

Use of Waste Plastic in Flexible Pavement Construction - A Case Study

Akanksha Yadav

Kalinga University, Raipur (C.G.), India

Abstract: *This work would help in increasing the Flexible pavement lifespan with durability. This paper represents the behavior of bitumen mix modified with waste plastic (OMFED). Various percentages of polythene are used for preparation of mixes with a selected aggregate grading as given in the IRC Code. The role of polythene in the mix is studied for various engineering properties by preparing Marshall Samples of BC mixtures with and without polymer. Marshall Properties such as stability, flow value, unit weight, air voids are used to determine optimum polythene content for the given grade of bitumen (80/100).*

Key words: *Bituminous Concrete (BC), Marshall Stability, Flow value, Optimum Polythene Content*

Introduction

Plastic is everywhere in today's lifestyle, it has numerous applications in various sectors such as packaging, protecting, agriculture, construction and even disposing of all kinds of consumer goods. As a result of rapid industrial growth in various fields together with population growth an obvious increase in waste generation rates for various types of waste materials is observed. Disposal of that large amount of wastes especially non-decaying waste material become a problem of great concern in developed as well as in developing countries. Recycling waste into useful products is considered to be one of the most sustainable solutions for this problem.

A wide variety of studies and research projects have been done to find useful applications of some of waste products in highway construction discussing wide range of aspects such as performance, suitability, environmental concerns and feasibility of using each material. This study try to find adequate combination of the need of safe and economic disposal of waste material and the need of better and more cost-effective construction material. Using recycled material in roads pavements in now days considered not only as a positive option in terms of sustainability, but also, as an attractive option in means of providing enhanced performance in service. It's proven that the addition of certain polymer to asphalt binder can improve the performance of roads pavement. The addition of polymer typically exhibit greater resistance to rutting and thermal cracking. Besides, it's decreased fatigue

damage, stripping and improve temperature susceptibility.

Asphalt material is a composite material of consisting of mineral aggregates, asphalt binder and air voids. The load carrying capacity behavior and resulting failure of such material depends on many mechanisms that are strongly related to a local load transfer between aggregates particles.

A material that contains one or more organic polymers of large molecules 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. Plastic can be divided two major categories: thermosets and thermoplastics. A thermo set solidify or "sets" irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications.

1. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyl-eneterephthalate. A thermoplastics softens when exposed to heat and returns to original condition at room temperature. Thermoplastics n easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibers. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone and polyurethane.

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 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 an easier way.

2. Construction

2.1 Mix Design

2.1.2 Overview

Construction of highway involves a huge outlay of investment. An accurate engineering design can save considerable investment; as well, a reliable performance of the highway, can be achieved.

2.1.3 Objectives of mix design

The bituminous mix design aims to estimate the proportions of bitumen, filler material, fine aggregates, coarse aggregates & polythene to produce a mix which should have

- Sufficient workability so that there is no segregation under load
- Enough strength to survive heavy wheel loads & tyre pressures.
- Sufficient durability
- Should be economical

2.1.4 Types of mix

- Hot mix asphalt concrete
- Warm mix asphalt concrete
- Cold mix asphalt concrete
- Cut-back asphalt concrete
- Mastic asphalt concrete or sheet asphalt

2.2 Polymer modification of BC

2.2.1 Need of the hour

The steady increase of wheel loads, tyre pressure, change in climatic conditions & daily wear and tear severely affect the performance of bituminous mix pavements. Hence any improvement in the property of the pavement is highly essential considering the present scenario.

2.2.2 Waste plastic is a concern

Plastics are durable & non-biodegradable; the chemical bonds make plastic very durable & resistant to normal natural processes of degradation. Since 1950s, around 1 billion tons of plastic have been discarded, and they may persist for hundreds or even, thousands of years. The plastic gets mixed with water, doesn't disintegrate, and takes the form of small pellets which causes the death of fishes and many other aquatic animals who mistake them as food materials.

Today the availability of the plastic wastes is enormous, as the plastic materials have become the part and parcel, of our daily life. Either they get mixed with the Municipal Solid Waste or thrown over a land area. If they are not recycled, their present disposal may be by land filling or it may be by incineration. Both the processes have significant impacts on the environment. If they are incinerated, they pollute the air and if they are dumped into some place, they cause soil & water pollution. Under these circumstances, an alternate use for these plastic wastes is required.

2.2.3 Role of plastic or polymer in pavement

Modification of BC, with the synthetic polymer binder can be considered as a solution to overcome

the problems, arising because of the rapid increase in wheel loads and change in climatic conditions. Polymer modification can be considered as one of the solution to improve the fatigue life, reduce the rutting & thermal cracking in the pavement.

Asphalt, when blended or mixed with the polymer, forms a multiphase system, containing abundant asphaltenes which are not absorbed by the polymer. This increases the viscosity of the mix by the formation of a more internal complex structure.

