"An experimental study on the properties of extruded Polystyrene waste polymer modified bitumen for flexible pavements"

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Abstract - *Disposal and recycling of waste, gains impels day by day and the need for waste management rises due to over generation, non-availability of space and resources for disposal. Poor management of plastic waste will also lead to environmental pollution. Utilization of waste polystyrene bowls in Bituminous mixes had turned out to enhance the properties of bitumen binder and there by solving the problem of disposal. In this study, 'Used Polystyrene Bowls' were cleaned and shredded into pieces using shredding machine. The size of such pieces was small enough to pass through 2-3mm sieve. The effect of extruded polystyrene waste polymer (EPWP) modified bitumen on properties such as penetration, softening point, specific gravity, ductility and viscosity values on 60/70 grade bitumen has been evaluated. Tests for properties were conducted for 0 %, 5%, 10% and 15% replacement of used polystyrene bowls by weight of the bitumen and optimum replacement was identified between 10-15%. EPWP also increases the performance of pavements by decreasing the formation of ruts and cracks. It also has got vast application in construction of flexible pavement, manufacturing of polystyrene blocks, insulating material etc.*

Key Words: Bitumen, extruded polystyrene waste polymer, flexible pavement, modified bitumen, Polystyrene bowls.

1. INTRODUCTION

Modification of bitumen can be done by replacement of either surfactants or polymers to it. Surfactants include silica, granite, quartz, lime stone and basalts. Polymers such as polyethylene [1] , reclaimed polyethylene [2], low density polyethylene[3], tyre rubber waste , Styrene Butadiene Styrene (SBS) , Polytetrafluroethylene, Epoxy resin, Poly olefin, Ethylene vinyl acetate (EVA) , Phenol formaldehyde [4] etc., shows enhanced properties of bitumen.

Polystyrene is a product obtained from petroleum. Polystyrene is non - sustainable, highly polluting and non-renewable. Food service polystyrene packings are not usually recyclable. Toxins in polystyrene include styrene and benzene which are identified carcinogen and neurotoxin. For the past few years, polystyrene beads are used for variety of construction works such as highways, retaining walls etc., one special characteristics of polystyrene is "super lightweight material". Few of the advantages of replacement include bitumen savings, disposal of used polystyrene bowls and increasing the engineering and thermal properties of bitumen. Total environmental effects caused by polystyrene ranks second highest where aluminum ranks first (waste-reduction group, Hong Kong, environmental protection department)

Polystyrene is commonly called as Styrofoam which is manufactured by adding blowing agent to polystyrene with petroleum based plastic material. Polystyrene contains 95% air and hence they are light in weight. Polystyrene is broadly classified into two types 1) expanded polystyrene (EPS) 2) Extruded polystyrene (XPS)

1.1 Expanded polystyrene

Small plastic beads are expanded and fused together forming products which are used for protective coating of electrical appliances.

1.2 Extruded polystyrene

Continuous mass of molten material are shaped into products such as lunch boxes and trays. XPS has got a little recycling possibility.

2. MATERIALS

2.1 Bitumen

As per definition given by the American Society of Testing Materials, bitumen has been defined as a "Mixture of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide." 60/70 penetration grade pure bitumen is brought from Indian Oil Corporation limited. Some of the physical properties of bitumen are showed in Table 1

Table 1: Physical properties of 60/70 bitumen

Test	Specified limits as per IS	Results
Penetration Test in 1/10 mm	60-70	64
Softening Point Test (̊ C)	50-65	50
Ductility Test (cm)	75 cm minimum	104.17
Viscosity test (Seconds)	14-45	27
Specific Gravity	1.1-1.15	1.11

2.2 Modifying agent (waste extruded polystyrene bowls)

Used extruded polystyrene bowls are collected from street food stalls in and around Peelamedu, Coimbatore, Tamilnadu. The properties of waste polystyrene bowls are given below in Table 2 [9]

Physical state	Solid ,granule
Boiling point	>100˚ c
Density	20 kg/m³
Colour	White
Smell	Odourless

Table 2: Physical properties of waste polystyrene bowls

2.3 Preparation of waste polymer modified bitumen

Bitumen along with extruded polystyrene are mixed in a vertical low shear mixer with mechanical stirrer @ 600 rpm at 200˚ C and polymer is modified by 5%,10% and 15% replacement by weight of bitumen.

