STUDY ON PERFORMANCE EVALUATION OF DENSE BITUMINOUS CONCRETE MIXES USING PET WASTE

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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. The main objective of present work is to study the benefit of PET (Poly Ethylene Terapthalate) polymer modified bituminous mixes performance. Various percentages of PET are used for preparation of mixes with a selected aggregate grading as given in the MORTH &IRC Code. The role of PET in the mix is studied for various engineering properties by preparing Marshall Samples of DBM 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 the two grades of bitumen VG10 (80/100) and VG 30(60/70). The physical and mechanical properties of PET modified and conventional binder mixes are evaluated. These Mixes are compacted using Marshall. Indirect tensile strength ratio tests were conducted and compared.

Keywords: *Polyethylene Terapthalate (PET), ,Indirect Tensile Strength, Marshall Stability*

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1. INTRODUCTION

The abnormal increase in the vehicular traffic volume and variation in daily temperatures in various parts of the world needs improved performance of the roads and better quality of bitumen.[7] As it is a Visco- elastic material having suitable mechanical and rheological properties it is used for waterproofing and protective coverings for roads and roofs , because of its good adhesion properties with aggregates [1,3]
Usage of plastic products has become an integral part of every one s daily life. Industrial growth in addition to population growth resulted increased production of various types of plastic materials .The consumption of plastic materials has been growing beyond all expectations leading to several environmental problems, mainly-because of the chemical constituents present in them.

One of the fastest growing beverage industry in the world is the bottled water. As per the international bottled water association (IBWA), over the last decade ,sales of bottled water have increased by 500 percent and 1.5 million tons of plastic are used to bottle water every year. Recycling of Plastic bottle has not kept pace with the dramatic increase in virgin resin polyethyleneTerephthalate (PET) sales.

As per the general surveys conducted, around 1500 bottles are dumped as garbage every second. PET is reported as one of the most abundant plastics in solid urban waste and the reduction this waste benefits the natural environment with indubitable economical advantages, since waste represents a large loss of resources and raw materials that could be recovered, recycled or considered for other uses .World's annual consumption of PET bottles is approximately 10 million tons in year 2007, and this number grows about up to 15% every year. where as ,On the other hand, the number of returned or recycled bottles is very low .An Indian,on an average , uses one kilogram (Kg) of plastics per year and the world annual average is at an alarming 18 kg. It is estimated that approximately 4-5% post-consumer plastics waste by weight of Municipal Solid Waste (MSW) is generated in India and the plastics waste generation is more i.e. 6-9 % in USA,Europe and other developed countries.

Approximately, 4000- 5000 tonnes per day post consumer plastics waste are generated, as per data available on MSW. Plastic waste Re use is an important step in the development of clean energy. In India approximately about 40 million tons of the municipal solid waste is generated annually, which is increasing at a rate of 1.5 to 2% every year. Plastics constitute to around 12.3% wt of the total MSW. It is worth to notice, that the most of plastics fraction are drinking bottles which are made mainly of PET. [2]

Consumption of plastics in India has increased over the years from 61,000 tonnes in 1996 to 17, 40,000 tonnes in 2013, with a projection of 20, 00,000 tonnes by year 2015. The discarded plastic is leading to enormous environmental pollution. The disposal of waste plastic may be done by land filling or by incineration - both cause environmental pollution. Waste plastic disposal is a big problem and it causes environmental pollution as it is a non bio degradable material. Disposal of plastic waste is a serious problem and dumping results clogging of drains, reduction of soil fertility etc.disposal of it by land filling and incineration causes health and environmental problems.

There are different ways of improving properties of bituminous mixes, either by constructing roads of higher thickness or by using different types of additives in bituminous mixes. Higher Thickness pavement results higher construction cost.

Use of PET waste would be a better solution to reduce pavement deterioration.which can be added in two ways, namely dry and wet process. Polyethylene Terapthalate (PET) is the polymer used in the manufacture of plastic bottles. It has a molecular formula of $(C_{10}H_8O_4)_{n.}$ Its solubility in water is negligible at less than 0.4 percent. The melting point is 473F to 500F (245°C to 260°C). PET material is incompatible with strong oxidizing agents and strongly alkaline materials. The extent of polymerization of polyethylene Terapthalate varies from product to product. PET waste used is in the form of chips or granules .