2.3. CHARACTERISTIC OF WASTE PASTIC THERMAL STUDY:-

A study of a thermal behavior of the polymers namely polyethylene, polypropylene, polystyrene, shows that those polymers gets softened easily without any evolution of gas around 130-140^oc, this has been scientifically verified.

At around 350^oc they get decomposed releasing gases like Methane, ethane etc.....and at 700^oc they undergo combustion, reducing gases CO & CO₂.

BINDING PROPERTY:-

The molten plastic waste inhibits good binding property. Following experiments were carried out to study the binding property:

The aggregate was heated to around 170^oc and the shredded plastic waste was added. Plastics got softened and coated over the aggregate. the mix of aggregate and plastic was compacted and cooled. The block was very hard and showed compressive strength not less than 130 Mpa and binding strength of 500 Kg/cm². This shows that the binding strength of polymer is good.

The polymer coated aggregate was soaked in water of 72 hours. There was no stripping at all. This shows that the coated plastic material sticks well with surface of the aggregate

CHEMICAL AND WATER RESISTANCE:-

The plastic have good chemical and water resistance property. The plastic have not allow, any liquid to pass through them. Water resistance property is very useful for the pavement to make it dry.

3. Problem and material identification

3.1 Basic materials

The materials used are as follows.

- i. Aggregates
- ii. Bituminous Binder
- iii. Mineral Filler
- iv. Polythene

3.1.1 Aggregate

Aggregate constitutes the granular part in bituminous concrete mixtures which contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a

good pavement. The properties that aggregates should have to be used in pavement are shown below:

- 1) Aggregates should have minimal plasticity. The presence of clay fines in bituminous mix can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Clay lumps and friable particles should be limited to utmost 1%.
- 2) Durability or resistance to weathering should be measured by sulphate soundness testing.
- 3) The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 & a minimum of 0.6.
- 4) It is recommended AASHTO T-209 to be used for determining the maximum specific gravity of bituminous concrete mixes.

3.1.2 Bitumen

Asphalt binder 60/70 and 80/100 are used in this research. The bitumen used should have the following properties

- a) Grade of bitumen used in the pavements should be selected on the basis of climatic conditions and their performance in past.
- b) It is recommended that the bitumen should be accepted on certification by the supplier (along with the testing results) and the State project, verification samples. The procedures for acceptance should provide information, on the physical properties of the bitumen in timely manner.
- c) The physical properties of bitumen used which are very important for pavements are shown below. Each State should obtain this information (by central laboratory or supplier tests) and should have specification requirements for each property except specific gravity.
 - (a) Penetration at 77° F
 - (b) Viscosity at 140° F
 - (c) Viscosity at 275° F
 - (d) Ductility/Temperature
 - (e) Specific Gravity
 - (f) Solubility
 - (g) Thin Film Oven (TFO)/Rolling TFO; Loss on Heating
 - (h) Residue Ductility
 - (i) Residue Viscosity

3.1.3 Mineral Filler

Mineral filler consists of, very fine, inert mineral matter that is added to the hot mix asphalt, to increase the density and enhance strength of the mixture. These fillers should pass through 75µm IS Sieve. The fillers may be cement or fly ash.

3.2 Materials used

3.2.1 Aggregates

The grades of aggregates and their quantities to be used for preparing Marshall samples were used according to the chart given in the MORTH specification.

So the aggregates of different grades were sieved through different IS Sieves and they were kept in different containers with proper marking.

Specific Gravity of Coarse aggregate = 2.7

Specific Gravity of Fine aggregate = 2.6

3.2.2 Bitumen

The bitumen used in preparing Marshall samples was of 80/100 penetration grade. Specific Gravity bitumen = 1.02

3.2.3 Filler

The filler material used was fly ash.

Specific gravity of fly ash = 2.2

3.2.4 Polythene

The polythene used in OMFED milk packets was used as raw material for preparation of the samples. These polythene packets were collected; they were washed and cleaned by putting them in hot water for 3-4 hours. They were then dried.

Specific Gravity of polythene = 0.905

Shredding:

The dried polythene packets were cut into tiny pieces of size 2 mm maximum. This is because when the polythene is to be added with bitumen and aggregate it is to be ensured that the mixing will be proper. The smaller the size of the polythene, the more is the chance of good mixing.

4. Methodology

The method of construction of waste plastic road is very complicated, because plastic waste is collected, clean, size reduction etc. process are include. The major polymers are namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. The plastic coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods of easy disposal of waste plastics. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many aspects. The studies on the thermal behavior and binding property promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction. Following procedure can be adopted for using plastic in road construction.

4.1 Collection of waste plastic

The waste plastics are collected from many sources like industries, commercial sector, agricultural sector, and municipal sector. The industrial plastic wastes are collected in one place than transported through trucks in used area. For collection of commercial plastic the big size dustbins are used than they are transported from the trucks.

