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PARAMETRIC STUDY ON WASTE PLASTIC UTILIZATION IN BITUMEN

Aditya A. Lanjewar[1], Dr. Girish M. Deshmukh[2], Ajay Mishra[3]

[1]*Research Scholar, Laxminarayan Institute of Technology, Nagpur, Maharashtra, India*
[2]*Professor and Head, Dept. Of Petrochemical Technology, Laxminarayan Institute of Technology, Nagpur, Maharashtra, India*
[3]*Research Scholar, Laxminarayan Institute of Technology, Nagpur, Maharashtra, India*

Abstract - *The use of plastic and related materials is increasing exponentially due to tremendous growth in population, urbanization and changed life style leads to widespread littering of plastic on the landscape. Disposal of waste plastic is a serious problem globally due to their non-biodegradability and hazardous to human health, since these are not disposed scientifically and thus, create ground and water pollution. In the present paper techniques has been developed to use plastic waste for construction of bituminous roads and flexible pavements. In general bitumen is used as binder in road construction. Binding properties of this bitumen can be modified by blending it with waste plastic pieces. It can be used for construction purpose. Waste plastic coated road aggregates can improve road strength. This modified bitumen mix and aggregates show better binding property, stability, density and more resistant to water thus increasing durability of roads with increased resistance to wear and tear of the road.*

***Key Words*: Plastic waste, Mechanical characteristics, Bituminous mix, Plastic roads.**

1. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided into two major categories: thermoses and thermoplastics. A thermo set used primarily in automobiles and construction applications. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyleneterephthalate. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Use of plastic along with the bitumen in construction of roads not only increases its life and smoothness but also makes it economically sound and environment friendly. Plastic waste is used as modifier of bitumen to improve some of bitumen properties Roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen. Further it has been found that such roads were not subjected to stripping when come in contact with water. Use of higher percentage of plastic waste reduces the need of bitumen by 10%. It also increases the strength and performance of the road. Plastic increases the melting point of bitumen and hence missing can be done in more better and easier way.

Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics. Plastic is a non-biodegradable material and researchers found that the material can remain on earth for 4500 years without degradation. Several studies have proven the health hazard caused by improper disposal of plastic waste [1]. Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Disposal of a variety of plastic & rubber wastes in an eco-friendly way is the thrust area of today's research [2]. Looking forward the scenario of present life style a complete ban on the use of waste plastic cannot be put, although the waste plastic taking the face of a devil for the present and the future generation. But the use of waste plastics in road construction is gaining importance these days because plastic roads perform better than ordinary ones and the plastic waste considered to be a pollution menace, can find its use. The main objectives of the study are: To determine the relevant index and engineering properties of plastic waste, and compare them with conventional bitumen. To select the optimum percentage of plastic waste to be blended with commonly used bitumen to produce maximum compressive strength. To study the important properties of the bitumen concrete mixes with polyethylene carry bags, PET bottles to determine how they affect the properties of mixes.

1.1 GENERATION OF PLASTIC SOLID WASTES

A material that contains one or more organic polymers of large molecular weight, solid in its finish state and at some state while manufacturing or processing into finished articles, can be shaped by its flow is termed as plastics. Both technological processes and consumptive processes result in the formation of solid wastes. Solid waste is generated, in the beginning, with the recovery of raw materials and thereafter at every step in the technological process as the raw material is converted to a product for consumption. The process of consumption of products results in the formation of solid waste in urban areas. In addition, other processes such as street cleaning, park cleaning, waste-water treatment, air pollution control measures etc. also produce solid waste in urban areas.

Table -1: Waste Plastic and its Source

Waste Plastic	Origin
Low density polyethylene(LDPE)	Carry bags, sacks , milk pouches, bin lining, cosmetic and detergent bottles.
High density polyethylene(HDPE)	Carry bags, bottle caps, house hold articles etc.
Polyethylene teryphthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.
Polystyrene (PS)	Yoghurt post, clear egg packs, bottle caps, food trays, egg boxes, disposable cups, protective packaging etc.
Polyvinyl chloride(PVC)	Mineral water bottles, credit cards, toys, pipes and gutters, electrical fittings, furniture, folders and pens, medical disposables etc.

