Plastics in Pavement: A Review

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ABSTRACT
2002 proved to be a significant year as Mr. Rajgopalan Vasudevan discovered "Plastic pavements" .The "Plastic Man" as he was called after the discovery came up with the idea of use of plastic waste for the construction of roads . Plastic disposal is one of the major problems for developing countries like India ,at the same time India needs a large network of roads for its smooth economic and social development. Plastic after recycling turns into a harmful material which has to be disposed because it would otherwise get into landfill or lead to incineration .It was therefore the need of time to find a way of proper disposal of plastic waste. To curb this the use of idea of use of plastic in pavement construction came up. Traditional pavement is constructed using bitumen and aggregate. The limited source of bitumen needs a deep thinking to ensure fast road construction. The main approach and aim at this research paper are to determine the physical and chemical properties of modified bitumen containing different percentages of plastic waste and to determine the optimum percentage of plastic waste in modified bitumen.

Modified bitumen was prepared by using blending techniques. Bitumen was heated and plastic was slowly added. Physical and chemical properties of bitumen were analysed by conducting the laboratory tests such as penetration, softening points ,viscosity and direct shear test.

As the content of plastic waste increase the penetration grade , softening point and viscosity increases. Performance of bitumen increases when added with plastic.

Plastic waste includes plastic bottles like bisleri , cold drink bottles ,portable glasses, milk polythenes etc and all the plastics included in thermoplastics. Plastic included in thermosis are strictly avoided in this process. Use of plastic reduces the use of bitumen by 10 -15%. The figures being self explanatory, one can easily understand this reduses the cost of bitumen. Including the cost of reclycling process of plastic, the plastic pavements prove to be economical. Engineering properties of aggregates include void ratio, tensile stress etc are improved . 2015 was the year in which the Government ordered to make it mandatory ,the use of plastic waste in road. India being a developing country needs such innovative ideas to accelerate its development.

Keywords- Pavement , Bitumen , thermoplastic , Thermoses , Plastic waste.

INTRODUCTION

In the year 2000, one of the millennium development goals (MDGs), which INDIA appended to was the promotion of environmental protection and sustainability; However, for well over a decade which has seen the transformation of the MDGs in to Sustainable Development Goals (SDGs), the country is still grappling with the proper disposal and management of its Municipal solid Waste (MSW), especially plastic waste.Currently, the common waste disposal methods employed are land filling, incineration and haphazard littering in the cities, municipalities and the countryside. These disposal methods have a negative impact on human health and the environment; consequently, rivers, gutters and roadsides are choked and filled with waste plastics. Polyethylene Terepthalate (PET) and High density Polyethylene (HDPE) are used in most bottling applications of water, yoghurt and soft drinks, but in terms of littering, however, one of the worst culprits is polyethylene (or "polythene") bags, for food packaging and sachet water bags. Every day, a multitude of items that are either partly or completely made of plastic are used and these plastics eventually end up in the landfills. Depending on the quality of the plastic, it may take anywhere from a few days to several years to break down in landfills, but it never breaks down completely into particles that can be used in nature. As such, plastic is one of the worst offenders when it comes to environmental pollution [1]. On the other hand, the volume of road traffic is increasing and demands a corresponding increment in the load bearing capacities of the road and its service life span. It has been proven possible to improve the performance of bituminous mixes used in the surfacing course of road pavements, with the help of various types of additives or modifiers to bitumen such as polymers, rubber latex, crumb rubber, etc. The choice of modifier for a particular project can depend on many factors including construction ability, availability, cost, and expected performance. Modification is achieved by two main procedures; Dry process involves direct incorporation of waste plastic, which is blended with aggregate before adding in bitumen, to prepare a plastic modified bituminous concrete mix and the Wet process which involves, simultaneous blending of bitumen and waste plastic.The use of polymer modified bitumen to achieve better asphalt pavement performance has been observed for a long time [2,3]. Zoorab&Suparma [4] reported the use of recycled plastics composed predominantly of polypropylene and low density polyethylene in plain bituminous concrete mixtures with increased durability and improved fatigue life. Resistance to deformation of asphaltic concrete modified with low density polythene was improved in comparison with unmodified mixes. The thrust of this study is to generate scientific data which will form basis for using plastic modified bitumen in the construction and repair of roads in INDIA, as well as provide scientific data on the alternative recycling options for managing plastic waste.

