International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.9, No.01 pp 248-252, 2016

Evaluation of Strength Properties of Pavement Binder Replaced with Waste Materials as Modifier

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Abstract: In India, bituminous pavement is commonly used for highways. Due to the increasing traffic intensity, distress such as rutting and cracking of pavements are very common in Indian roads. Under varying seasonal temperature, flexible pavements tend to become soft in summer and brittle in winter. Investigations revealed that properties of bitumen can be improved with the incorporation of modifiers. The bitumen treated with these modifiers is known as Modified Bitumen. In this study, bitumen of grade VG 30 is selected and improved its properties by the addition of modifiers. Low Density Poly Ethylene (LDPE) waste and Pulverised Tyre Waste (PTW) the modifiers used. Basis parameters such as penetration, softening point and ductility of modified bitumen were found. Results showed enhancement in the properties of bitumen. Marshall stability value of modified bitumen is also improved when compared to the selected raw bitumen.
Keywords: Binder, Bitumen, Modifier, Pavement, Viscosity Grade.

1. Introduction

Plastic is a non-biodegradable material. Despite, the quantum of plastic waste is also increasing day by day which is hazardous to our health. Thus using plastic waste for construction purpose of flexible pavements will be one of the alternatives for disposing them in an eco friendly manner. The better binding property of plastics in its molten state has helped in finding out a method of safe disposal of waste plastics, by using them in pavements. Modified Bitumen is one of the important construction materials for flexible pavements which may have improved properties thereby reducing the distress faced by a conventional flexible pavement.

2. Materials and Methods

The study involves in determining the properties of raw bitumen and bitumen mixed with various percentages of modifier. The bitumen used in the study is VG 30 grade which is equivalent to 50/70 penetration grade. Low Density Poly Ethylene (LDPE) waste and Pulverised Tyre Waste (PTW) were used as modifiers. The LDPE waste was sieved through 4.75mm sieve and retained at 2.36mm sieve. The portion of the material retained at 2.36mm sieve was collected and used for the study. The other modifier PTW was sieved through 600 micron sieve and retained at 150 micron sieve. The retained material was collected and used further. Bitumen was heated up to 140^{O}C. Pieces of modifiers were added slowly to the hot bitumen. The mixture was stirred manually for about 20-30 minutes and thus the modified bitumen was prepared.

3. Physical Properties of Modified Bitumen

Various laboratory tests were conducted to determine the properties of modified bitumen as per standards conforming to IS 1203 – 1978, IS 1205 – 1978 and IS 1208 – 1978 respectively for penetration test, softening point test and ductility test. The values of these properties are reported in Tables 1 to 3.

Table 1 Penetration values of modified bitumen

Sl.No	PTW modified bitumen		LDPE modified bitumen	
	% of modifier	Penetration Value (at 25^{O}C, 100g, 5sec, 0.1mm)	% of modifier	Penetration Value (at 25^{O}C, 100g, 5sec, 0.1mm)
1.	0	59	0	59
2.	4	70	3	58
3.	6	66	4	55
4.	8	60	5	54
5.	10	57	6	51
6.	12	55	--	--

Table 2 Ductility values of modified bitumen

Sl.No	PTW modified bitumen		LDPE modified bitumen	
	% of modifier	Ductility Value (cm)	% of modifier	Ductility Value (cm)
1.	0	53	0	53
2.	4	52	3	55
3.	6	45	4	59
4.	8	41	5	60
5.	10	36	6	63
6.	12	32	--	--

Table 3 Softening Point values of modified bitumen

Sl.No	PTW modified bitumen		LDPE modified bitumen	
	% of modifier	Softening point value (^{0}C)	% of modifier	Softening point value (^{0}C)
1.	0	49	0	49
2.	4	50	3	50
3.	6	48	4	52
4.	8	51	5	53
5.	10	51	6	56
6.	12	53	--	--

4. Marshall Stability Test

Marshall stability and flow values of both raw bitumen and modified bitumen were studied and compared. The test is done at various percentages as per IRC 111 – 2009. The test is carried out as per ASTM D 1559.

4.1. Proportioning of Materials

Proportioning is done for the materials used to prepare the specimen. Sieve analysis test is carried out individually for the materials used.

4.2. Combined Gradation

With respect to the sieve analysis values, the combined gradation of aggregates is done by trial and error method. Number of trials was done and the combined gradation of aggregates which satisfies the limits as per IRC 111 - 2009 specifications is shown in the table 4.

Table 4 Combined Gradation of Aggregates

Size of Aggregate		%	13.2 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	300 micron	75 micron
11.2mm	% passed		100	70.90	0.30	0.00	0.00	0.00	0.00
	jobmix %	18	18.00	12.76	0.05	0.00	0.00	0.00	0.00
6.7mm	% passed		100	100	22.40	1.70	0.00	0.00	0.00
	jobmix %	50	50.00	50.00	11.20	0.85	0.00	0.00	0.00
Dust	% passed		100	100	100	96.20	75.80	41.90	12.40
	jobmix %	32	32.00	32.00	32.00	30.78	24.26	13.41	3.97
Combined grading		100	100	94.76	43.25	31.63	24.26	13.41	3.97
IRC 111 - 2009 specification			100	90 - 100	35 - 51	24 - 39	15 - 30	9 - 19	3 - 8

4.3. Design Mix

From the sieve analysis and combined gradation tables, the Marshall mix design is obtained and is shown in the table 5.

