

Medical Plastic Waste Disposal by Using in Bituminous Road Construction

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ABSTRACT

The measure of plastic in the solid waste generated is increasing due to increase in factors such as urbanization, various development activities and changes in life style of humans which is leading to an unrestricted scattering on the landscape. Thus the disposal of these waste plastic has become a severe issue globally due to their non-biodegradability nature. Another area of concern is the deteriorating quality of roads due to the increase in traffic and their lower resistant's to withstand adverse climatic conditions. Studies are being carried out to develop suitable alternatives for providing good, conventional road constructional materials for providing eco-friendly roads which have good design life. In this work, autoclaved medical plastic waste in the form of shredded syringes used in road construction is tested. The main objective of this work is to study how to use shredded Biomedical Plastic waste (BMPW) in Bituminous Mix and to compare the performance of the aggregate and bitumen when modified with bio-medical plastic waste. The results from the case studies showed improved properties for Plastic Coated Aggregate when compared to normal aggregates. There by showing that by using biomedical waste in bituminous road construction could bitterly change the quality of road and also the design life of bituminous roads by improving their properties.

Keywords: *Deteriorating Quality, Non Biodegradability, Plastic Coated Aggregates, Shredded Syringes, Urbanization.*

1. INTRODUCTION

Wastes are those unwanted or useless materials which are generated from consumption. These are produced in solid, liquid and gaseous forms and may be generated during the extraction of raw materials, and also during the processing of raw materials into intermediate and final products, the consumption of final products. Of the various waste materials generated, plastic waste and municipal solid waste are of great concern due to its non-biodegradable nature. Some of the most used plastic materials are bags, cups, films and foams, made up of Polyethylene (PE), Polypropylene (PP) or Polystyrene (PS). Of these Plastic Waste is of greater concern and one of the major plastic waste generators are the hospitals, and the waste generated by them are called biomedical waste. Biomedical waste means any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological and including categories mentioned in Schedule I of

the Biomedical Waste Management Handling Rules, 1998. These wastes has to be managed properly because of their infectious and hazardous characteristics.

In hospitals the waste generated usually eange from 1.4 to 2.2 kg waste per day and and of these, 55% of them includes plastics. These littered plastics, are non-biodegradable material. If proper treatment is not provided it would get mixed with domestic waste and cause infections, thereby making difficulty in the disposal of municipal solid waste. Usually the municipal solid waste is either incinerated or used for land filling. Both these methods are not environment friendly techniques, as they may create both land and air pollution. So, these is a need for finding proper use of the generated biomedical plastic waste.

Reusing of these waste materials can make a significant contribution to the environment and economy from different aspects, such as:

- 1) It helps to reduce the overuse of natural resources and saves them from exhaustion.
- 2) It helps to reduce the environmental pollution level as a result of the waste materials generated in urban and industrial areas.
- 3) It helps in reducing disposal needs.
- 4) It provides a valuable outlet for such materials.
- 5) It contributes to saving energy and money.

On the other side, the road traffic is increasing and hence the load bearing capacity of the roads are to be increased. Traditionally soil, stone aggregates, sand, bitumen, cement etc. are used for road construction. Natural materials are being exhaustible in nature and their quantity is declining gradually, with their cost of extraction shooting up. Road surfaces with neat bitumen can cause bleeding in hot climate, may develop cracks in cold climate, possess fewer load bearing capacity and can cause serious damages because of higher axle load in present conditions due to rapid infrastructure development.

According to the research undertaken by Vidula Swami et al. (2012), the useful life of bituminous overlays in India has reportedly declined from an average life of 5-6 years in the past to about 3-4 years at present as compared to average pavement life (5-6 years) abroad.

Concerned about the above problems, the scientists are looking for alternative materials for highway construction, and plastic wastes thus form the perfect choice because of the following reasons.

- a) Extreme versatility
- b) Ability to be tailored to meet very specific technical needs.
- c) Plastics have lighter weight than the competing materials, thus helping to reduce fuel consumption during transportation.
- d) Extreme durability.
- e) Resistance to chemicals, water and impact.
- f) Excellent thermal and electrical insulation properties.
- g) Relatively inexpensive.

If these materials can be suitably utilized in highway construction, the pollution and disposal problems may be partly reduced and the durability of roads can also be increased. Thus, the techniques developed would be socially highly relevant, giving better infrastructure.

OBJECTIVE

The Main Objective of this study is the disposal of shredded Biomedical Plastic Waste (BMPW) by using it in Bituminous Road Construction. The work was limited to the use of Biomedical Plastic waste only and it was carried out by adding treated autoclaved syringe plastic waste.

There are two methods for using Syringe plastic waste in bituminous mix. One method is by coating the aggregate with Biomedical Syringe Plastic Waste (BMSPW) and other method is using BMSPW as a modifier in Bitumen. So here in this study comparisons between the two methods were done and the best method was suggested.

