

Ecofriendly Flexible Pavement Incorporating Waste Product from Metal Casting Industries and PET Bottles

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ABSTRACT: The continuous increase in road traffic in combination with insufficient maintenance due to paucity of funds has resulted in deterioration of road network in India. During last three decades in many countries around the world it has been tested that modification of the bituminous binder with polymer additives enhances the properties. This waste plastic modified bitumen mix show better binding property, stability, density and more resistant to water. Disposal of waste plastic has become a serious problem globally due to their non-biodegradability and unaesthetic view. Since these are not disposed scientifically & possibility to create ground and water pollution. Most plastics collected for recycling from the household waste stream are plastic bottles. The majority of bottles are made from Polyethylene Terephthalate (PET). This project will come up with useful information and creating awareness amongst the learner in the industry regarding waste material. So that one can have a step towards further detailed information about these materials and thus be able to implement on field which will definitely improve the level of construction.

KEYWORDS: Polymer additives, Bitumen mix, Binding Property, Polyethylene Terephthalate (PET)

I. INTRODUCTION

Plastic is everywhere in today's lifestyle. It is used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. With the industrial revolution, mass production of goods started and plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, been virtually revolutionized by the applications of communication or InfoTech has plastics. Plastic in different form is found, which is toxic in nature. It is commonly collected both urban and rural areas. It creates stagnation of water and associated hygiene problems. Plastic waste hazard to the environment. Plastic waste can be reused productively in the construction of road.

Manufacturing process of bitumen:

The refining of petroleum crude in refineries is carried out on the principle of "Fractional Distillation" crude oil is heated in tube still. The volatiles are separated in a fractionating column gasoline; kerosene; gas oil and heavy oil get separated thus. Stream is injected into the fractionating column to assist in the process. This residue is collected as bitumen.

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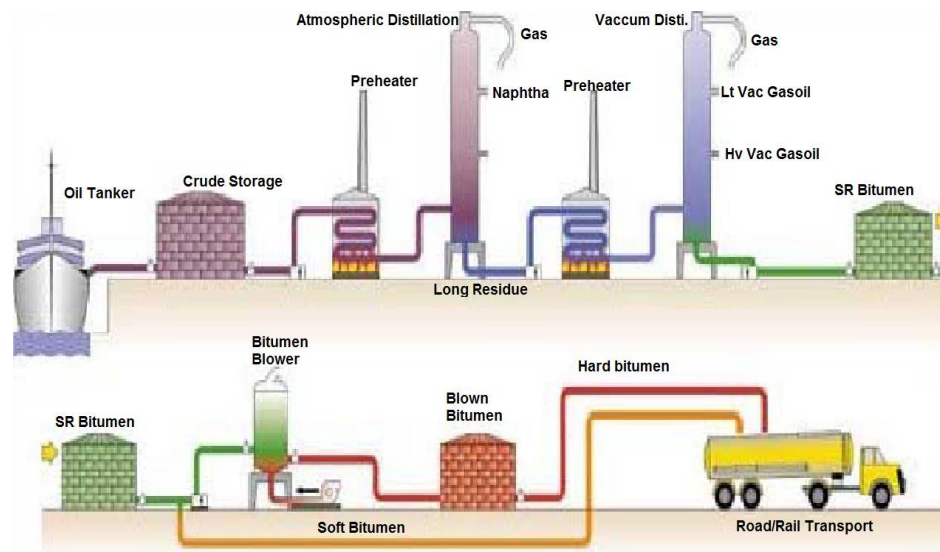


Fig.1 Manufacturing process of bitumen

In the modern refining process, the distillation is achieved in two or three stages. In the first stage, the crude oil is first passed through a tube still operating at a relatively low temperature (less than 350°C), to take off, in a fractionating column operating at atmospheric pressure, the light ends of the crude oil. i.e. naphtha and kerosene. The "topped crude" is then passed through another still for subsequent transfer to another column operating under vacuum, with the assistance of steam injection. A more modern system dispenses with steam injection and relies on dry vacuum only, thus enabling a wider range of bitumen to be produced.

II. RELATED WORK

^[1]**Ravindra N. Patil et.al.** Plastic wastes could be used in road construction and the field tests withstood the stress and proved that plastic wastes used after processing as an additive would enhance the life of the roads and also solve environmental problems. Plastic roads mainly use plastic carry-bags, disposable cups and PET bottles that are collected from garbage dumps as an important ingredient of the construction material. The binding property of plastic makes the road last longer besides giving added strength to withstand more loads. Research highlights the developments in using plastics waste to make plastic roads.