1.2 BITUMEN (ASPHALT)

Bitumen is a sticky, black, non-volatile and highly viscous liquid or semi-solid, in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. It is the heaviest fraction of crude oil with highest boiling point. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing carbon, hydrogen ,sulfur, nitrogen, and oxygen . In USA bitumen referred to as asphalt or sometimes asphalt cement. Asphalt is a combination of bitumen and mineral matter in any proportion. Asphalts are high molecular weight complex molecules, black color, soluble preferably in aromatic solvents and carbon disulphide.

The following are the different forms of bitumen:
Cutback Bitumen: A suitable solvent is mixed to reduce viscosity.
Bitumen Emulsion: Bitumen is suspended in finely divided condition in aqueous medium 60% bitumen and 40% water.
Bituminous Primers: Mixing of penetration bitumen with petroleum distillate.
Modified Bitumen: Blend of bitumen with waste plastics & or crumb rubber.

Various grades of bitumen used for pavement purpose:
Basically, there are two important processes namely dry process and wet process used for bitumen mix flexible pavement.
• Grade 30/40: These are the thicker material having higher softening point & these are used in high temperature regions.
•Grade 60/70: These are semi viscous material having moderate softening point. It is widely used because of its availability & cheaper cost.
• Grade 80/100: This type of bitumen is thinner material & is used in tropical regions. It is having lower softening point.

2. Wet process

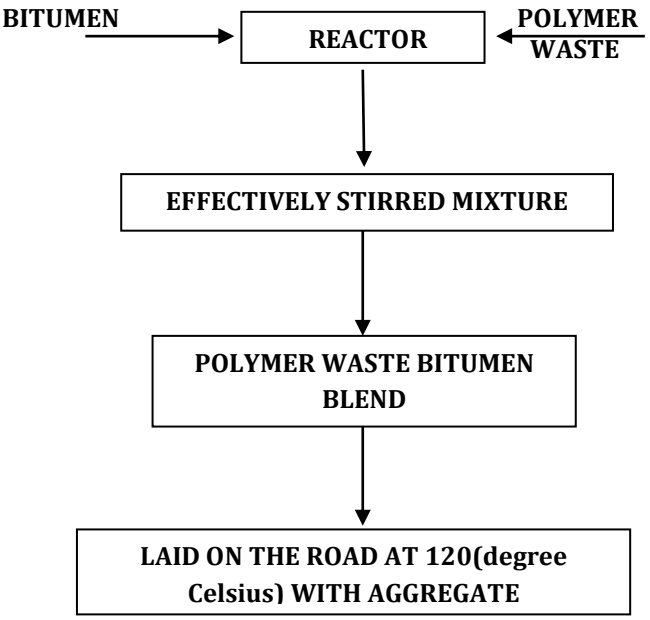


Fig-1: Process flow of bitumen mix

These are the method used for formation of polymer based modified bitumen, in which the waste polymer directly added with bitumen and heated up to temperature of 160 (degree Celsius) so that proper blend is to be formed with proper dispersion of waste polymer into bitumen, then the hot mix is then cooled up to 120 (degree Celsius) into another chamber, which is then added to the aggregate in paddling chamber. The mix is to be cooled because when hot mix poured on aggregate then there are chances to form air pocket into

small gap of aggregate and chances in lower the strength of roads and chances of rutting of roads. After addition of modified bitumen at 110 (degree Celsius) on aggregate, it is then laid on the road and then spreader material is compacted by 8 tone roller.

3.EXPERIMENTAL SETUP

3.1 Development of initial blends

Selection of appropriate polymers:

These include low and high density polyethylene (LDPE, HDPE) widely used in packaging and plastic bottles; polypropylene (PP) often used in straws and sweet wrappings; polyvinyl chloride (PVC), used in plumbing pipes and fittings; polyethylene teryphthalate (PET), widely used in water and soft-drink bottles and acrylonitrile butadiene styrene (ABS), used in electronic devices such as laptops and mobile phones. It was suspected that some of these materials would be unsuitable for use in manufacturing recycled polymer modified bitumen. So samples were taken from main three components of waste viz. HDPE, LDPE, PP and also crumb rubber from rubber waste.

Fig-2: Polymer used (Low density polyethylene)

Initial evaluation process:

The initial evaluation process involved attempting to incorporate the recycled polymers into a straight run bitumen. The selected bitumen was 60/70 grade bitumen with a softening point of avg. 52.5 (degree Celsius) and a penetration value of avg. 65 dmm . And 80/100 grade bitumen with a softening point of avg.48.5 (degree Celsius) and penetration value of avg. 90 dmm.