The objectives of the study are:

- To evaluate and compare the properties of plastic coated aggregates and normal aggregates
- To compare the properties of modified bitumen and pavement grade bitumen
- To suggest better approach for the use of BMPW from the two methods for Bituminous Road Construction in Cold Regions.

LITERATURE REVIEW

Plastics have become an indispensable part of our daily life. It has got a very wide application especially in industries like packaging, construction etc. Plastics are now replacing many conventional materials because of their ease in manufacture, greater economy and also due to easier maintenance of such materials. They offer great flexibility in their usage. But a major disadvantage with plastics is that they are non-biodegradable. This has been a growing cause of concern and various researches are being conducted in various parts of the world to find an effective method for the disposal of plastic waste. The properties of plastics are greatly influenced by their molecular structure. Many studies have been conducted in using Plastic as an additive in bituminous mix in hotter regions but not much in case of colder regions. Thus a question has been raised, Can plastic roads can be constructed in colder regions?

Wet weather conditions have been causing a great threat to the pavements due to improper drainage characterises and day by day the quality of road is deteriorating. Another area of concern is the bitumen availability and scarcity which has been reported recently. So a solution has to be has to be obtained for these problems. Hence before incorporating them in any project, one should have a general idea on their properties so that they can be suitably utilized.

A. Open Graded Friction Course

Open graded friction courses (OGFCs) are a type of pavement that have been built across the United States since the 1950's to improve the surface frictional resistance of asphalt pavements. These asphalt mixes contain only a small portion of fine aggregate, creating a pavement with a relatively large percentage of air voids. They are primarily composed of single size coarse aggregate, and generally have a high asphalt content. OGFC was designed as an open mix with interconnecting voids that provided drainage during heavy rainfall. The rainwater drains vertically through OGFC to an impermeable, underlying layer and then laterally to the day lighted edge of the OGFC. In addition to minimizing hydroplaning and providing high frictional resistance on wet pavements, it was realized that OGFC as compared to other dense surfaces had the following advantages:

- Reduce splash and spray behind vehicles
- Enhance visibility of pavement markings

- Reduce night time surface glare in wet weather
- Reduce tire-pavement noise
- Permit use of thin layers (minimize material).
- Improved surface drainage reduces hydroplaning
- Improves wet pavement friction

OGFC improves wet weather driving conditions by allowing the water to drain through its porous structure away from the roadway. A well-designed and well-constructed OGFC should not have ravelling/delaminating problems and should reasonably retain its high permeability and macro texture.

Dr.G.Malarvizhi and C.Kamaraj (2015) conducted study on OGFC graded aggregate using polymer modified bitumen. Open Graded Friction Courses (OGFC) are formulated to result in an internal structure of interconnected voids that allow water to drain through the mix. OGFC is a porous, gap- graded, predominantly single size aggregate bituminous mixture that contains a high percentage of air voids. The high air void content and the open structure of this mix promote the effective drainage of rainwater, which also minimizes hydroplaning during wet weather. This characteristic also reduces splash and spray behind vehicles and improves wet weather skid resistance. Other purported benefits of this type mix are lower pavement noise and reduced roadway glare during wet weather, which improves the night visibility of pavement markings. The properties of OGFC are found to have increased with the addition of various additives and with the use of Modified Binders like PMB (Polymer Modified Bitumen), CRMB (Crumb Rubber Modified Bitumen) etc. This study is intended to develop a mix design of OGFC for the Indian pavement conditions with different gradation and with conventional bitumen and Polymer Modified Bitumen and to suggest a rational mix design and to evaluate the performance of OGFC in the laboratory and field test.

B. Overview of Plastics

Plastic is the general term for a wide range of synthetic or semi synthetic polymerization products. They are composed of organic condensation or addition polymers and may contain other substances to improve performance or reduce costs. There are many natural polymers generally considered to be “plastics”. Plastics can be formed into objects, or films, or fibers. Their name is derived from the malleability, or plasticity of many of them.

C. Overview on Biomedical Wastes

Biomedical wastes unlike other wastes cannot be disposed off to the environment as such. They cannot be buried as this may lead to the pollution of our underground water resources. Their incineration produces toxic gases such as dioxin. A law was passed by the Central Government in the year 1998 called the Biomedical Waste Handling and Management which forbid the hospitals to dispose off the wastes as such. But as the installation of such a plant requires a huge capital, Indian Medical Association (IMA) set up a private organization under it called IMAGE (IMA Goes Eco friendly), which was given the responsibility to collect and treat the biomedical wastes as per the rules laid by IMA. After the collection of wastes from the hospitals the incinerable wastes are incinerated and the wastes which cannot be incinerated are autoclaved which ensures the destruction of all the pathogenic micro-organisms. The plastics after autoclaving such as glucose bottles, syringes etc. are then shredded so as to ensure the prevention of their re-use. These plastics are then sent for recycling. The metal sharps which include needles, knives etc. are usually buried deep. In Kerala, IMAGE is located at Kanjikode and has the responsibility of the collection and treatment of all the biomedical wastes.

