basket = W_1	2800
2	Weight of basket suspended in water= W_2	875
3	Weight of saturated aggregate in water (W1-W2) = Ws	1925
4	Weight of saturated surface dry aggregate in air = W_3	2890
5	Weight of water equal to the volume of the aggregate=(W_3-Ws)	965
6	Weight of oven dried aggregate =W_4	3000
7	Specific gravity	3.1

Table 2. 5: Observation of Specific Gravity Fine Aggregate

Sl. No.	Description	Weights in gms
1	Empty weight of pycnometer = W_1	665
2	Pycnometer+1/3 of sand= W_2	965
3	Pycnometer+1/3 of sand+water = W_3	1742
4	Pycnometer + water= W_4	1544
5	Specific gravity	2.94

Table 2. 6: Observation of Specific Gravity Filler Material

Sl. No.	Description	Weights in gms
1	Wt of empty specific gravity bottle = W_1	42
2	Wt of bottle + 1/3rd of filler material = W_2	88
3	Wt of bottle + 1/3rd of filler material + kerosene = W_3	152
4	Wt of bottle + kerosene = W_4	122
5	Wt of bottle + water alone = W_5	145
6	Specific gravity of filler material	2.87

Table 2. 7: Specific Gravity Values

Sl. No.	Type of Aggregate	Coarse	Fine	Mineral Filler
1.	Basalt	3.1	2.94	2.89

Table 2. 8: Dimensions of the Thickness and Length Gauges

Sl. No.	Sieve Size	Wt of Aggregate Passing through Thickness		Weight of Aggregate Retained on Length Gauge	
		Passing	Retained	Passing	Retained
1.	20 -16	200	610	530	80
2.	16-12.5	70	330	290	40
3.	12.5-10	65	120	110	10
4.	10-6.3	25	74	40	34
	Total	**360**	**1134**		**164**
	Flakiness Index	24.09%			
	Elongation Index	14.46%			
	Combined FI & EI	38.55%			

Table 2. 9: Flakiness Index

Size of Aggregate		(a) Thickness Gauge (0.6 Times the Mean Sieve) Mm	(b) Length Gauge (1.8 Times the Mean Sieve), Mm
Passing through IS Sieve Mm	Retained on IS Sieve Mm		
1	2	3	4
63	50	33.9	--
50	40	27	81
40	25	19.5	58.5
31.5	25	16.95	--
25	20	13.5	40.5
20	16	10.8	32.4
16	12.5	8.55	25.6
12.5	10	6.75	20.2
10	6.3	4.89	14.7

Table 2. 10: Result of Water Absorption Test

Sl. No.	Description	Weights in gms
1	Weight of wet aggregate = W_1	3022
2	Weight of aggregate after oven dry = W_2	2968
3	Water absorption	1.81

III. PHYSICAL PROPERTIES OF BITUMEN

The following tests were conducted in order to find the physical properties of bitumen.

- Penetration test
- Ductility test
- Softening point test
- Specific gravity test for bitumen

Flash and fire point tests

Table 3. 1: Details of Bitumen Grades

Bitumen Grade	A25	A35 & S 35	A 45 & S 45	A 65 & S 65	A 90 & S 90	A 200 & 200
Penetration value	20 to 30	30 to 40	40 to 50	60 to 70	80 to 100	175 to 225

Table 3. 2: Penetration Test on Bitumen

Sl. No.	Penetration Reading		Difference in Reading	Average
	Initial Reading	Final Reading		
1	73	160	87	84.75 mm
2	80	155	75	
3	79	165	86	
4	80	171	91	

Table 3. 3: Details of Bitumen Grades

Sl. No.	Source of Paving Bitumen and Penetration Grade	Minimum Ductility Value cm
1	Assam petroleum A 25	5
2	A 35	10
3	A 45	12
4	A 60,A 90 and A 200	15
5	Other than Assam S 35	50
6	S 45, S 65 & S 90	73

