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Experimental Study on Marshall Stability of BC Mix by adding PET as an Additive

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Abstract - *A significant portion of the total municipal solid waste (MSW) generated in India consists of Plastic waste. As per the recent estimates, approximately Ten thousand tons per day (TPD) of plastics waste is generated. As plastics are not biodegradable, it is better to use the waste plastic for some beneficial purposes. Various percentages of PET are used for preparation of mixes with a selected aggregate grading. The role of PET in the mix is studied for various engineering properties by preparing Marshall Samples of BC mixtures with and without addition of polymer. Various Properties such as stability, flow, unit weight and air voids are used to determine optimum polythene content for 80/100 grade Bitumen. The physical and mechanical properties of PET modified and conventional binder mixes are calculated. These Mixes are compacted using Marshall Stability. Indirect tensile strength ratio tests were conducted and compared.*

Key Words: Bitumen, PET, Bituminous Concrete.

1. INTRODUCTION

In recent years, the amount of waste plastic bottles being generated had become a serious problem to our environment. Polyethylene Terephthalate (PET) plastic is now used as a packaging material for a whole range of consumer products in addition to carbonated beverages. Although PET is very useful for us but the disposal of the waste plastic bottles in large quantities has been a problem and is of great concern. One of the solutions to the disposal of plastic bottles is recycling the plastic bottles into useful products.

Due to increasing demand in highway construction, scientists and researchers are constantly trying to improve the performance of bitumen pavement. Asphalt concretes are widely used in pavements. Bitumen is the naturally occurring byproduct of crude oil. Due to increase in vehicles in recent years the road surfaces have been exposed to high traffic resulting in deformation of pavements due to excessive stress. Permanent deformation happens when pavement does not have sufficient stability, improper compaction and insufficient pavement strength.

The performance of pavement is determined by the properties of bitumen. Bitumen is a visco-elastic material with suitable mechanical and rheological properties for water proofing and protective covering for roofs and roads, because of its good adhesion properties of aggregates. One of the most important properties of bitumen mixture is its ability to resist shoving and rutting under traffic. Therefore, stability should be high enough to handle traffic adequately, but not higher than the traffic conditions require.

Low stability causes unraveling and flow of the road surface. Some improvements in asphalt properties have been achieved by selecting the proper starting crude, to make asphalt. From practical experiences it is proved that the modification of asphalt binder with polymer additives, offers several benefits. To enhance various engineering properties of asphalt many modifiers such as styrene based polymers, polyethylene based polymers, polychloroprene, Gilsonite, various oils have been used in asphalt.

Plastic usage has been increased in our daily life. Due to this increased usage of plastic the disposal of plastic has been difficult. Some studies say that 10million tones of plastic are produced in India and only 2million tones of plastic waste are recycled. Plastics have to be disposed or else it will be hazardous to nature and environment. Thus one of the best ways of disposal of these plastics is to use in bituminous road construction by melting them. Many highway agencies are doing various studies on environmental suitability and performance of recycled products in high construction. Use of these waste plastic in bituminous road construction will help in disposal of vast quantities of plastic. Consumption of mineral water bottles which are made up of high density polyethylene has increased abnormally. These bottles are not readily biodegradable, environmental problems are created due to dumping; these are either land filled or incinerated which are not eco-friendly which pollute land and air.

1.1 Objectives

The main objectives of this study are:

- To determine the optimum binder content for the bituminous concrete surface course.
- To evaluate the stability performance on modified BC mix with PET.
- To evaluate the maximum percentage of Polyethylene Terephthalate as bitumen modifier.
- To compare the PET added BC mix with conventional BC mix in term of stability and flow value.

2. Literature Review

For many years, researchers and development chemists have experimented with modified bitumen mainly for industrial uses, adding asbestos, special filler, mineral fibers and rubber. In the last thirty years many researchers have looked at a wide spectrum of modifying materials for bitumen's used in road construction.

The study was done by Mahabir Panda [1] and Mayajit Mazumdar using 80/100 penetration grade bitumen and Ethylene Vinyl Acetate (EVA) copolymer. The study that there was a increase in stability value in case of polymer modified bitumen. Stability value was high as 14kN in case of polymer modified bitumen. Tensile strength was also increased and stripping properties were improved.

