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Sustainable Solution for Road Pavements and Review of Bituminous Mixes with Mixed Waste Plastic

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Abstract: ***The results of the present study were compared with that of existing experimental work available in the literature and were found to be in coherence with existing data. The results of strength and durability tests suggest that waste plastic bottle (PET)) can safely be used even up to 15% of bitumen content but 7 % and 10% are the most efficient dose for bituminous concrete and dense bituminous macadam mixes for achieving stronger and durable flexible pavements.***

Keywords: bituminous concrete, waste plastic in pavement, flexible roads, strength and durability, sustainable construction

1.Introduction

Due to non-bio degradable properties plastics have long life. Uncontrolled burning of plastics leads to generation of many hazardous air pollutants which depend s upon the type of plastic. End of plastic life in one application can be recycled in to a second life application through thermal treatment; each thermal treatment leads to certain degree of degradation plastic quality. Several studies have concluded that incorporating waste plastic into bituminous mixes enhances their engineering properties. Waste plastic can be incorporated into bituminous mixes using two methods: the wet method, also known as polymer-modified bitumen, and the dry method. In the polymer-modified bitumen method, waste plastic is mixed directly with the bitumen. In the dry method, waste plastic is used to coat aggregates The Indian Road Congress (IRC: SP: 98-2013) provides "Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses," which outline the advantages and limitations of using plastic waste in flexible pavements.

2.Sources of Waste Plastic

Thermal Characteristics of Waste Plastic

Thermal behaviors of various polymers used as commercial plastic areas given in Table.

Table 1: Details of thermal Behavior of Polymer

Sr. No.	Commercial Plastic	Plastics	Thickness (µ)	Softening Point (°C)
1	Cup	Polyethylene	160	100-120
2	Carry Bag	Polyethylene Terephthalate	215	170-180
3	Water Bottle	Polyethylene Terephthalate	215	170-180
4	Soft Drink Bottles	Polyethylene Terephthalate	215	170-180
5	Chocolate Covers	Polyester+Polyethylene+ Metalized Polyester	18	155
6	Covers of parcel	Polyethylene	55	100-120
7	Covers of supari	Polyester+ Polyethylene	65	120-135

Importance of Research Topic

The topic “Experimental Investigation on Bituminous Mixes using Plastic Waste” has been selected for the research to determine suitability of waste plastic in road construction. This will help to increase the performance along with decrease in cost of road as well as saving of environment de gradationing terms of reduced pollution.

The mixing up of these wastes with other bio-degradable organic waste materials in the garbage of the urban areas generates problem. Therefore, attempts are being made in some are as to limit or even to prohibit the use of plastic for packing and other common use, so as to control this "undesirable waste material" from getting mixed up with the other organic garbage. Being, a non-biodegradable material, waste plastic does not decay over time.

So, there is a need to use plastic waste in environmental and eco-friendly way for its safe disposal. The prime significance of this study is to find out an alternate for disposal of plastic waste, that too with value addition in road construction along with economy.

3.Objectives of the Study

Methodology

The detailed methodology adopted in the present study is expressed in the form of a flow chart, Figure 3.1. The objectives of present study are to characterize the materials used for making bituminous mixes and mix designing of bituminous mixes with and without waste plastic using dry process, satisfying the requirements of strength and durability.

The methodology followed in the present research was decided with aim to:

- Study the information about the existing and possible future use of plastic waste in bituminous mixes.

- Study the effects of varied percentages of Polyethylene Terephthalate (PET) on mechanical and volumetric properties of Bituminous Concrete (Grade -II) and Dense Bituminous Macadam (Grade -II) mixes.
- Discuss the suitability of waste plastic (PET) in flexible pavement with special reference to India

Materials Used

In order to achieve the defined objectives material comprising of aggregate (coarse and fine), filler, bitumen and waste plastic bottle (PET) was procured and tested for basic engineering properties as under:

Bitumen

Bitumen is a petroleum product obtained through fraction distillation of crude. It is hydrocarbon material of pyrogenous origin, found in gaseous, liquid, semisolid form and is completely soluble in carbon disulphide and in carbon tetra chloride. Bitumen has mainly four grades depending upon viscosity such as VG-10, VG-20, VG-30 and VG-40. Bitumen sample of VG-30 grade. The sample was tested for various engineering properties required for bituminous mixes as per Indian Standard.