Similarly plastic waste are collected from the entire source and placed in a place. There are four basic ways in which communities can offer plastic recycling collection services for plastic bottle and containers – curbsides, drop-off, buy-back, or deposit/refund program.

4.2 Cleaning of waste plastic

The plastic which are collected for pavement construction is must to clean. If the impurities are present in the plastic they are decrease the binding property of the plastic. The dust and dirt are mix with plastic particle and they are creating the voids, and after sometimes they are filled with air or water. The water and air voids are decreasing the strength, hardness, shear capacity. So it must to clean the plastic pieces. But sometimes the chemical of the plastic are mix with water due to the cleaning process of the plastic and they are do harmful effect on the humans and animals so it is a negative point of this process. The cleaning process is done near the water bodies like lake or rivers. The cleaning mills are generally situated away from the cities. The water in which the plastics are washed is treated by treatment plant and cost is increase

4.3 Size Reducing of plastic

After the cleaning of plastic, the size of plastics is reducing by the cutting mills. They are cut in small size between 2.36mm – 4.75mm using shredding machine. Small pieces are mix uniformly and give better result. To maintain the strength the size of plastic is uniform. The clean plastic fed in the shredding machine after that the shredded plastics are removed from the machine. Once sorted the raw plastics are reduced the size by shredding and granulating machinery. These machines are capable of processing any size of materials from ordinary domestic plastic waste to much larger lumps or spoils from industrial, commercial processes. To maintain our high standards of purity and quality all shredders and granulators have metal detectors fitted to their purpose built conveyor systems.

4.4 Clean plastic pieces

After the cutting of plastic they are in small and clean which is sent to continue the process. The clean plastic pieces are sent in the field to mix with aggregate. The clean plastic pieces are free from dust, dirt, clay, sand and other agents.

4.5 Heating the aggregate and mixing with clean plastic pieces

The aggregate is heated about temperature 160oc. After the heating of aggregate, the hot aggregate is transfer into the mixing chamber. At the mixing chamber, the shredded plastics waste is to be added. It gets coated uniformly over the aggregate within 30 to 60 seconds, giving an oily look. From the heating the aggregates molecules are active and they are sufficiently bind with the clean plastic pieces. And from the heating the aggregate the clean plastic pieces are properly spread over hot aggregate. The

heating process is done by air blast aggregate heaters. The aggregate is heated with hot air in the overhead bins, or in the receiving hoppers. A high pressure industrial fan distributes the heated air via pipes and diffusers into the material in the bins.

4.6 Adding bitumen and Mix

After the collection, cleaning and size reducing the plastic pieces are mix with the hot aggregate (temperature about 165oc) the bitumen is add in hot plastic coated aggregate (the bitumen is heated up to 160oc). The hot bitumen is mix uniformly on hot plastic coated aggregate. The bitumen is also as a binder they are bind all aggregate from each-other.

4.7 Road laying

After the adding bitumen the Polymer Bitumen Aggregate Mixture is get. This Polymer Bitumen Aggregate Mixture is used to road laying, by use of paver finisher machine. After pavement finishing, the road roller machine are use the dump the pavement, to give better strength and hardness. To archives extreme durability. The temperature of Polymer Bitumen Aggregate is approximate 110oc – 120oc during road laying. The roller used is 8-ton capacity.

5. Conclusion

From the study of the behavior of polythene modified BC it was found that the modified mix possesses improved Marshall Characteristics as mentioned below.

It is observed that Marshall Stability value increases with polyethylene content upto 4% and thereafter decreases. we observe that the marshall flow value decreases upon addition of polythene i.e the resistance to deformations under heavy wheel loads increases. Also the values of the parameters like VMA, VA, VFB are within the required specifications.

Considering these factors we can assure that we can obtain a more stable and durable mix for the pavements by polymer modifications. This small investigation not only utilizes beneficially, the waste non-degradable plastics but also provides us an improved pavement with better strength and longer life period.

Polymer modified pavements would be a boon for India's hot and extremely humid climate, where temperatures frequently rises past 50°C and torrential rains create havoc, leaving most of the roads with heavy distresses. This adversely affects the life of the pavements. The polymer modified bitumen show improved properties for pavement constructions. This also can reduce the amount of plastics waste which otherwise are considered to be a threat to the hygiene of the environment.

In this modification process plastics-waste is coated over aggregate. This increases the surface area of contact at the interface and ensures better bonding between aggregate and bitumen. The

polymer coating also reduces the void spaces present in the mix. This prevents the moisture absorption and oxidation of bitumen by entrapped air. The road can withstand heavy traffic and show better service life. This study will have a positive impact on the environment as it will reduce the volume of plastic waste to be disposed of by incineration and land filling. It will not only add value to plastic waste but will develop a technology, which is eco-friendly. However, it is recommended that more research regarding the topic should be done and more trial sections should be laid and their performance should be studied.

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