CONVENTIONAL ROADS

An ideal pavement should meet the following requirements:

1. Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,

A. Structurally strong to withstand all types of stresses imposed upon it,

B. Adequate coefficient of friction to prevent skidding of vehicles,

C. Smooth surface to provide comfort to road users even at high speed,

1 Produce least noise from moving vehicles,

2 Dust proof surface so that traffic safety is not impaired by reducing visibility,

- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

Types of pavements

The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

Flexible pavements

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure (see Figure 1)

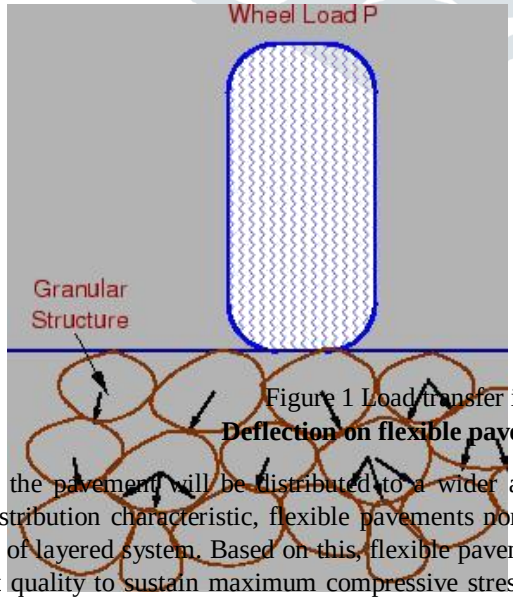


Figure 1 Load transfer in granular structure

Deflection on flexible pavement

The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade

then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

Types of Flexible Pavements

The following types of construction have been used in flexible pavement:

Conventional layered flexible pavement, Full - depth asphalt pavement, and Contained rock asphalt mat (CRAM).

Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water.

Typical layers of a flexible pavement

Typical layers of a conventional flexible pavement includes seal coat, surface course, tack coat, binder course, prime coat, base course, sub-base course, compacted sub-grade, and natural sub-grade

Seal Coat:

Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.

Tack Coat:

Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layer of binder course and must be thin, uniformly cover the entire surface, and set very fast.

Prime Coat:

Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed. It provides bonding between two layers. Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface.

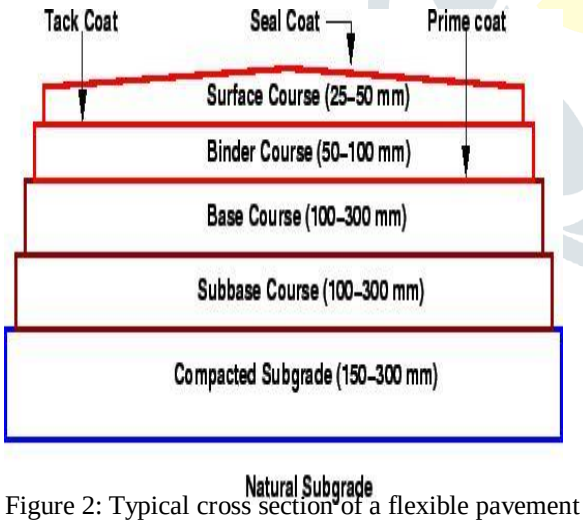


Figure 2: Typical cross section of a flexible pavement

Surface course

Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete(AC). The functions and requirements of this layer are:

It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,

It must be tough to resist the distortion under traffic and provide a smooth and skid-resistant riding surface,

It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Binder course

This layer provides the bulk of the asphalt concrete structure. It's chief purpose is to distribute load to the base course The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course

The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course

The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.

Sub-grade

The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

WHY USE OF PLASTIC?

Polymers have a number of vital properties, which exploited alone or together make a significant and expanding contribution to construction needs.

[1]Durable & corrosion resistant.

[2] Good insulation for cold, heat & sound saving energy and reducing noise pollution.

[3]It is economical and has a longer life.

[4]Maintenance free.

[5]Hygienic & problems.
[6]Ease of processing/ installation.

[7]Light weight.

TYPES OF PLASTIC & MATERIALS USE IN PROJECT

Types of plastic

[1] Thermosets.

[2] Elastomers.

[3] THERMOPLASTICS.

[4] PET, polyethylene terephthalate.

[5] HDPE, high-density polyethylene.

[6] PVC, polyvinyl chloride.

[7] LDPE, low-density polyethylene.

[8] PP, polypropylene.

[9] PS, polystyrene.