3.2 Preparation of blend

Waste plastic LDPE was collected.
These samples prepared, were added slowly to hot molten bitumen of temperature around 170-180(degree Celsius)
All samples were first mixed at low polymer concentrations as follows:

For mixing with 60/70 grade bitumen: Beginning with 3% by weight of the bitumen, further in the concentrations of 5%, 7%, 9%, 11% and 20%.
The mixture was stirred well using stirrer for about 20-30 minutes.
Blends of different compositions were prepared
(as shown in table-2)

Fig-3 : Bitumen mixed sample.

Fig-4 : Blends of different compositions prepared.

Table -2: Preparation of blends using addition of different percentage of plastics:

Sr. NO	BITUMEN WEIGHT (gm)	PLASTIC (%)	PLASTIC BY WEIGHT
1	500 gm.	3%	15 gm
2	500 gm.	5%	25 gm
3	500 gm.	7%	35 gm
4	500 gm.	9%	45 gm
5	500 gm.	11%	55 gm
6	500 gm.	12%	60 gm
7	500 gm.	20%	100 gm

4.TESTS PERFORMED

The following are the important tests performed:

DUCTILITY

The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.

PROCEDURE
Bitumen is heated to 160^0C-170^0C
Heated bitumen is poured into the ductility machine.
The mould is kept until it cools to room temperature
The mould is placed in ice and kept at 27^0C for 1 hour
The mould is placed in ductility machine
The readings are noted when the bitumen breaks into threads.

Fig-5: Ductility machine

FLASH POINT TEST

The flash point of a material is the lowest temperature at which the application of test flame causes the vapors from the material to momentarily catch fire in the form of a flash under specified conditions of the test.

PROCEDURE
Soften the bitumen between 75 and 100oC. Stir it thoroughly to remove air bubbles and water.
Fill the cup with the material to be tested up to the filling mark. Place it on the bath. Fix the open clip. Insert the thermometer of high or low range as per requirement and also the stirrer, to stir it.
Light the test flame, adjust it. Supply heat at such a rate that the temperature increase, recorded by the thermometer is neither less than 5oC nor more than 6oC per minute.
Open flash point is taken as that temperature when a flash first appears at any point on the surface of the material in the cup. Take care that the bluish halo that sometimes surrounds the test flame is not confused with the true flash. Discontinue the stirring during the application of the test flame.
Flash point should be taken as the temperature read on the thermometer at the time the flash occurs.

Fig-6 : Pensky-Martens flash point apparatus

FIRE POINT TEST

It is the lowest temperature at which a particular sample catches fire.

PROCEDURE
After flash point, heating should be continued at such a rate that the increase in temperature recorded by the thermometer is neither less than 5oC nor more than 6oC per minute.
The test flame should be lighted and adjusted so that it is of the size of a bead 4mm in dia.

Fig-7: Pensky-Martens fire point apparatus

SOFTENING POINT

This test is conducted using ring and ball apparatus. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

PROCEDURE:
Sample Grade of bitumen is heated to 160^0C - 170^0C
LDPE(≥ 40 μ) are added to the hot bitumen & mixed homogeneously.
The rings are placed on the glass plate to weigh the plastic added bitumen is poured
The rings with plastic added bitumen is kept until it cools to room temperature
The rings are placed in the stand and then kept in the beaker. The beaker is filled with ice and kept at 5^0C for 15 mins
After 15 min the apparatus is kept on the flame with a mesh under.
The ball is placed in the center of the ring &thermometer is placed in the beaker.
When the ball comes down along with the plastic added bitumen the temperature is noted. That is the softening point of the plastic added bitumen.

Fig-8: Softening point apparatus by ring and ball

PENETRATION INDEX

The penetration index represents a quantitative measure of the response of bitumen to variation in temperature. Knowing the penetration index of particular bitumen, it is possible to predict its behavior in an application.