Aggregates

Aggregates constitute bulk of the total volume of bituminous mixes. Hence, it is very important to study the quality of aggregates. The durability and performance of road are influenced by characteristics of aggregates used in bituminous mixes. Aggregates are broadly classified in to two types, i.e. Coarse aggregate and fine aggregate. The properties of both the coarse and fine aggregates such as size, shape, specific gravity, hardness, surface texture, water absorption and gradation affect the quality of bituminous mixes.

Mineral Filler

"Filler may originate from fines in the aggregate or be added in the form of cement, lime or ground rock. Filler has an important effect on the voids content and the stiffness of the bitumen-fines matrix. It should have a plasticity index not greater than This requirement does not apply, if filler is lime or cement" (MoRT&H, 2013, India). The grading requirement for the mineral filler as per Ministry of Road Transport and Highways specifications is given in Table 3.4. Hydrated lime of specific gravity 2.25 was used as mineral filler.

Modifier

The waste plastic bottle (Polyethylene Terephthalate (PET)) was used as a modifier. The plastic bottles were cut in uniform size, passing through 2.36mm sieve and retaining through 600µ sieve, so that the process of coating over aggregates could be carried out with ease. Properties of waste plastic (PET) are given in Table 3.5

Bituminous Mix Design

Bituminous mix designing is a process to determine optimum bitumen content along with appropriate proportioning of aggregate to fulfil the requirement of an ideal mix. The desirable properties of an ideal bituminous mix are stability, durability, flexibility, skid resistance and workability. Four mix design methods namely Marshall, Hveem, Hubbard- Field and Smith Triaxial are commonly used for mix designing of bituminous mix. The same have been described in the chapter on literature review. The requirements of bituminous mixes are explained as below:

- Sufficient stability to satisfy the service requirements of pavement without undue is placement.
- Sufficient amount of bitumen to ensure a durable pavement by coating and bonding of aggregate and water proofing of mix.
- Sufficient voids for slight amount of additional compaction due to traffic load
- Sufficient flexibility to prevent tracking due to repeated application of loads.
- Sufficient workability during placing and compacting
- Sufficient resistance of pavement against skidding and a function of surface texture and bitumen content.

4.Result

Bulk Density of Bituminous Concrete Mixes at different PET Content Theoretical Density of Bituminous Concrete Mixes

Table 4.2 and Figure 4.2 show the theoretical density (Gt) of bituminous concrete mixes. Theoretical density of modified bituminous concrete mixes decreases with increase in PET content. This decrease in theoretical density may be due to the lower specific gravity of PET. Maximum value of theoretical density is 2.439gm/cc for conventional mix (BC5.0-P0) and 2.434gm/cc for modified mix (BC5.0-P4). The minimum value of theoretical density is found to be 2.392gm/cc for BC5.8-P14mix.

Table: Theoretical Density of Bituminous Concrete Mixes at different PET Content

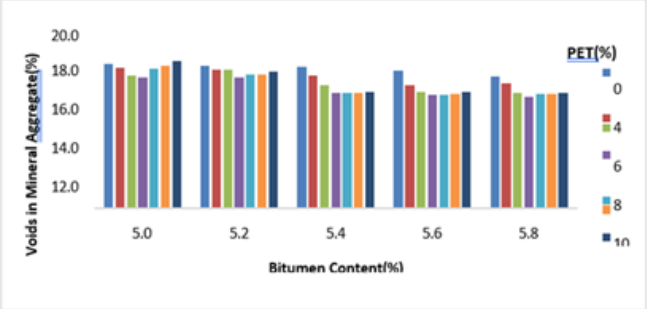
Sr. No.	Bitumen (%)	Theoretical Density(gm/cc)						
		PET (%)						
		0	4	6	8	10	12	14
1	5.0	2.439	2.434	2.432	2.430	2.427	2.425	2.423
2	5.2	2.430	2.427	2.424	2.422	2.420	2.417	2.415
3	5.4	2.424	2.419	2.417	2.415	2.412	2.410	2.407
4	5.6	2.417	2.412	2.410	2.407	2.405	2.402	2.400
5	5.8	2.410	2.405	2.402	2.400	2.397	2.395	2.392

Volume of Air Voids in Bituminous Concrete Mixes

Total volume of air pockets between the coated aggregate particles throughout a compacted paving mixture is known as volume of air voids (Vv). The amount of air voids in a mixture is extremely important and closely related to stability, durability and permeability. It is evident from the Table 4.3 and Figure 4.3 that volume of air voids for bituminous concrete mixes decreases as the PET content increases up to 8% and increases with further increase in PET content. The decreases in volume of air voids indicate better cohesion between bitumen and PET coated aggregate. The volume of air voids decreases as the bitumen content increase. BC5.0-P14and BC5.8-P8 mixes reported maximum and minimum value of volume of air voids respectively.