Table 3. 4: Details of Range Softening Point as per ISI [1]

Bitumen Grades	Softening Point, °C
* A 25 & A 35	55 to 70
* S 35	50 to 65
A 45, S 45 & A 65	45 to 60
S 65	40 to 55
A 90 & S 90	35 to 50
A 200 & S 200	30 to 45

Table 3. 5: Softening Point of Bitumen

Sl. No.	Test Property	Ball Number		Mean Value, Softening Point
1.	Temperature (°C) at which sample touches bottom plate	38°	40°	39°

Grade of Bitumen = **A 90 & S 90, A 200 & S 200**

Table 3. 6: Specific Gravity Test for Bitumen

Sl. No.	Description	Weights in gms
1	Weight of empty pycnometer = W_1	668
2	Weight of empty pycnometer + 1/3rd of bitumen = W_2	850
3	Weight of pycnometer + 1/3rd of bitumen + water = W_3	1564
4	Weight of pycnometer + water = W_4	1548
5	Specific Gravity	1.09

Table – 3. 7: Density and Voids Analysis for Plain Mix

Sample No.	Bitumen Content %	Height of Sample in Mm				Mean Height	Weight of Sample (gm)		Bulk Density (Gb)	Theoretical Density (Gt)	Vv	Vb	VMA	VFB
		h1	h2	h3	h4		Air	Water						
1.	4.5	62.0	63.0	65.0	66.0	64.0	1232	686	2.25	2.39	5.95	32.76	38.71	84.62
2.	4.5	67.0	68.0	66.0	65.0	66.5	1226	688	2.27		5.02	33.05	38.07	86.81
3.	4.5	67.0	65.0	65.0	67.0	66.0	1228	682	2.24		6.2	32.62	38.82	84.02
Average									**2.25**		**5.72**	**32.81**	**38.53**	**85.15**
4.	5.0	63.0	64.0	65.0	63.0	65.0	1234	698	2.30	2.4	4.16	33.49	37.65	88.95
5.	5.0	66.0	64.0	65.0	66.0	65.2	1240	708	2.33		2.91	33.93	36.84	92.10
6.	5.0	67.0	65.0	67.0	66.0	66.2	1238	706	2.32		3.33	33.78	37.11	91.02
Average									**2.31**		**3.466**	**33.73**	**37.20**	**90.67**

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7.	5.5	68.0	66.0	66.0	69.0	67.2	1236	704	2.32	2.41	3.73	33.78	37.11	91.02
8..	5.5	67.0	66.0	64.0	68.0	66.2	1222	684	2.27		5.80	33.05	38.85	85.07
9.	5.5	67.0	68.0	69.0	68.0	68.0	1252	700	2.26		6.22	32.91	39.13	85.10
Average									**2.28**		**5.25**	**33.24**	**38.36**	**86.65**

Type of grading BC grade – 2
Mixing temperature, °C = 150°
Proving ring constant = 28.2

Grade of bitumen 80/100
compacting temperature, °C= 135°C

Table 3. 8: Marshall Stability Test Plain Mix Stability and Flow Value Determination

Sample No.	Bitumen %	Max Proving Ring Reading	Correction factor	Stability Value, Kg		Flow Dial Reading	Flow Values (mm)
				Measured	Corrected		
1	X1 = 4.5%	320	0.9875	20.48	20.224	250	2.5
2		340	0.93375	22.61	21.112	280	2.8
3		410	0.943125	27.0602	25.52	350	3.5
				Avg.	**22.28**		**2.93**
1	X2 =5.0%	310	0.9625	20.15	19.39	260	2.6
2		360	0.95812	22.972	21.53	290	2.9
3		420	0.9393	27.804	26.116	370	3.7
				Avg.	**22.34**		**3.06**
1	X3 = 5.5%	330	0.9175	22.176	20.34	290	2.9
2		370	0.9393	24.494	23	270	2.7
3		400	0.8975	27.2	24.412	320	3.2
				Avg.	**22.58**		**2.93**
1	X4=6.0%	325	0.93375	21.612	20.18	320	3.2
2		330	0.943125	21.78	20.54	310	3.1
3		390	0.9625	25.35	25.35	330	3.3
				Avg.	**21.7**		**3.2**