The total weight of the aggregate used is 1200g. Modified bitumen is prepared using 12% modifier for PTW and 6% modifier for LDPE waste.

Table 5 Marshall Design Mix

Sl.No	Aggregate	Percentage	Weight taken (g)
1.	11.2mm	18	216
2.	6.7mm	50	600
3.	Dust	32	384
Total		100	1200

4.4. Marshall test results

The Marshall stability and flow values for the raw bitumen and modified bitumen are represented in table 6. The values of stability and flow are the representation of 4 samples prepared with 4.5%, 5%, 5.5% and 6% respectively and optimum binder content is obtained.

Table 6 Results of Marshall test

Sl.No	Modifier	Optimum bitumen content (%)	Stability (kN)	Flow (mm)
1.	Raw bitumen	5	9.31	4.9
2.	PTW	5.22	12.11	3.20
3.	LDPE	5.19	11.96	2.96

5. Cost Analysis

Cost analysis was carried out based on PWD Schedule of rates 2012 – 2013. It is calculated for 50mm thick Bituminous Macadam (BM) road for 10sq.m area. With the available rates for machineries, labour and material, the total cost of bituminous pavement paved with modified bitumen is calculated as per the Marshall design. Tables 7 and 8 show the cost table for PTW and LDPE waste modified bituminous pavement respectively.

1. Central Hot Mix Plant - Rs.1025.71
2. Vibratory roller - Rs.20.68
3. Paver finisher - Rs.43.49
4. Tipper Trucks - Rs.130.21
5. Labour charges - Rs.112.72

Total machinery & labour charges - **Rs.1332.81**

Table 7 Cost analysis for PTW

Sl.No	Quantity	Description	Rate Per Unit (Rs)	Amount (Rs)
1.	0.13 m^3	Cost of 26.5 – 11.2mm graded metal (m^3)	1032.38	433.60
2.	0.10 m^3	Cost of 11.2 – 2.8mm graded metal (m^3)	535.94	53.59
3.	0.22 m^3	Cost of 2.8mm & below size metal(m^3)	500.75	90.14
4.	38.15 kg	Cost of bitumen(per MT)	42932.40	1637.87
5.	10 m^2	Hire & Labour Charges (10m^2)	1332.81	1332.81
		Total charges per 10m^2 for 50mm thick		3402.64
		Rate per m^3 = 3402.64 x (10/0.050)		6805.28

For bitumen content of 5.22%, rate per m^3 **Rs. 6805.23**

For bitumen content of 5.22%, with 12% PTW modifier, rate per m^3 **Rs. 6702.76**

Table 8 Cost analysis for LDPE

Sl.No	Quantity	Description	Rate per unit (Rs)	Amount (Rs)
1.	0.13 m^3	Cost of 26.5 – 11.2mm graded metal(m3)	1032.38	433.60
2.	0.10 m^3	Cost of 11.2 – 2.8mm graded metal(m3)	535.94	53.59
3.	0.22 m^3	Cost of 2.8mm & below size metal(m^3)	500.75	90.14
4.	38.15kg	Cost of bitumen(per MT)	42932.40	1637.87
5.	10 m^2	Hire & Labour Charges (10m^2)	1332.81	1332.81
		Total charges per 10m^2 for 50mm thick		3412.09
		Rate per m^3 = 3412.09 x (10/0.050)		6824.18

For bitumen content of 5.19%, rate per m^3 **Rs. 6824.18**

For bitumen content of 5.19%, with 6% LDPE modifier, rate per m^3 **Rs. 6587.74**

6. Results and Discussion

6.1. Penetration values

Penetration value of modified bitumen decreases by 6.8% for PTW and 13.6% for LDPE waste. The decreased value of penetration for the modified bitumen shows that it has become stiffer due to increase in hardness of the sample after adding modifier.

6.2. Softening point values

Softening point value increases by 8.16% for PTW and 14.28% for LDPE waste. This again is due to the stiffness effect of waste materials that modified the bitumen binder to become less susceptible to temperature.

6.3. Ductility

Ductility value has decreased by 39.6% for PTW and increased by 18.86% for LDPE waste.

6.4. Marshall stability and flow values

In Marshall test, the stability value has increased by 30% for PTW and 28.46% for LDPE waste. The higher stability value obtained for modified bitumen is due to its increased stiffness due to the addition of waste materials.

Addition of this modifier reduced the flow value by 34.69% for PTW and 39.59% for LDPE waste, which shows that the flow property has increased.

7. Conclusions

The results of this study concluded that addition of PTW and LDPE waste has improved the properties of penetration, ductility and softening temperature of the modified bitumen. As the stiffness of the material is improved, it is capable of taking high load and increase the resistance to pavement ruts. Therefore, the durability of the pavement is improved by the use of waste material that also helps to use the waste in an efficient manner.

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