As per the data provided by IMAGE, a brief overview of the biomedical waste generated in Kerala is shown below:

Table 1. Quantity of BMW treated & Disposed per Day

Incinerable waste	2.9 tonnes/day
Autoclaved waste	2.5 tonnes/day
Plastic	1.3 tonnes/day
Glass	1.1 tonnes/day
Metals	100 kg/day

From the above statistics one can get a clear picture of the difficulty involved in the effective disposal of such accumulating plastic wastes. As the plastics are non-biodegradable, we have to ensure that they are effectively disposed. Among the many alternatives for their disposal, one of the effective ways is to use them in the process of road laying. Many studies have revealed that such incorporation helps to increase properties such as strength, durability etc. of roads and this has encouraged researchers to find more and more ways of using plastics in pavement construction.

Vidula Swami and Abhijeet, J (2012) suggested that plastic waste consisting of carry bags, cups and other utilized plastic could be used as a coating over aggregates and this coated stone could be used for road construction. Their results showed that the increase in percentage of polymer decreased the penetration value, increased the hardness of bitumen and decreased the ductility value. The increase in flash and fire point of bitumen indicated that the plastic modified bitumen blend road surfaces were less affected by fire hazards. The increase in softening point of bitumen showed that there would be less bleeding during summer. Results also proved 7.99% material cost reduction. Modified bitumen with 10% plastic content showed improved properties of bitumen and higher stability values.

In another study investigation had been carried out by the potential use of waste plastic as a modifier for asphalt concrete and cement concrete pavement. Different ratios of plastic such as Polypropylene (PP), Low Density Polyethylene (LDPE), and High Density Polyethylene (HDPE) by weight of asphalt were blended with 80/100 paving grade asphalt. Unmodified and modified asphalt binders were subjected to rheological test. The performance tests including, Marshall Stability, loss of stability tests were conducted using plastic coated aggregates and polymer modified bitumen on different mixtures. Work had been done by using plastic coated aggregates in cement concrete pavements. The results showed better values for asphalt concrete. By using plastic as a coating over aggregates, the properties of aggregates were improved. By adding plastic to the unmodified bitumen, the rheological properties had been improved. By increasing the percentage of plastic, the stability values were increased and required quantities of binder contents were decreased.

Gawande and Zamare(2012) reviewed techniques to use plastic waste for construction purpose of roads and flexible pavements. Waste plastic modified bitumen mix showed better binding property, stability, density and more resistance to water. The use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helped in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improved the longevity and pavement performance with marginal saving in bitumen usage. The process was environment friendly. The use of waste plastics in the manufacture of roads and laminated roofing also helped to consume large quantity of waste plastics. Thus, these processes were socially highly relevant, giving better infrastructure.

Vasudevanand Ramalinga Chandra Sekar(2011) stated that the polymer bitumen blend was a better binder compared to plain bitumen. The blend had increased softening point and decreased penetration value with a suitable ductility. When it was used for road construction it could withstand higher temperature and load. The coating of plastics reduced the porosity, absorption of moisture and improved the soundness. The polymer coated aggregate bitumen mix formed better material for flexible pavement construction as the mix showed higher Marshall stability value and suitable Marshall coefficient. Hence the use of waste plastics for flexible pavement was one of the best methods for easy disposal of waste plastics.

Bindu and Beena (2010) investigated the benefits of stabilizing the stone mastic asphalt (SMA) mixture in flexible pavement with shredded waste plastic. Conventional (without plastic) and the stabilized SMA mixtures were subjected to performance tests including Marshall Stability, tensile strength and compressive strength tests. Triaxial tests were also conducted with varying percentage bitumen by weight of mineral aggregate (6% to 8%) and by varying percentage plastic by weight of mix (6% to 12% with an increment of 1%). Plastic content of 10% by weight of bitumen was recommended for the improvement of the performance of Stone Mastic Asphalt mixtures. 10% plastic content gave an increase in the stability, split tensile strength and compressive strength of about 64%, 18% and 75% respectively compared to the conventional SMA Mix. Triaxial test results showed a 44% increase in cohesion and 3% decrease in angle of shearing resistance showing an increase in the shear strength.

Raji (2007) investigated the suitability of mixes prepared with biomedical syringe and glucose plastic waste and found that the mix had better Marshall Stability than the conventional bituminous mixes. The optimum percent of syringe was found to be 3% and that of glucose bottles was found to be 5%. By this way, the hazardous biomedical plastic waste could be judiciously disposed off and cost of construction could also be reduced as some part of bitumen was saved.