Over 75 % of plastics corresponds to thermoplastics (mainly polyolefin, low density polyethylene, LDPE-17%, high density polyethylene, HDPE-11%, polypropylene, PP-16%) and the remaining to thermo sets (mainly epoxy resins and polyurethanes). PET waste is not biodegradable and it will create lot of environmental hazards if disposed in landfills .Recycling is the only way of addressing the problem of disposal of post-industrial and post-consumer PET waste.[15]

Various methods for recycling polymer waste have been developed and new recycling approaches are being investigated.[1] Recycling PET waste polymer in road construction as a bitumen modifier is a new method

Which has been found to be one of the most effective polymer additives.[5]

2. OBJECTIVES

Various objectives of present investigation are

1. To find out the various Physical properties of Bitumen
2. To find out the various Physical properties of Coarse aggregate
3. To evaluate the changes in Properties of Bitumen and Coarse Aggregate with the addition of varying percentages of PET waste
4. To find the Optimum Bitumen content(OBC) for the Bituminous mix
5. To evaluate the stability,flow values and volumetric properties of DBM mixes with and without the addition of PET waste by using the Marshall method of mix design
6. To study the Indirect tensile strength and Tensile strength ratio values for DBM mixes with and without addition of PET waste

3. LABORATORY INVESTIGATIONS

3.1 Engineering Properties Of Materials:

3.1.1 Bitumen:

There were two grades of bitumen used in this study i.e., VG10 (80/100 Penetration) and VG 30 (60/70Penetration). Various laboratory tests were conducted to evaluate the various bitumen properties like Specific Gravity, Ductility, Penetration and Softening point and Flash point temperature. The properties of asphalt binder, which are presented in Table 1, and are within the specification of penetration bitumen grades VG 10 and VG 30.

Table 1.

Designation	Test result		Permissible limits as per IS codes		Test Method
	60/70	80/100	60/70	80/100	
Penetration at 25 C,100gr, 5s , in mm	65	90	60-70	80-100	IS 1203-1978
Softening Point,°C	43	41	47	40	Is:1205-1978
Ductility,at27°C,cm	82	75	40min	75 min	IS:1208-1978
Specific gravity at 27 °C ,g/cc	1.00	1.02	0.97 - 1.02		IS 1202-1978
Flash point , ° C	220	220	175 min		Is 1209-1978

Properties of Modified Bitumen with PET waste

Table 2. VG 30 (60/70 Pen)

Properties with PET %	Specific gravity	Penetration, in mm	Ductility in cm	Softening point,°C
0.5%	1.08	65	96	43
1%	1.08	58	94	45
1.5%	1.08	56	92	46
2%	1.086	50	90	47

Properties of Modified Bitumen with PET waste

Table 3. VG 10 (80/100 Pen)

Properties with PET %	Specific gravity	Penetration in mm	Ductility in cm	Softening point,°C
.5%	1.08	65	96	41
1%	1.08	58	98	42
1.5%	1.08	56	92	44
2%	1.086	50	102	47

3.1.2 AGGREGATES:

In this investigation, as per MORTH-2001 Specification, mix designation for Dense Bituminous Macadam was selected .The gradation of the aggregates with specified limits is adopted.The properties of coarse aggregateand fine aggregate is determined using ASTM C 127 and ASTM C 128 standards respectively,and cross verified with MORTH specifications.Properties of coarse aggregates and fine aggregates used are furnished in Table No 4.

Table 4.

Property	IS method	MORTH specification	Result
Specific gravity a)Coarse aggregate(passing 20mm) b)Coarse aggregate(passing 10mm&4.75 mm) c)Fine aggregate	IS 2386 (III)		2.7 2.6 & 2.6 2.54
Aggregate Impact value	IS 2386 (IV)	Max 30%	21.21%
Los Angeles Abrasion value	IS 2386 (IV)	MAX 30%	26.2%
Water absorption	IS 2386 (III)		0.5%
Combined Flakiness and Elongation index	IS 2386 (I)	Max 30	29.51%
Aggregate crushing value	IS 2386 (IV)	Max 30	25.98%

Table 5. Variation in properties of Coarse Aggregates (with addition of PET Waste)

PROPERTIES WITH % PET WASTE	IMPACT VALUE, in %	CRUSHING VALUE , in %
2%	24.56	28.71
4%	20.27	19.59
6%	19.32	15.32
8%	18.64	13.71
10%	13.24	12.34

3.1.3 Polyethylene Terapthalate (PET Waste):

In this investigation, waste PET in the granule forms added at 2%, 4%,6%, 8% and 10% (by the weight of bitumen) was used as a modifier.