Classification of Plastic Waste:

a) Polyethylene:

LDPE (Low Density Poly-Ethylene) : Low density poly-ethylene this plastic waste available in the form of carry bags generally in stores these plastic bags are very thin and also easily available.

HDPE (High Density Poly-Ethylene): Generally High density poly-ethylene type of plastic waste is available in the form of carry bags and easily available in the market.

b) Polypropylene:

This plastic may be available in the form of carry bags or solid plastic it' depend upon the use and need of the industries. It is available in the form of plastic bottles and mat sheets etc

Materials & methods

1.Aggregate - Broken pieces of stone.

2.Bitumen – Grade AC-20.

3.Plastic – Plastic bottles, bags, wrappers etc. upto thickness 60µ .

TYPE OF PROCESS & METHODOLOGY

Type of process

1) Dry Process
2) Wet Process

Dry process

1.Plastic waste like bags , bottles ,etc are cut into a size between 2.36 mm and 4.75 mm using shredding machine.

2.The aggregate mix is heated to 170^0C and then it is transferred to mixing chamber.

3.Similary the bitumen is to be heated up to maximum of 160^0C.

4.At the mixing chamber, the shredded plastic is added over the hot aggregate.

5.The plastic waste coated aggregate is mixed with hot bitumen.

Wet process

1. Waste plastics by direct mixing with hot bitumen at 160°C.
2. Mechanical stirrer is needed.
3. Addition of stabilizers and proper cooling.
4. Since the wet process require a lot of investment and bigger plants.

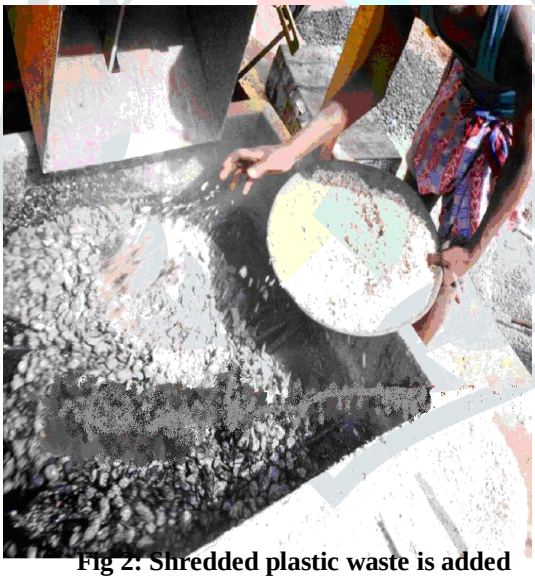


Fig 2: Shredded plastic waste is added

Methodology

Methodology gives idea about how to prepapre modified bitumen mix. Waste plastic bags were collected from roads, garbage trucks, dumpsites and compost plants, rag pickers, waste-buyers at Rs 5-6 per kg. Household plastic was also collected for the project work, like empty milk bags, used plastic bags etc. The collected Plastic waste was sorted as per the required thickness. Generally, polyethylene of 60 micron or below is used for the further process. Less micron plastic is easily mixable in the bitumen at higher temperature (160°c-170°c).It is clean by de-dusting or washing if required. Collected Plastic was cut into fine pieces as far as possible. The plastic pieces were sieved through 4.75mm sieve and retaining at 2.36mm sieve was collected. The wet process was employed; Samples were prepared, using melt-blending technique. Bitumen (400 g) was heated in oven till fluid condition and polymer was slowly added. The speed of the mixer was kept above 120 rpm and temperature, between 160 _C and 170 _C. The concentration of PP and HDPE, ranged from 0.5% _3% by weight of blend with an increment of 0.5%. Mixing was continued for 30mins-1hr to produce homogenous mixtures. The polymer modified bitumen (PMB) was then sealed in containers and stored for further testing. Empirical test such as penetration, softening point and viscosity were then conducted on the prepared samples

Tests on bitumen

a) Penetration Test [Is: 1203-1978]