Another study was done by Sharma D K [2] and others using 60/70 penetration grade bitumen. Here waste plastic/polymer was used as modifiers. The waste plastic/polymer was added on the aggregate before

Study on Marshall Stability Properties of BC Mix Used In Road Construction by Adding Waste mixing Optimum Binder Content (OBC) in dry process at 150-160o C temperature. This type of mixing increases the bonding between aggregates coated with plastic/polymer which increases the strength of the bituminous concrete mixes. Stability values and indirect tensile strength values were observed to be more in polymer modified bitumen than in conventional bitumen. Rutting values were also higher in polymer modified bitumen mixes than in conventional mixes.

Another study was carried out by Shivangi Gupta and Veeraragavan [3]. They used 60/70 penetration grade bitumen and Styrene Butadiene Styrene (SBS) modified binder. Here tests were conducted by two methods, marshal stability and Superpave Gyratory Compactor (SGC) and results of these two methods were compared. The test results showed that SBS modified bitumen mixes were superior to the conventional mixes. But as far as Marshall Method is concerned SGC method shows better results. Strength parameters like tensile strength, marshal stability values of SBS modified mixes were higher than 21% to 25% than that of conventional mixes. Fatigue life of SBS modified binder mix was 2.1% to 2.4% higher than the conventional mix.

3. Methodology

Present investigation:

Present investigation of the work is to investigate the effects of waste plastic bottles on the strength and stability characteristics of BC mix which is used for surface course in road construction.

3.1 Material Characterization:

Study involves the use of materials like Bitumen, Aggregate and Shredded plastic bottles.

1. **Bitumen:** is a material which is a byproduct of petroleum refining process. It is a highly viscous at temperature above 100 degrees Celsius and is solid at room temperature. 80/100 grade bitumen was used in the present study.
2. **Aggregates:** which has good and sufficient strength, hardness, toughness and soundness have to be chosen. Crushed aggregates produce higher stability.

a. **Coarse aggregate** should be clean, hard and durable, should be of cubical in shape. They must consist of crushed aggregates retained on 2.36mm IS sieve. Coarse aggregate gives a good interlocking property and offer a compressive strength and shear strength.

b. **Fine Aggregate** may consist of mineral materials or crushed materials or may be a combination of two materials. The fine aggregate should pass 2.36mm IS sieve and should retain on 75 micron sieve.

3. **Plastic:** Polyethylene Terapthalate (PET) is the type of plastic labeled with the #1 code on or near the bottom of bottles and containers and is commonly used to package soft drinks, water, juice, peanut butter, bakery goods, produce, frozen foods, salad dressings and oil, cosmetics and household cleaner and many other products. Waste bottle plastic of water cans is made up of either High Density Polyethylene (HDPE) or Low Density Polyethylene (LDPE). These plastic bottles are shredded and used for the present investigation.

3.2 Methods of testing materials:

3.2.1 Tests on bitumen

1) Penetration Test

The penetration test was carried out on bitumen in accordance with ASTM D92 (2005) so that they can be classified into standard grades. The dish containing the sample was transferred to the stand of the penetrating machine with the container covered completely with water. The pointer was brought to zero and the needle was released for the specified period of time then the distance penetrated was measured.

2) Ductility Test

This test was carried out in accordance with ASTM D113 (2005). To measure the internal cohesion of bitumen, rings were attached to each of the clips to the hooks in the testing machine and pull the two clips apart at a uniform speed of 5cm/minute. The distance through which the clips had been pulled to produce rupture was measured. The water in the tank of the testing machine covered the specimen; the

specimen was immersed to a depth of not Less than 10cm and was supported on a perforated shelf not less than 5cm from the bottom of the bath. The average of the three normal tests is the ductility of the sample.