3. TESTS ON BITUMEN

Properties of the EPWP bitumen are investigated by conducting the following tests

3.1 Penetration Test (IS 1203-1978):

The penetration test is used to determine whether the bitumen is hard or soft by measuring the depth in tenths of an mm to which a standard loaded needle of 1 mm cross section will penetrate vertically in 5 seconds. The test set up is shown in the Fig.1

Fig -1: Experimental setup for penetration test

3.2 Ductility Test (IS 1208 -1978):

The ductility is expressed as the distance in centimeters to which a standard briquette of bitumen can be stretched before the thread breaks. The test is conducted at 27 °c and at a rate of pull of 50mm per minute. The test set up is shown in Fig 2.

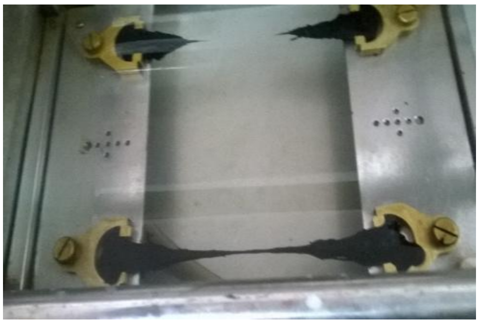

Fig- 2: Experimental set up for ductility test

3.3 Float Test (IS 1210 – 1978)

The float assembly is floated in a water bath at 50°C and the time required in seconds for water to force its way through the bitumen plug is noted as the float test value. Higher the float test value, stiffer is the material.

Fig- 3: Experimental setup for float test

3.4 Softening Point Test (IS 1205 -1978)

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test. The temperature at which the softened bitumen touches the metal plate at a specified distance below the ring is noted as softening point of bitumen.

Fig-4: Experimental setup for softening point test

3.5 Specific Gravity (IS 1202 – 1978):

The specific gravity of bituminous materials is determined by preparing a specimen in semi solid or solid state and by weighing in air and water.

Specific gravity = W_1 / (W_1 –W_2)

Where, W_1 = Weight in air

W_2 = Weight in water

4. RESULTS AND DISCUSSION

4.1 Effect on penetration:

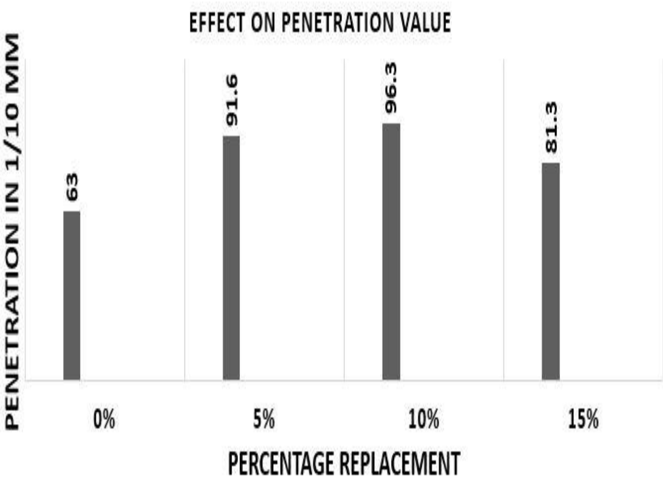

Chart-1: Percentage replacement Vs Penetration value

Table3: Penetration values EPWP bitumen

Percentage replacement (%)	Penetration value (mm)			
	Trial1	Trial2	Trial3	Mean
0	64	62	63	63
5	91	92	92	91.6
10	99	94	96	96.3
15	80	81	83	81.3

Comparing the Penetration values with that of conventional bitumen reveals that the penetration value increases by 42%, 8.79% on 5%, 10 % replacement respectively and suddenly the value decreases by 19% at 15 % replacement. The decrease in penetration value occurs in between 10-15% suggesting that further increase in the % of replacement would result in further reduction of the penetration value.

4.2 Effect on specific gravity

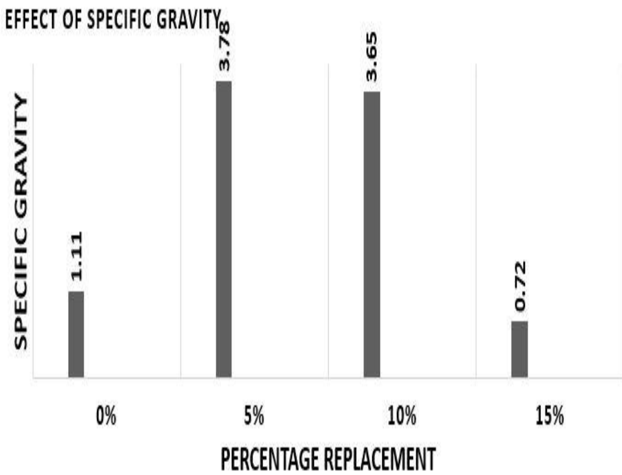

Chart-2: Percentage replacement Vs Specific Gravity

Table-4: Specific gravity of EPWP bitumen

Percentage replacement (%)	Weight in air(g)	Weight in water(g)	Specific gravity
0	85.5	40.5	1.11
5	88.5	18.5	3.78
10	100.5	21.5	3.65
15	189.5	110	1.72

Value of specific gravity increases with 5% and 10 % replacement but suddenly decreases at 15% replacement. So it is evident that replacement of EPWP can be done in the range of 10-15%.