Fig.1 Biomedical Waste

D. Biomedical Waste Management Process

The hospital waste like syringes, plastic bottles, etc. has to be collected properly from infected and contaminated areas are very essential to be segregated, stored, transported, treated and disposed of in safe manner to prevent nosocomial or hospital acquired infection. The various processes include:

- Waste collection
- Segregation
- Transportation and storage
- Treatment & Disposal
- Transport to final disposal site
- Final disposal

These being the older methods, new method for recycling the biomedical wastes have been introduced and it's in the field of pavement design

E. Biomedical Waste in Field Of Pavement Design

Many studies have been conducted wherein marginal materials have been used in bituminous pavements giving considerable saving in bitumen and aggregates. Among them, plastics like polyethylene have successfully replaced bitumen and have also increased the pavement characteristics like durability, strength etc. It is seen from the review that only a few experiments have been reported on the use of biomedical plastic waste. This proves the significance of a study to be conducted when biomedical plastic wastes are used as additives in bituminous pavements. Hence in this study, the properties of bitumen and aggregate when modified with shredded syringe plastic waste are investigated.

METHODOLOGY

This section provides the explanation of the steps involved in this work. The bio-medical waste plastic waste needed for the project was collected from a private organization, IMAGE ((Indian Medical Association Goes Eco-friendly), Kanjikode, Palakkad. Tests were conducted on aggregate, bitumen, plastic coated aggregate and modified bitumen.

A. Test on Aggregate

Following tests were conducted on aggregates:

1. Aggregate crushing value test
2. Aggregate impact value test
3. Los Angeles abrasion test
4. Specific gravity and Water absorption tests

B. Test on Bitumen

Following tests were conducted on bitumen:

- Penetration test
- Softening point test
- Specific gravity test
- Flash and fire point test
- Ductility test

C. Test on Modified Bitumen

Following test was conducted on modified bitumen:

- Elastic Recovery Test

EXPERIMENTAL STUDY & TEST RESULTS

This chapter discusses the results of various tests conducted on aggregates, bitumen and mix.

Table 2. Tests on Normal Aggregates and Plastic Coated Aggregates (PCA)

Tests conducted on aggregate & plastic coated aggregate	Values Obtained		IRC Specification (% Max)	% Reduction
	Normal Aggregate (%)	Plastic Coated Aggregate (%)		
Crushing Test	28.30	16.03	30	12.2
Impact Test	29.67	15	30	14.6
Abrasion Test	28.46	21	30	7.46
Water Absorption Test	1.26	-	2	-

Table 3. Tests on Bitumen and Modified Bitumen

Tests conducted on normal&modified bitumen	Values Obtained		IRC Specification (% Max)	Reduction
	Normal Bitumen	Modified Bituenn		
PenetrationTest	98 mm	23 mm	80 / 100	75 mm
Ductility Test	61 mm	45.5 mm	63-75 mm	15.5 mm
Softening point Test	52.70 °C	54.9 °C	54° to 58°C	Increased
Elastic Recovery Test	0	0%	Max 25 %	-
Stripping Value Test	-	8%	Minimum 75 %	-

A. Result Analysis

- Properties of OGFC aggregate and bitumen were evaluated and comparison was done.
- Aggregate properties (crushing reduced by (12.27%), impact reduced by (14.67%), abrasion reduced by (7.46%) showed a good improvement by coating aggregates with plastic.
- In modified bitumen following were observed:
 - Penetration value – decreased by 75 mm – Cannot be used in cold climate regions (higher penetration grade is needed) but in warmer regions it can be used.
 - Ductility value – decreased by 15.5 mm – low ductility value results in cracks
 - Softening point increased by 2.2 °C – suitable in warmer regions
 - Elastic recovery was only 8 %.
- Heating required was much in case of modified bitumen than in case of coating aggregate with BMPW.

- So, its better to use Plastic coated aggregates than using it as a modifier in bitumen. There by we can provide strong, durable and eco-friendly roads – which relieve the earth from all type of plastic-waste.

CONCLUSIONS

From this study it was able to study and know the changes in characteristics of plastic coated aggregate and modified bitumen. Thereby best method for using Biomedical Plastic Waste in aggregates was found out. So, that a method was obtained for the safe disposal off BMW by using in pavement construction. Thus the quantity of Bitumen needed can be reduced to an extent, thereby bringing down costs of construction and maintenance of Pavement. By this study we can provide strong, durable and eco-friendly roads – which relieve the earth from all type of plastic-waste.

The Future Scope of this study are as follows:

- Bituminous mix analysis needed to be done so that better comparison between plastic coated aggregate and modified bitumen can be made.
- Plastic modified bitumen tests such as separation test, Fraass breaking point test, complex modulus test and sensitivity test can also be conducted so that the variation in properties of modified bitumen can be studied clearly.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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