^[2]**Gupta Reena et.al.** Every year, around 500 billion plastic bags are used worldwide. Over one million bags are being haphazardly disposed every minute and they are damaging our environment. Yet, precious little has been done to recycle, re-use and disposal of non biodegradable plastic waste. Plastic bags are difficult and costly to recycle and therefore mostly end up on landfill sites where they take around 300 years to photo degrade. According to her search already developed technologies on utilization of waste plastic for construction of roads in four metros (Bangaluru, Delhi, Bombay and Calcutta) are the basis of implementing these technologies in urban and rural areas.

^[3]**S.Rajasekaran et.al.** Waste plastics both by domestic and industrial sectors can be used in the production of asphalt mix. Waste plastics, mainly used for packing are made up of Polyethylene Polypropylene polystyrene. Their softening varies between 1100C – 1400C and they do not produce any toxic gases during heating but the softened plastics have tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 1600C. According to him Plastics Coated Aggregates (PCA) is a better raw material for the construction of flexible pavement. PCA was then mixed with hot bitumen of different types and the mixes were used for road construction.

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^[4]**Anzar Hamid Miret.al.** Plastic which is toxic in nature is found to be nearly 5% in Municipal Solid Waste (MSW). A major problem nowadays is the disposal of plastic wastes. These wastes are non biodegradable in nature causing environmental pollution and hygiene problems. The experimentation at several institutes indicated that waste plastic can be utilized in Asphaltting of roads. The bitumen can be modified with plastic waste pieces forming a mix which can be used as a top layer of flexible pavement, showing better binding property, stability, density and which is more resistant to water.

^[5]**Yash Menaria et.al.** In manufacturing firms, construction industries and products delivery services, use of plastic is a priority to handle and pack things comfortably due to its light weight, cost effectiveness and strength. Plastics cannot be banned as it will result in usage of natural resources like paper, wood at a great extent. Temperature varying between 120°C - 160°C gives the softening point of these plastics. The main objective of this paper was to discuss the significance of plastic in terms of cost reduction, increase in strength and durability when these plastics are heated and coated upon the aggregates (160°C) to compensate the air voids with plastic and binds with aggregate to provide stability.

III. METHODOLOGY

It was process divided into two stages: In which first stage involves Basic process on PET bottles which includes Collection of PET Bottles, Cleaning Process, Shredding Process and Collection Process. Second stage was all about field trials on modified bitumen .

Stage 1

1) Collection of PET Bottles:

We found that the daily waste was about 5-10 tonne. And hence we can use the waste PET bottles in the construction of road pavements. Maximum thickness is 60 microns of plastic.

2) Cleaning:

Plastic wastes get cleaned and dried.

3)Shredding:

Waste material i.e PET bottles will be shredded or cut into small piece in shredding machine. The machine was available at Plot 69 Shobha Plastic MIDC Satpur 422007 and its efficiency ranges between 20 to 60 kg /hr. The component parts of the machine are Hopper, Electric Motor, Shredding blade etc.

4) Collection:

The plastic waste retaining on 2.36 mm IS sieve was collected and used for further work.



Fig.2: Shredding of PET

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Stage 2

Field Trials: There are two field trials: Dry Process, Wet Process.

Dry Process: In this experiment we have adopted Dry Process. In which shredded plastic was added along with bitumen (1600C) to the aggregates heated up to 1700C. Plastic was coated over stones – improving surface property of aggregates. Coating is easy & temperature required was same as road laying temp.

IV. EXPERIMENTAL INVESTIGATION

4.1 Ingredients Used:

1) **Aggregates:** The following tests on aggregates were done:

Table 1: Physical Property of Aggregates

Sr.no.	Test description	Test method	Result
1	Combined flakiness and elongation index (%)	IS:2386 (Pt 1-1963)	27
2	Specific gravity	IS:2386 (Pt IV-1963)	2.67
3	Water Absorption (%)	IS:2386 (Pt III-1963)	0.4

2) **Bitumen:**

80/100 grade bitumen was used in this study. The physical properties of bitumen were tested and results are tabulated as:

Table 2: Physical Properties of Bitumen

Sr. No.	Test Description	Test Method	Result
1	Penetration (100 gm, 5 25 ⁰ C) (1110 of mm)	IS 1203-1978	65
2	Ductility [at 27c (mm)]	IS 1208-1978	75+
3	Specific gravity	IS 1208-1978	1.00
4	Softening Point (⁰ C) (Ring method)	IS 1208-1978	50
5	Flash point ⁰ C & Fire Point	IS 1208-1978	240-270

3) **Waste plastic:** Polyethylene Terephthalate (PET) is linear thermoplastic, long-chain molecule consists of repeating units, white but bluish resin made from terephthalic acid and ethyleneglycol through poly condensation. Plastic PET is very important raw material used in man-made fibers. PET is a kind of polyester material for fiber, injection molded parts, as well as blow molded bottles and jars. Special grades are offered with the required properties for the different applications.