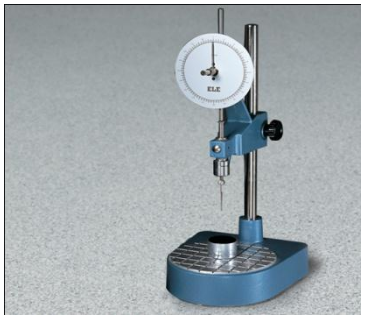


Fig-9 : Penetration Index Apparatus

5. Results and Discussion

Table-3 : Property check of different grade

Sr .NO	PROPERTY	UNIT	GRADE (10)	GRADE (20)	GRADE (30)	GRADE (40)	TEST METHOD REF
1.	VISCOSITY AT 60 oC	POISE	800	1600	2400	3200	IS:1206: 1978
2.	PENETRATION VALUE AT 25	1/10 mm	80-100	60-80	50-70	40-60	IS:1203: 1978
3.	SOFTENING POINT	^{0}C	40	45	47	50	IS:1205: 1978
4.	DUCTILITY VALUE	Cm	75	50	40	25	IS:1208: 1978
5.	FLASH POINT	^{0}C	220	220	220	220	IS:1209: 1978
6.	FIRE POINT	^{0}C	230	230	230	230	IS:1207: 1978

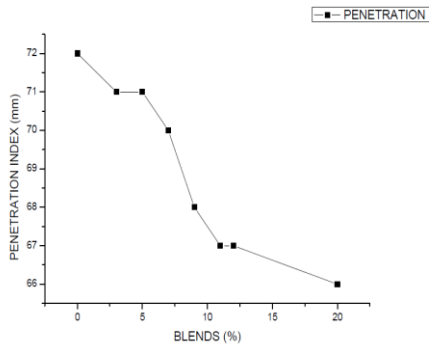
Table -4 : Bitumen property check

Sr .N0	PROPERTY	VALUE	APPARATUS USED
1.	PENETRATION INDEX	72 mm	PENETRATION INDEX (NEEDLE)
2.	SOFTENING POINT	64 ◦C	BALL AND RING APPARATUS
3.	DUCTILITY VALUE	70 cm	DUCTILITY TESTING MACHINE
4.	FLASH POINT	235◦ C	CLEAVLAND OPEN CUP
5.	FIRE POINT	251◦ C	CLEVLAND OPEN CUP

Table-5 : Conventional mix (different blends) property check

BLENDS	PROPERTY	VALUES
BLEND 1 (3%)	PENETRATION INDEX	71mm
	SOFTENING POINT	65^{0}C
	DUCTILITY VALUE	70 cm
	FIRE POINT	253^{0}C
	FLASH POINT	238^{0}C
BLEND 2(5%)	PENETRATION INDEX	71mm
	SOFTENING POINT	68^{0}C
	DUCTILITY VALUE	71 cm
	FIRE POINT	259^{0}C
	FLASH POINT	242^{0}C

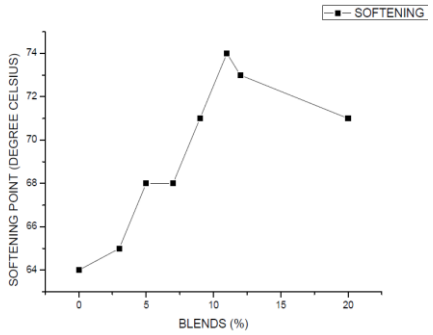
BLEND 3(7%)	PENETRATION INDEX	70mm
	SOFTENING POINT	68°C
	DUCTILITY VALUE	71 cm
	FIRE POINT	265°C
	FLASH POINT	247°C
BLEND 4 (9%)	PENETRATION INDEX	68mm
	SOFTENING POINT	71°C
	DUCTILITY VALUE	72 cm
	FIRE POINT	273°C
	FLASH POINT	255°C
BLEND 5 (11%)	PENETRATION INDEX	67mm
	SOFTENING POINT	74°C
	DUCTILITY VALUE	75 cm
	FIRE POINT	285°C
	FLASH POINT	260°C
BLEND 6(12%)	PENETRATION INDEX	67mm
	SOFTENING POINT	73°C
	DUCTILITY VALUE	75 cm
	FIRE POINT	288°C
	FLASH POINT	261°C
BLEND 7(20%)	PENETRATION INDEX	66mm
	SOFTENING POINT	71°C
	DUCTILITY VALUE	72 cm
	FIRE POINT	284°C
	FLASH POINT	265°C



GRAPH -1: Effect of plastics in different blends on penetration index of mix.

The penetration test is carried out to know the hardness or softness of bitumen used in road construction by measuring the distance to which the needle penetrates. Samples having different percentage of plastic waste in bitumen is prepared and their penetration values are determined .The penetration values of the blends are decreasing depending upon the percentage of polymer added.