Voids in Mineral Aggregate for Bituminous Concrete Mixes at different PET Content

Sr. No.	Bitumen (%)	Voids in Mineral Aggregate (%)						
		PET (%)						
		0	4	6	8	10	12	14
1	5.0	18.37	18.14	17.68	17.58	18.06	18.25	18.54
2	5.2	18.25	18.04	18.03	17.58	17.73	17.76	17.91
3	5.4	18.17	17.70	17.15	16.65	16.67	16.70	16.74
4	5.6	17.96	17.12	16.74	16.55	16.56	16.61	16.71
5	5.8	17.61	17.25	16.67	16.43	16.61	16.62	16.68



Void sin Mineral Aggregate for Bituminous Concrete Mixes at different PET Content Voids Filled with Bitumen for Bituminous Concrete Mixes

Voids filled with bitumen (VFB) are the voids in the mineral aggregate frame work filled with bitumen binder. VFB increases as the bitumen content increase for conventional mixes. The value of voids filled with bitumen increases up to 8% PET content for all the modified mixes and decrease with further increase in PET content. This decrease in voids filled with bitumen indicates that effective bitumen film thickness between aggregates decreases, which will result in cracking and lower durability of bitumen mixture, since bitumen perform the filling and healing effects to improve the flexibility of mixture. The maximum and minimum values of VFB are 80.86 % and 59.39 % corresponding to BC 5.8-P8 and BC5.0-P14 mixes respectively.

Voids Filled with Bitumen for Bituminous Concrete Mixes at different PET Content

Sr. No.	Bitumen (%)	Voids Filled with Bitumen (%)						
		PET (%)						
		0	4	6	8	10	12	14
1	5.0	61.04	61.89	63.54	63.80	61.63	60.69	59.39
2	5.2	64.06	64.86	65.92	66.51	65.66	65.35	64.55
3	5.4	67.10	69.15	71.47	73.88	73.58	73.21	72.85
4	5.6	70.71	74.80	76.41	77.49	77.12	76.89	76.37
5	5.8	75.16	76.93	79.74	80.86	79.94	79.37	78.80

5.Conclusions

(i) Stability value of bituminous mixes increases with addition of PET – waste plastic. An increase of more than 24% and 10% was observed in case of BC and DBM respectively, at optimal dose of PET content, as compared to conventional mixes.
(ii) Higher value of Marshall Quotient in case of PET modified bituminous mixes reveal stiffer bituminous mixes, more suitable for heavily trafficked roads.
(iii) Tensile strength ratio (TSR) for conventional bituminous concrete and dense bituminous macadam (at optimum bitumen content) was 86.50% and 85.19% respectively. PET modified mixes have higher TSR i.e. 93.45% and 93.70% for BC and DBM respectively. This indicates that PET modified mixes are less susceptible to moisture damage as compared to conventional mix.
(iv) Optimum bitumen content for conventional bituminous concrete and dense bituminous macadam mix was observed as 5.66% and 4.82% respectively. A reduction in optimum bitumen content was observed with use of waste plastic (PET), which is 4.59% in case of bituminous concrete and 6.64% in case of dense bituminous macadam mix.
(v) Optimal dose of waste plastic (polyethylene terephthalate (PET)) was observed as 8% and 10% for bituminous concrete and dense bituminous macadam mix.
(vi) Utilization of waste plastic (PET) in bituminous mixes, using dry process, is a cost-effective solution for safe disposal of waste plastic with improved engineering properties of bituminous mixes.

6.Scope For Future Work

Some of the suggestions for further studies concerning modified bituminous mixes used in flexible pavements are given below:

- With other types of waste plastic.
- Study bituminous mixes with different combination of waste plastic.
- Study with emulsion and cut back in respect of bitumen.
- Studyrecycledaggregateinbituminousmixeswithadditiono fwasteplastic.
- Study the field performance of flexible pavement using waste plastic modified material.

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