Properties of PET:

PET consists of carbon, hydrogen and oxygen. It can be incinerated without residues for energy recovery. PET is the most valuable of the recyclable plastics. Also it is reusable as fiber filling for clothing, pallet strapping molding, carpeting, as well as in the manufacture of PET containers.

4.2 Laboratory Mix Design:

The bituminous mix was design using Marshal Method of the mix design. The Marshal test was conducted to determine the optimum binder content of the bituminous concrete mix as per ASTM D-1559-1965. Marshal specimens were prepared with varying binder content 4.8, 5.2, 5.6, and 6.0 percent by the weight of aggregate. Three specimens

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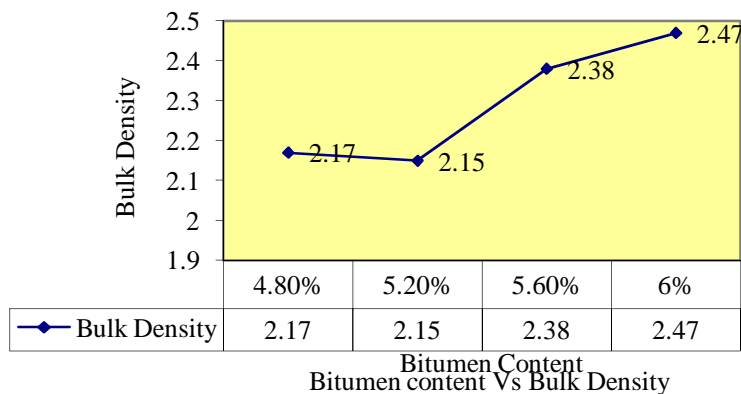
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for each combination were prepared to obtain optimum binder content for the bituminous concrete mix is as show in the Table no.3

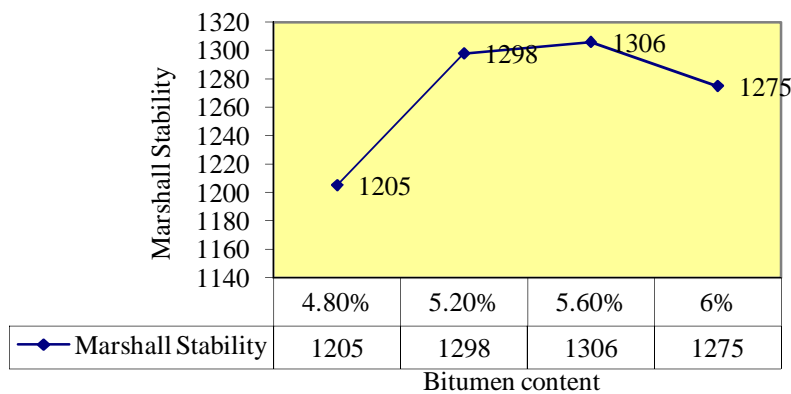
Table 3: Properties of Bituminous to determine optimum binder content

Property	Binder content by weight of aggregate (%)			
	4.8	5.2	5.6	6.0
Marshal Stability (gm.)	1205	1298	1306	1275
Bulk density (gm/cc)	2.17	2.15	2.47	2.38
Flow values (mm)	3.5	2.6	4.9	4.2
Air Voids (%)	29.54	30.19	19.80	22.72
Voids filled with bitumen VFB (%)	37.02	41.60	49.96	45.51
OBC (Optimum bitumen content) (%)	5.6			

From the result it was found that the OBC was 5.6 per cent by weight of aggregate.



Graph 1: Bitumen Content vs. Bulk Density



Graph 2: Bitumen Content vs. Marshall Stability

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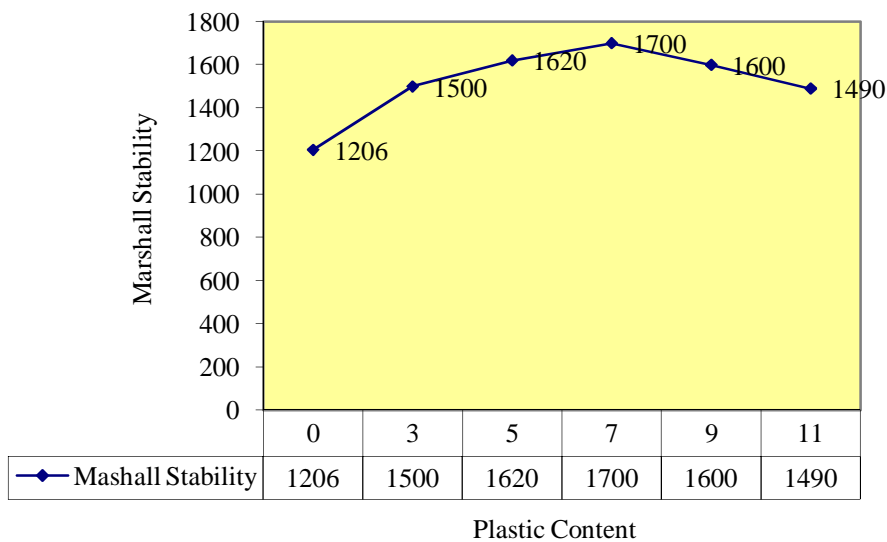
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Optimum waste plastic content:

- Varying percentages of waste plastic by weight of bitumen was added into the heated aggregate.
- Marshall stability specimen with varying waste plastic content was tested for bulk density and stability.
- Maximum value of stability was considered as criteria for optimum waste plastic content.