The decrease in penetration index indicates the increase in hardness of the blend. This further concludes that bitumen-plastic roads will be of more hard nature as compared to the conventional roads and will not penetrate easily in any conditions.

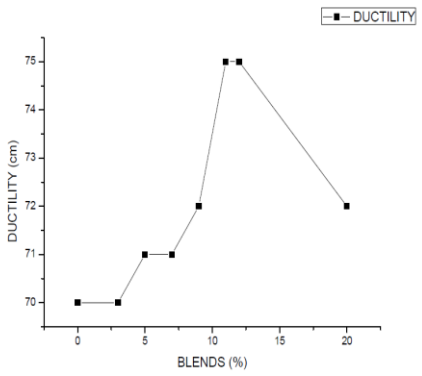


Graph-2: Effect of plastics in different blends on softening point of mix.

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of tests. Higher softening point is generally preferred in warm climate, whereas lower the softening point lower will be preferred in cold climate.

The graph above indicates an increase in softening point of the blend. This concludes that higher softening point will ensure that the bitumen-plastic roads will not flow during service. Also with higher softening point, there is an increase in temperature susceptibility. Bitumen with higher softening point is suitable for warmer places.

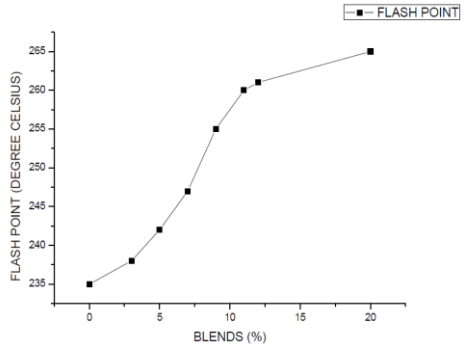
Also it is observed that best results are obtained at 11% plastic composition and after that softening point value decreases.



Graph-3: Effect of plastics in different blends on ductility value of mix.

This test is done to determine the ductility of bitumen. The principle of this test is that: the ductility of a bituminous material is measured by distance in cm to which it will elongate before breaking. The ductility test gives a measure of adhesive property of bitumen & its ability to stretch .Bitumen with low ductility value may get cracked when subjected to repeated traffic loads especially in cold weather.

The best result for ductility is obtained at a plastic composition of 11 percent.

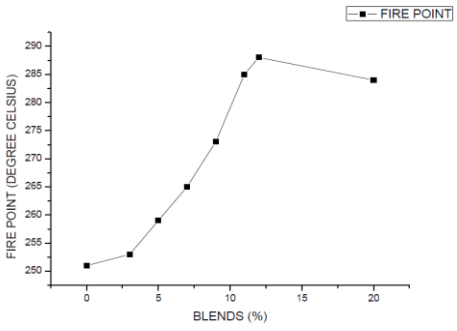


GRAPH-4: Effect of plastics in different blends on flashpoint of mix.

The studies of flash and fire points of the plastic waste-bitumen blend helps to understand the inflammability nature of the blend.

Experiment shows that there is an increase in the flash point of the mix with increase in the plastic content in the bitumen. A low flash point can be indicative of the presence of highly volatile and flammable materials. Thus an increased flash point value is always favorable and will increase the temperature at which the mix will create a flash.

The best results for all the properties are obtained at a plastic mix content of 11 percent.



Graph-5: Effect of plastics in different blends on fire point of mix.

Bituminous materials give rise to volatiles at high temperature, as they are basically the Hydrocarbons. These volatiles catch fire , which is very hazardous.

Higher fire point as shown in the graph shows the plastic mix has developed better resistance to burning. Thus road surfaces will be less affected by fire hazards

The best results for all the properties are obtained at a plastic mix content of 11 percent.

6. CONCLUSIONS

As seen the above results and graphs, when 11% polymer is blended in the bitumen mix, the values of the characteristics goes on increasing as compared to the conventional mix. This shows and proves that by adding certain amount of plastic waste in the bitumen, it gains strength and thus becomes more durable and tough. The coating of plastics reduces the porosity, absorption of moisture and improves strength. Hence the use of waste plastics for flexible pavement material is one of the best methods for easy disposal of wastes. The use of polymer is better than the use of conventional aggregates in many respects. As shown in the table, it is clearly shown that there is a huge difference in the values of the mix when compared with the conventional value. Thus the process is eco-friendly.

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