4. METHODOLOGY

Bitumen was collected from Bharat Petroleum, Mysore. The waste plastic was obtained from K.K Plastics, Kanakapura Road, Bangalore. The basic tests were conducted on both aggregates and bitumen of VG-10 and VG-30 grades. The results obtained were satisfying the specified limits as per MORTH and IS73:2006 standards. The proportioning of materials was done as per Rothfutch's method to satisfy the required gradation. The obtained values were within the specified limits of MORTH for Dense Bituminous Macadam mix. Marshall Specimens were prepared and tested to determine the Optimum Binder Content (OBC) for each of the grades of bitumen. OBC value was found by considering the maximum values pertaining to stability, maximum unit weight and the air voids corresponding to 4%. The average value of these three parameters is considered as the OBC. The OBC value obtained was within the specified limits of MORTH. The samples were prepared at OBC to check for flow, VFB and VMA and they were found to be within the range specified by MORTH. At the obtained OBC, different percentages of waste plastic were added to the aggregates to study the improvement in the properties of the bituminous mix for each of the two grades of bitumen.

4.1 Modified Aggregates With PET Results

Various Marshall cylindrical specimens were prepared at 160-165 C at Six different percentages of asphalt content these were tested to find out optimum binder content in this study.Marshall flow and Stability tests were conducted on cylindrical samples according to ASTM D 1559.The specimen is used in water bath at a temperature of 60 C for 30 minutes.

Marshall Stability is expressed as the the maximum load applied at a constant strain which causes failure. During the stability test dial gauge is used to measure the vertical deformation of the specimen. Marshall flow value is the vertical deformation at the failure point of the specimen and usually in the units of 0.25 mm.Higher flow value indicates plastic mix where as lower flow value indicates a mix with higher voids than normal one with lesser ductility and permanent cracking due to brittleness Bulk specific gravity of compacted mix can be done in accordance with ASTM D 2726.

Table 6: Properties of DBM Mix at Optimum Bitumen Content

Sl No	Properties						
	PET %	0%	2%	4%	6%	8%`	10%
1	Marshall Stability(KN)	15.20	17.38	21.10	22.15	23.41	13.45
2	Flow (mm)	3.89	3.76	3.48	3.28	3.05	2.99
3	Bulk density (gm/cc)	2.163	2.159	2.152	2.148	2.153	2.163
4	Air voids (%)	4.73	4.63	4.5	4.35	4.33	4.25
5	VMA (%)	14.73	15.07	14.43	14.17	13.52	13.64
6	VFB (%)	71.57	71.43	72.26	72.90	73.40	73.09

Table 7: Tensile strength and Tensile strength ratios of mix modifiedWith % PET

Mix with % of plastic	Tensile Strength, in N/mm²	Tensile Strength Ratio ,in %
0%	0.93	66.17
2%	1.01	80.05
4%	1.045	81.55
6%	1.142	83.55
8%	1.15	85.21
10%	1.18	84.32