Table 3. 9: Marshall Properties at Optimum Bitumen Content [3]

Sample No.	Bitumen Content %	Height of Sample in Mm			Mean height	Weight of Sample (gm)		Bulk Density (Gb)	Theoretical Density (Gt)	Vv		Vb	VMA	VFB
		h1	H2	h3	H4		Air	Water						
1.	6.0	65.0	67.0	67.0	66.0	66.5	1268	708	2.21	2.42	6.61	32.93	39.54	83.28
2.	6.0	66.0	66.0	66.0	66.0	66.0	1256	708	2.29		5.30	33.34	38.64	86.50
3.	6.0	66.0	65.0	64.0	65.0	65.0	1252	720	2.35		2.89	34.22	37.11	92.21
Average								**2.28**		**3.30**		**33.49**	**38.43**	**89.74**

Table 3. 10: Marshall Properties at Optimum Bitumen Content [3][8]

Sl. No.	Properties Tested	BC Mix with Plain	Requirements as per IS:2386 Part-1
1.	Optimum bitumen content	5.5	--
2.	Stability KN	22.60	9
3.	Flow mm	3.2	2 to 4
4.	Unit weight gms / cm3	2.315	--
5.	% Air voids	4	3 to 6
6.	VMA %	37.22	13% Minimum
7.	VFB %	92	65 to 78

Specific Gravity of Waste Plastic Observation

Table 3. 11: Specific Gravity Test for Plastic

Sl. No.	Description	Weights in gms
1	Weight of empty pycnometer = W_1	668
2	Weight of empty pycnometer + 1/3rd of Plastic= W_2	672
3	Weight of pycnometer + 1/3rd of Plastic + water = W_3	1560
4	Weight of pycnometer + water = W_4	1548
5	Specific Gravity	0.49

Table 3. 12: Density and Voids Analysis for Plastic Content at OBC (5.5) [4]

Sample No.	Plastic Content %	Height of Sample in Mm				Mean height	Weight of Sample (gm)		Bulk Density	Theoretical Density (Gt)	Vv	Vb	VMA	VFB
		h1	h2	h3	h4		Air	Water	(Gb)					
1	8	63	64	63	63	63	1260	690	2.21	2.3539	6.113	32.184	38.297	84.038
2	8	66	68	68	66	67	1268	698	2.22		5.688	32.33	38.018	85.038
3..	8	66	67	68	69	67.5	1240	686	2.24		4.838	32.62	37.458	87.084
Average									**2.22**		**5.688**	**32.33**	**38.018**	**85.038**
4	10	66	64	63	66	64.7	1206	678	2.28	2.35419	3.151	33.203	36.354	91.32
5	10	65	66	67	68	66.5	1236	698	2.29		2.726	33.349	36.075	92.44
6	10	67	68	67	69	67.7	1244	688	2.23		5.275	32.475	37.75	86.026
Average									**2.27**		**3.57**	**33.058**	**36.628**	**90.25**
7	12	75	75	72	72	73.5	1250	692	2.24	2.3544	4.85	32.62	37.47	87.056
8..	12	71	70	68	70	69.7	1247	694	2.25		4.43	32.767	37.197	88.09
9	12	68	66	69	71	68.5	1270	711	2.27		3.58	32.058	36.638	90.228
Average									2.25		4.434	32.767	37.201	88.08

Table 3. 13: Marshall Stability Test – Plastic Mix at OBC (5.5)