3) Softening test

It is used to specify hard bitumen and it helps to characterize its rate of settling. This test was conducted in accordance with ASTM D30 (2005). Glass vessels were filled to a depth of 4-4.25m with fresh boiled distilled water at 510C (1240F). The ring containing the sample was then suspended in water, in such a way that the lower surface of the filled ring was 1.0 m above the upper surface of the lower horizontal plate which is 0.5-0.75 above the bottom of the glass level. The initial

temperature of the water was maintained at this level for 15 minutes. The ball was then placed in the center of upper surface of the bitumen in the ring. The effect of the draft is avoided in such a way that shields were used.

4) Specific Gravity Test

This is the ratio of the mass of a given volume of bitumen to the same of an equal volume of water. The specific gravity test was carried out on bitumen in accordance with ASTM D70 (2005). It was determined by preparing a cube shape specimen of solid state and weighing in air and water.

3.2.2 TEST ON COARSE AGGREGATES

i. Specific gravity

Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It is the measure of strength or quality of the specific material. Aggregates having low specific gravity are generally weaker than those with higher specific gravity values. Specific gravity test of aggregates is done to measure the strength or quality of the material while water absorption test determines the water holding capacity of the coarse aggregates.

ii. Water absorption Test

Water absorption test gives an idea of strength of rocks, stones having more water absorption are more porous in nature and generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

iii. Impact Test

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load.

iv. Los Angeles Abrasion Test

Abrasion test is carried out to test the hardness property of aggregates. The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

4. Results and discussions

The test result obtained to determine the basic properties of aggregates and bitumen are discussed below. The effect of Polyethylene Therapthalate on the various properties of BC mix in terms of Marshall Stability and flow test has been discussed.

Aggregate gradation:-

The table shows the specifications of aggregate gradation of bituminous asphalt mix.

Table -1: Aggregate gradation

IS sieve (mm)	Percentage passing (%)		
	20mm grade Aggregate	12mm grade Aggregate	M-sand
25-20	100	-	
20-16	79.8	-	
16-12.5	34.6	100	
12.5-10	4.4	100	
10-6.3	0.6	38.65	
6.3-4.75	0.5	17.14	
4.75-2.36	0	0	100
2.36-1.18			81.9
1.18-0.6			36.3
0.6-0.3			2.8
0.3-0.15			0.4
0.15-0.075			0.2
pan			0.1

Table -2: Test results of bitumen

SL NO	Name of the test conducted on Bitumen	Obtained Values	Standard value as per (IS 1202-1978
1	Specific Gravity	1.00	0.97-1.02
2	Ductility test	95cm	>95cm
3	Softening point	72^{0C}	$70\text{-}80^{0C}$
4	Penetration test	0.09mm	80-100mm

Table -3: Test results on aggregates:

SL NO	Name of the test conducted on Aggregates	Obtained Values
1	Specific gravity of 20mm CA	2.64
2	Specific gravity of 12mm CA	2.5
3	Specific gravity of FA	2.34
4	Los Angeles Abrasion Test	15.04%
5	Impact test	9.68%

Table -4: Test results on PET:

SL NO	Name of the test conducted on Aggregates	Obtained Values	Standard values
1	Specific Gravity	1.03	1.0-1.1
2	Melting Point	253^{0C}	250^{0C} -260^{0C}