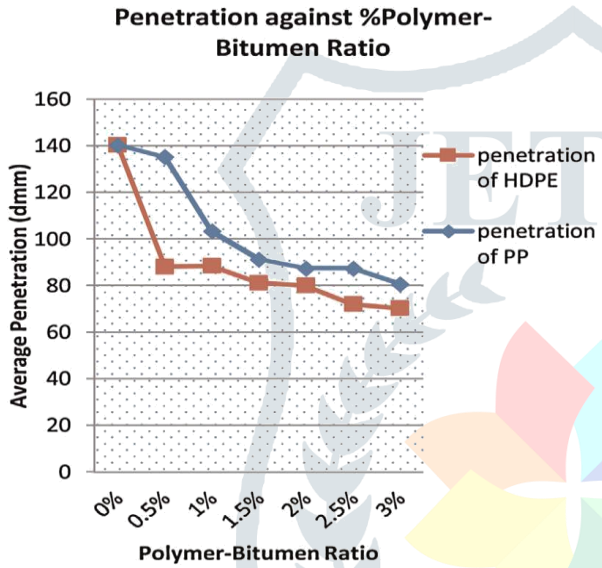
b) Softening Point Test [Is: 1205-1978]

c) Ductility Test [IS: 1208-1978]

f) Flash Point and Fire Point

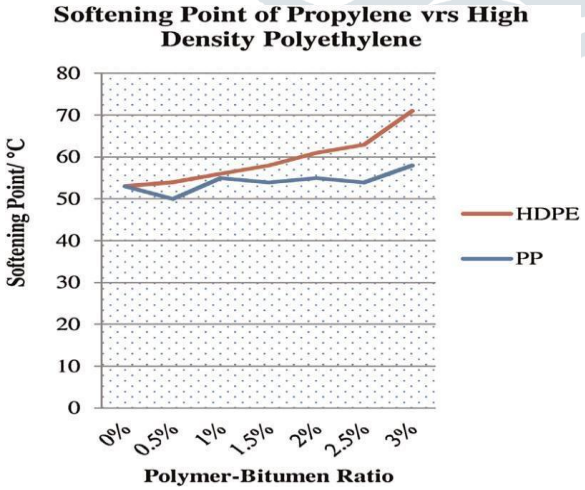
a)Penetration test -

The increase in percentage of polymer decreased the penetration value. This shows that the addition of polymer increases the hardness of the bitumen. The penetration values of the blends are decreasing depending upon the percentage of polymers and the type of polymer added.



b)Softening Point Test-

The softening point increased by the addition of plastic waste to the bitumen. Higher the percentage of plastic waste added, higher is the softening point. The influence over the softening point may be due to the chemical nature of polymers added. The increase in the softening point shows that there will be less bleeding during summer.



C) Ductility Test-

The decrease in the ductility value may be due to interlocking of polymer molecules with bitumen

d) Flash Point and Fire Point-

Flash and fire point increased with the increase in the percentage of polymer. The polymer bitumen blend road surfaces are less affected by fire hazards. This shows that the blend has better resistance towards water. This may be due to better binding property of the polymer bitumen blend.

RESULT

STABILITY DUE TO PLASTIC ADDITION

Bitumen Content	Stability (KN)	
	Plain bitumen	10 % bitumen replaced by plastic waste
4.5 Percent	17.03	20.28
5.0 Percent	17.18	21.15
5.5 Percent	17.68	22.43
6.0 Percent	17.61	21.81

RESULT FROM ALL TEST BEFORE AND AFTER ADDITION OF PLASTIC WASTE

Sr.no	Tests conducted	Test results		
		Plain bitumen		*Modified I (10% plastic*
1.	Penetration test	68mm		58m
2.	Ductility	83mm		52m
3.	Flash point	235°c		260°
4.	Fire point	251°c		295°
5.	Stripping value	0.4%		0.0%
6.	Softening point	Temp.in°c	Time in sec	Temp.in°c
		53	334	64 5

Material cost comparison for 1km road:

Description	Unit	Rate/unit	For control mix		For modified sample	
			Quantity	Amount(Rs)	Quantity	Amount(Rs)
Material						
Aggregate	Ton	597	545.06	325400.88	495.65	295903.05
Bitumen	Ton	35000	31.78	112300	28.85	1009750
Plastic waste	Ton	6000			2.885	17310
Total material cost				1437700.88		1322963.05
Total material cost reduction= 7.99%						

CONCLUSION

1. The addition of waste plastic modifies the properties of bitumen.
2. The modified bitumen shows good result when compared to standard results.
3. The optimum content of waste plastic to be used is between the ranges of 5% to 10%.
4. The problems like bleeding are reduce in hot temperature region.
5. Plastic has property of absorbing sound, which also help in reducing the sound pollution of heavy traffic.
6. The waste plastics thus can be put to use and it ultimately improves the quality and performance of road
7. Total material cost of the project is reduced by 7.99%

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