Plastic Content vs. Marshall Stability

Graph 3: Plastic Content vs. Marshall Stability

Waste plastic were added by the varying the proportions from 3-11 percent by weight of bitumen with an increment of 2 percent (3, 5, 7, 9 and 11). The modifier was added into the heated aggregate just before mixing the bitumen at the optimum 5.6 percent binder content. It was found that the optimum modifier (waste plastic) content was 7 per cent by weight of bitumen.

Design of Bituminous mix using Modifier:

Further, Marshall mix design was conducted by varying the binder content viz 4.8, 5.2, 5.6, 6.0 percent by weight of aggregate and 7 per cent waste plastic (by weight of binder). Marshall samples were prepared and tested for the mix properties and the results are as shown in table 4.

Table 4: Properties of Bituminous to determine optimum plastic content

Property	Binder content by weight of aggregate (%)					
	Normal	3	5	7	9	11
Marshall Stability (gm.)	1206	1500	1620	1700	1600	1490
Bulk density (gm/cc)	2.38	2.367	2.356	2.35	2.345	2.33
Flow values (mm)	4.6	3.2	3.6	4.8	5.1	5.4
Air Voids (%)	22.72	23.14	23.50	23.70	23.86	24.35
VFB (%)	45.51	32.02	38.3	45.40	47.8	49.5
VMA (%)	41.77	45.9	43.7	42.3	39.6	38.4
OPC(Optimum plastic content)(%)	7.0					

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The mix design procedure repeated with addition of waste plastic to find if there could be any reduction in optimum binder content was 5.6 percent by weight of aggregate.

V. RESULT AND DISCUSSION

Waste plastic were added by the varying the properties from 3-11 per cent by weight of bitumen with an increment of 2 percent (3, 5, 7, 9, and 11). The modifier was added into the heated aggregate just before mixing the bitumen at the optimum 5.6 percent binded content. It was found that the optimum modifier (waste plastic) contents were 7 per cent by weight of bitumen.

Following are results of various tests performed on pure and mixed bitumen:

Table 5: Results Of Test Carried Out On Bitumen

Test	Normal Bitumen	3%	5%	7%	9%	11%
PENTERATION	50	75	80	90	100	105
DUTILITY	50cm	45cm	38cm	32cm	35cm	30cm
SOFTENING	50.5 ⁰	51.5 ⁰	52 ⁰	52.8 ⁰	53.6 ⁰	54.4 ⁰
VISCOSITY	60.5sec	70 sec	78 sec	84 sec	93 sec	97 sec

5.1 Comparative Study:

The comparison of volumetric properties of modified mix and the conventional mix with, 7 percent of waste plastic and OBC was studied.

Table 6: Comparison of volumetric properties of the mixes

Properties	Modified Mix (waste plastic)	Conventional mix
Marshal stability (gm.)	1700	1306
Bulk density (gm/cc)	2.35	2.47
VFB (Voids Filled with Bitumen) (%)	45.40	49.96
Flow values (mm)	4.8	4.9
VMA (Voids in mineral Aggregate(%))	42.3	41.77
Retained Stability (%)	94	87.13

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5.2 Cost Analysis:

Table 7: Comparison of volumetric properties of the mixes

Cost Of Bitumen (Per MT)	Cost saving Due to 7 % plastic replacement(Per MT)	Cost Of processed Waste Plastic (Per MT)	Total Cost Saving on Bitume (Per MT)	% Cost Saving (Per MT)
38000	2960	1000	1960	5.12%

Above analysis shows that cost of construction of flexible pavement can be reduces up to 5.12% by replacing bitumen with waste plastic.

VI. CONCLUSION

Conclusions were made regarding this research it reduce the need of bitumen up to 7%, Increase the strength and performance of road, Reduce cost of road construction up to 5.12%,Develop a technology, which is eco-friendly.By using the waste plastic reduces the dumping problems and more over by mixing it with bitumen it also decreases the maintenance cost of the roads and also increases the life of the road.In addition to the improvement of the quality of the road, this technology has helped to use the waste plastics obtained from domestic and industrial packing materials.The addition of waste plastic modifier inbituminous road construction (Dry process)also increases the volume of total mix as thewaste plastic modifier is added as an extra item to the whole mix, thus contributing muchmore strength and service life to the roads.

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