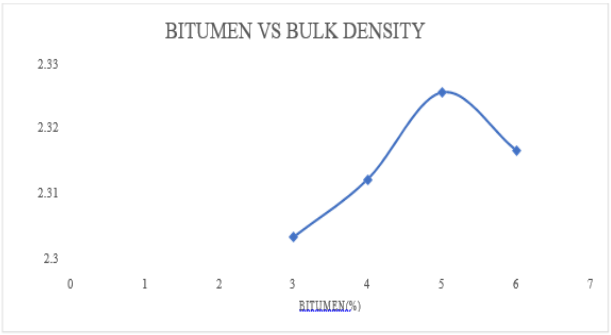

Fig:1 Shows the variation of percentage of Bitumen & Bulk density

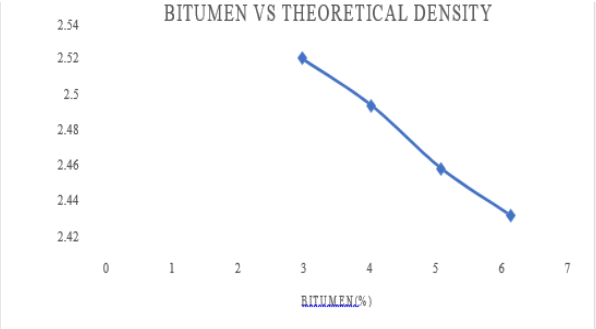

Fig:2 Shows the variation of percentage of Bitumen & Theoretical density

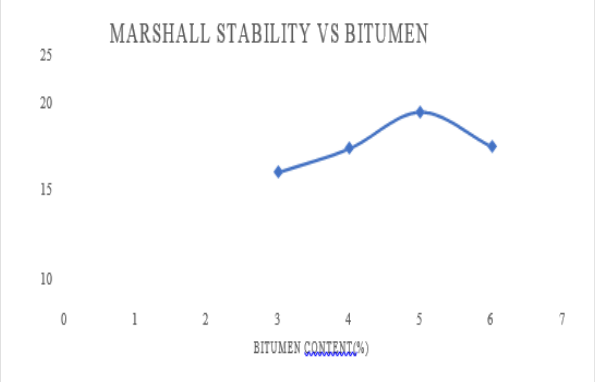

Fig:3 Shows the variation of percentage of Bitumen & Marshall Stability value

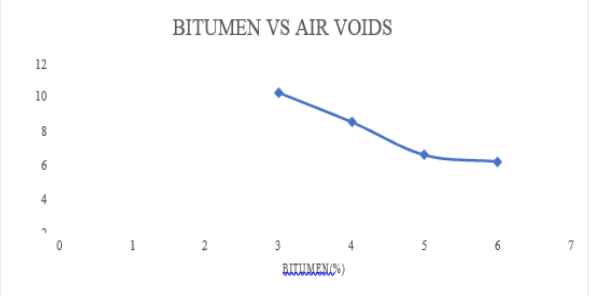

Fig:4 Shows the variation of percentage of Bitumen & air voids

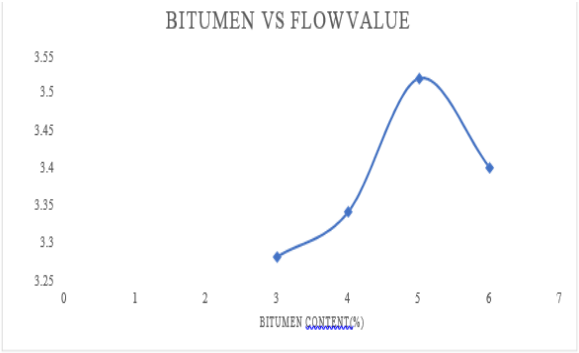

Fig:5 Shows the variation of percentage of Bitumen & Flow rate

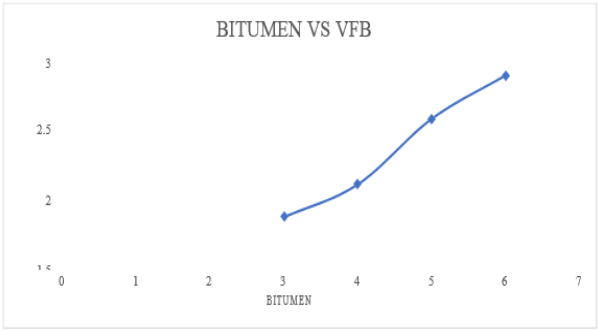

Fig:6 Shows the variation of percentage of Bitumen & VFB

DISCUSSIONS &CONCLUSIONS

Use of waste plastic has made a good progress in bituminous road construction in recent years. Waste plastic are used in bituminous courses Viz BM BC SDBC PMC and MSS. This investigation is on attempt to evaluate the addition of waste plastic bottles to bituminous concrete (BC) wearing course mix of aggregate gradation I along with 80/100 bitumen.

The optimum amount bitumen content that can be used in BC mix is found out be 5% based on the Bulk density, Marshall Stability, flow value, Air voids and VFB test results.

PET along with bitumen for a BC mix is varied with 1%, 2%, 3% & 4%. For 4% of PET content gives better results in terms Marshall Stability, Flow value etc.

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