Sample No.	Plastic %	Max Proving Ring Reading	Correction factor	Stability Value		Flow Dial Reading	Flow Values (mm)
				Measured	Corrected		
01.	X1 = 8	360	1.0125	22.68	22.96	240	2.4
02.		430	0.922	28.81	26.56	320	3.2
03.		405	0.910	27.33	24.87	340	3.4
				Avg.	**24.79**		**3.00**
01.	X2 =10	370	0.85	27.19	23.11	380	3.8
02.		440	0.8637	30.66	26.48	580	5.8
03.		540	0.8862	36.99	32.72	620	6.2
				Avg.	**27.43**		**5.26**
01.	X3 = 12	330	0.97	21.35	20.70	210	2.1
02.		365	0.934	24.27	22.66	430	4.3
03.		380	0.905	25.72	23.27	440	4.4
				Avg	**22.21**		**3.6**

Table 3. 14: Marshall Properties at Optimum Plastic Content [5][8][10]

Sl. No.	Properties Tested	BC Mix with OPC	Requirements as per IRC: SP:53-2002
1.	Optimum bitumen content	5.5	--
2.	Stability KN	27.6	10.2
3.	Flow mm	5.22	2.5 to 5
4.	Unit weight gms / cm^3	2.27	--
5.	% Air voids	3.5	3 to 6
6.	VMA %	36.6	13% Minimum
7.	VFB %	90.25	65 to 75

IV. RESULTS AND DISCUSSION

The various results obtained are as shown in the table:-

Table 4. 1: Comparison Between BC Mix of OPC and BC Mix of OBC

Sl. No.	Properties Tested	BC mix of OPC	BC mix of OBC
1	Optimum bitumen content	5.5	5.5
2	Stability in kN	27.6	22.60
3	Flow in mm	5.22	3.2
4	Unit Weight gm/cm^3	2.27	2.315
5	% Air Voids	3.5	4
6	VMA %	36.6	37.22
7	VFB %	90.25	92

V. DISCUSSION

By comparing the results between BC mix with waste plastic and plain BC mix, it has been found that O.B.C with waste plastic is same as than that of plain BC mix. The stability value of BC mix with waste plastic is 27.6% higher than that of plain BC mix. The unit weight of BC mix with waste plastic is less than that of plain BC mix. The voids ratio for BC mix with waste plastic is 12.5% lower than plain BC mix. Voids in mineral aggregate for BC mix with waste plastic are 1.66% lower than plain BC mix.

The voids filled with bitumen for BC mix with waste plastic are 1.902% lower than that of the plain mix. The above results are within the limits specified by MoRT&H-2001 specifications.

VI. CONCLUSION

1) OPC mix shows 27.6% higher stability when compared to OBC mix.
2) As plastic cannot be decomposed, it can be used for constructing pavement as proved by test results
3) Using Plastic paving mix, the cost of scarce material and amount of energy required can be reduced.
4) The plastic-coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient.
5) Hence the use of waste plastics for flexible pavement is one of the best Methods of easy disposal of waste plastics.
6) Inter molecular bonding between bitumen & waste pp aggregate enhances Strength & thus quality of bituminous concrete mixes.
7) Significant improvements were observed in performance parameters in Marshall Stability ITS, Rutting, retained stability of bituminous concrete mixes More durable, less susceptible to moisture in actual field conditions with Improved performance.
8) Coating of waste PP on stone aggregate improves AIV, LAAV, & reduces Water absorption capacity of aggregate.

DECALARION STATEMENT

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Authors Contributions	I am only the sole author of the article.

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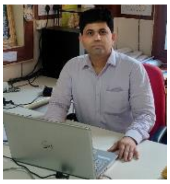
AUTHOR PROFILE



Dr. Md. Imran Khan, He has earned Master degree in structural engineering, PDACE Gulbarga, Visvesvaraya technological university (VTU), Belgaum, Karnataka, He has completed his PhD in structural engineering, Rabindranath Tagore university Bhopal MP. He has published more than 15 peer review research articles.