4.3 Effect on viscosity

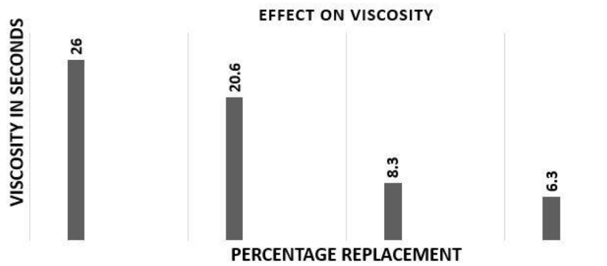

Chart- 3: Percentage replacement Vs Viscosity

Table5: Viscosity of EPWP bitumen

Percentage replacement (%)	Flow in seconds			
	Trial 1	Trial2	Trial3	Mean
0	27	27	26	26
5	20	21	21	20.6
10	8	8	9	8.3
15	6	7	6	6.3

Viscosity value decreases with 5%, 10%, 15% replacement which indicates that EPWP bitumen is less stiffer as increase in flow value increases the stiffness.

4.4 Effect on Ductility

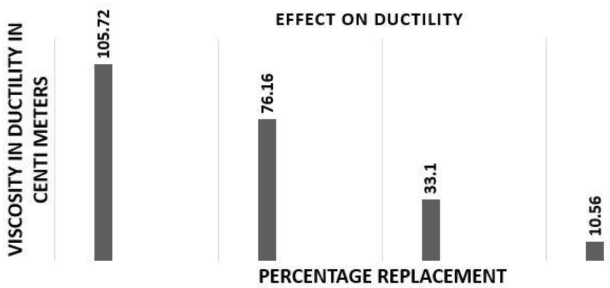

Chart-4: Percentage replacement Vs Ductility

Table6: Ductility of EPWP bitumen

Percentage replacement (%)	Ductility in cm			
	Trial 1	Trial 2	Trial 3	Mean
0	104.17	105	108	105.72
5	76	77.5	75	76.16
10	33	33.5	32.8	33.1
15	10	11.5	10.2	10.56

It is observed that ductility value is decreasing linearly with increase in percentage of replacement.

4.5 Effect on softening point

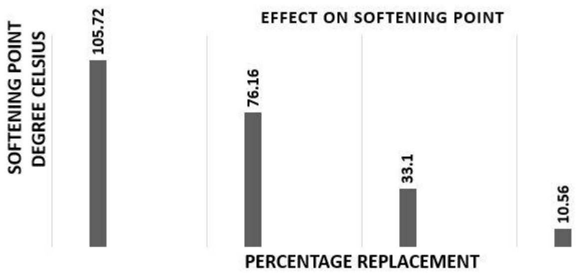

Chart-5: Percentage replacement Vs Softening point

Table-3: Softening point of EPWP bitumen

Test property	0%	5%	10%	15%
Temperature (̊ C) at which the sample touches the bottom plate	50	56	57	59

The increase in the value of softening point indicates that the bitumen is highly resistant to permanent deformation like stripping, bleeding and rutting.

5. CONCLUSION

The results indicate that the use of EPWP in Bitumen binder increases the penetration value of conventional bitumen which in the range of 6-7 mm for 60/70 grade to 9.63 mm for 10 % replacement and 15 % replacement of EPWM decreases the value to 8.13 mm which indicates that the addition of EPWP above 10 % may result in the increase of stiffness and hence decrease the penetration value. Higher Specific gravity values of 5 % and 10 % replacement shows modified bitumen is more denser but when the EPWP is added beyond 10%, reduces the density and hence a considerable decrease in value at 15% replacement. The elasticity of bitumen as determined from the ductility test indicate that the value of ductility comply with the standard value of minimum 75 centimeters up to 5% replacement. Further increase in the EPWP content to 10 % and 15 % replacement, the results indicate a significant decrease in the ductility value. From the flow values for 5%, 10% and 15% EPWP modified bitumen; it is evident that the viscosity of the EPWP modified bitumen is found to be increasing with increase in the % replacement of EPWP. The increase in the softening temperatures of 5%, 10% and 15% replacements of EPWP modified bitumen signifies that the modified binder could be best used in hot arid regions for flexible pavement construction.

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