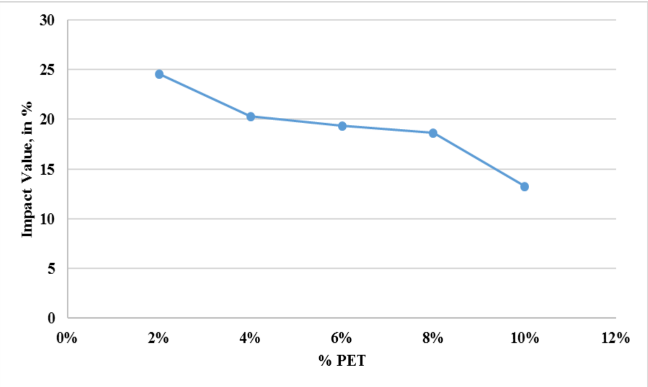

Fig 1: Variation of Aggregate Impact value with change in % PET

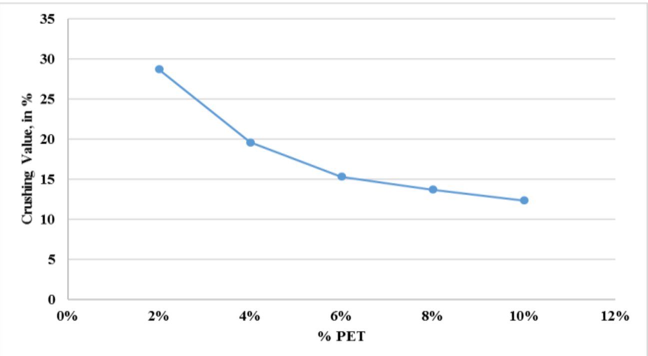

Fig 2: Variation of Aggregate Crushing Value with change in %PET

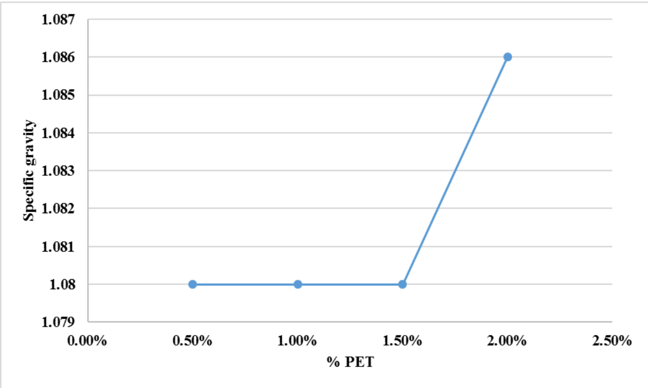

Fig 3: Variation of specific gravity with change in % PET

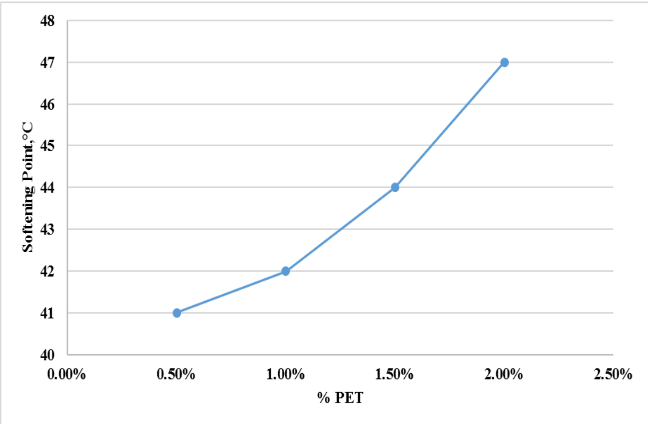

Fig 4: Variation of Softening Point with change in % PET:

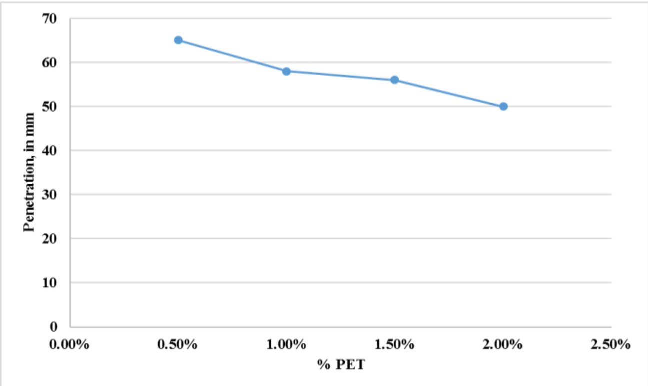

Fig 5: Variation of penetration with change in % PET

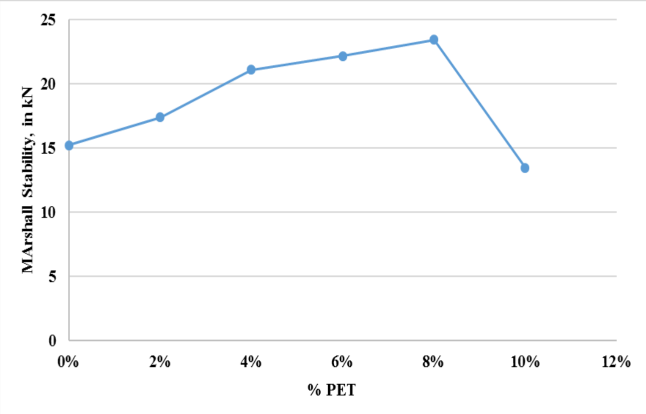

Fig 6: Variation of Marshall Stability with change in % PET:

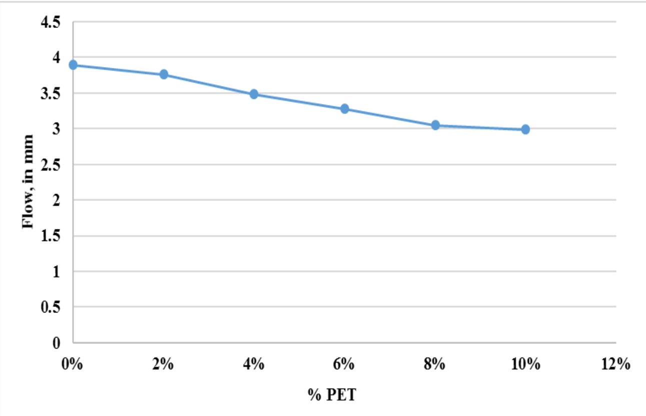

Fig 7: Variation of Flow with change in % PET:

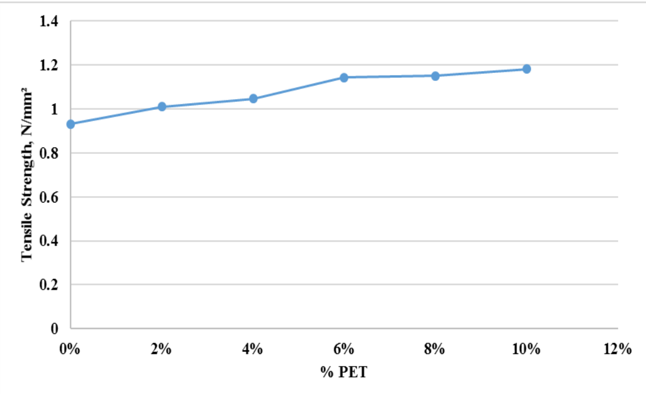

Fig 8: Variation of Tensile strength with change in % PET:

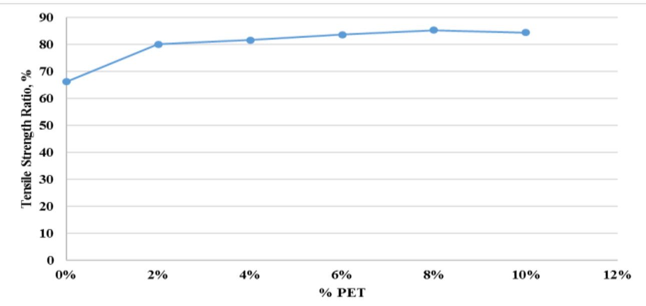

Fig 9: Variation of Tensile strength ratio with change in % PET:

5. CONCLUSIONS

Some of the conclusions drawn from the various results established from the studies are as follows :

1. TheOptimum Bitumen Content (OBC) determined from Marshall stability test for Conventional mix was found to be 5.22 % .
2. Maximum value of Marshall stability value was obtained for the mix added With 6 percent of PET waste. Stability value has increased by 1%value for the mix with 6% PET Waste as compared to that of DBM mix without PET waste.therefore ET waste blended bituminous mix is better and more suitable for flexible pavement construction.
3. Indirect tensile strength value for unconditioned sample increased by 26 % for the mix with 8% PET waste as compared to ITS value of neat mix.
4. Indirect tensile strength values for conditioned sample increased by 50% for the mix with 10 percent PET Waste .
5. Tensile Strength ratio value at optimum binder content increases for Bituminous mixes from Zero to 6% of PET waste.
6. Mix with 6 % of PET waste shows better performance when compared With Neat or conventional mix.Modified mix can be used to improve Pavement quality economically which helps to use PET waste in Pavement construction to avoid waste disposal by incineration and land filling Which makes it eco friendly pavement.
7. Penetration value decreases with increase in % PET which indicates that the consistency of the PET modified bitumen decreases with the increase in PETContent.

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