Characterisation of Waste Plastic in Flexible Pavem

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Abstract - The quantum of plastic waste in municipal solid waste (MSW) is increasing due to increase in population, urbanization, development activities and changes in life style which leading widespread littering on the landscape. Thus disposal of waste plastic is a menace and 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. This waste plastic partially replaced the conventional material to improve desired mechanical characteristics for particular road mix. In the present paper developed techniques to use plastic waste for construction purpose of roads and flexible pavements has reviewed. In conventional road making process bitumen is used as binder. Such bitumen can be modified with waste plastic pieces and bitumen mix is made which can be used as a top layer coat of flexible pavement. This waste plastic modified bitumen mix show better binding property, stability, density and more resistant to water.

INTRODUCTION

Plastic have become part of our today's lifestyle. It is used for packaging, for protecting, serving purpose, & even discharging all types of goods. With the industrial mass production of goods and plastic would be a cheaper and good constituent. Using of plastic non-biodegradable (Subjected to recent studies, plastics can stay for as long as 4200 years) product is growing speedily and leads problem in disposal of plastic waste. Now a day, plastic wastes have been considered in pavement construction with great interest in developing countries such as India. The use of these materials in road construction is totally based on economic, technical and ecological point of view also. India has a large network of metro cities located in different parts of the country and many more are planned for future. Several metric tons plastic wastes are produced every year in India.Keeping in mind that the need for bulk use of these plastic wastes in India develops specifications to enhance the use of these wastes in pavement construction, in which higher economic returns also possible.

LITERATURE REVIEW

A.Boomika, M.A.Naveen, J.DanielRichard, A.Mythili, R.Vetturayasudharsan, (2017)

A nation's development mainly depends on the development of transportation of the country. As flexible pavement is majorly used in India, it is important that steps has to be taken to increase the life of the bituminous pavements. Flexible pavement is often subjected to problems like rutting, cracking, and other failures due to repeated traffic loads. In this project, we have used the waste

Vikas R Agarwal, Saurav Anand Agarwal, and Nikhil Kale (2016)

Stated the to provide low cost roads and environment friendly roads by proper usage of waste plastic in hot bitumen mix to improve pavement performance. Here Bitumen modifier is plastic to improve properties of mix, and the pavement constructed with modified bitumen mix prove to be better performed than conventional bituminous mix. Also they are found to be less affinity towards water and less stripping. Also it is stated that use higher percentage of plastic reduces Bitumen percentage by 10 also improves strength.

Athira R Prasad, Dr Sowmya N J, (2015)

The use of waste materials like plastics and rubber in road construction is being increasingly encouraged so as to reduce environmental impact. Plastics and rubbers are one of them. The plastic waste quantity in municipal solid waste is increasing due to increase in population and changes in life style. Similarly, most tires, especially those fitted to motor vehicles, are manufactured from synthetic rubber. Disposal of both is a serious problem. At the same time, continuous increase in number of vehicles emphasizes on need of roads with better quality and engineering design. This waste plastic and rubber can be used to partially replace the conventional material which is bitumen to improve desired mechanical characteristics for particular road mix. . In the present study, a comparison is carried out between use of waste plastic like PET bottles and crumb rubber (3%, 4.5%,6%,7.5%,9%by weight of bitumen) in bitumen concrete mixes to analyze which has better ability to modify bitumen so as to use it for road construction.

Yash Menaria, Rupal Sankhla (2015) stated that polyethylene, polypropylene, and polystyrene are the main constituents or source of waste plastics. Where the softening point of this type of material ranges from 120˚C - 160˚C. These heated materials will do not generate any poisonous gases on heating but it has good laminating property when spewed over the hot aggregate at 160˚C. the importance of this study shows reduction in the cost of construction as waste plastic used and increase in durability and strength is observed, the combination of plastic binding with aggregates provide good stability.

OBJECTIVE OF THE STUDY

GENERAL OBJECTIVES

The main objective of this experimental investigation is to provide tools to evaluate and to improve the properties of pavement using waste plastic such that it may be more confidently employed in roadways and driveways etc.

SPECIFIC OBJECTIVES

Keeping in view of the above point the following specific objectives have been set for study.

To study on polymer modified asphalt mixtures to evaluate engineering properties using marshal stability.

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To study basic properties of aggregates and plain bitumen.

To study the strength and stability characters of BC mix for 80/100 grade bitumen.

To study the effect of waste plastic on strength and stability characteristics of BC mix.

To study characteristics of bitumen.

Study on performance of Stability characters of BC mix.

To study Strength characteristics of waste plastics

Strength characteristics of BC mix

SIGNIFICANCE OF THE STUDY

There are many significance of present study as follows.

To develop recycled plastics with enhanced physical and mechanical properties and that are strong, chemically inert and environmental-friendly.

To study the effects of type of reused plastics, content of recycled plastics as replacement of aggregate.

To select the optimum mix or mixes for use in the road by comparing and standing various concrete mixes built on the performance measures in physical properties (hardened density, water absorption etc..) and mechanical performance (compressive and flexural strength, etc..).

Increase the strength and performance of pavement.

Creating jobs for rag pickers.

Develop a technology, which is eco-friendly.

SCOPE OF THE STUDY

The scope of the study is to evaluate the performance of Plastic tar flexible pavement road constructed using plastic coated aggregate bitumen mix.

THE BASIC MATERIALS

Aggregate

Bitumen

Waste plastic

AGGREGATES

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often a bye product of other manufacturing industries.

DESIRABLE PROPERTIES

Strength

The aggregates used in top layers are subjected to

Stress action due to traffic wheel load,

Wear and tear,

Crushing.

For a high quality pavement, the aggregates should posses high resistance to crushing, and to withstand the stresses due to traffic wheel load.

Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyred vehicles moves over the aggregates exposed at the top surface.

Toughness

Resistance of the aggregates to impact is termed as toughness. Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyred

wheels from one particle to another at different levels causes severe impact on the aggregates.

Shape of aggregates

Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

Adhesion with bitumen

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped off in presence of water.

Durability

The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action

Freedom from deleterious particles

Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material. Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, chert, silt and other organic impurities

BITUMEN

Bitumen is a sticky, black 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. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulphur, 1% nitrogen, 1% oxygen and 2000 ppm metals. Also bitumen is Mixture of about 300 - 2000 chemical components, with an average of around 500 - 700. It is the heaviest fraction of crude oil, the one with highest boiling point (525º).

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

Grade: 30/40; Grade: 60/70; Grade: 80/100

The desirable property of bitumen for pavement

Good cohesive and adhesive binding property.

Water repellant property.

It is its thermoplastic nature (stiff when cold liquid when hot), that makes bitumen so useful.)

PLASTIC

Why Waste plastic?

As a Binder and Modifier

Soften at around 130℃.

No gas evolution in the temperature range of 130℃-180℃.

Have a binding property hence used as a binder.

Can also be mixed with binder like bitumen to enhance their binding property.

Safe & Hygienic – Inert and Chemical Resistance

Light Weight & Non-Breakability

Excellent Barrier Properties - Enhancing Shelf-life

Superior Impact Resistance

Transparency as well as Opacity

Lower Fuel Consumption and Product Loss during Transportation Consumption of plastic

PLASTIC CONSUMPTION	
GLOBAL	180 Million Tonnes – 28 Kg Per capita
INDIA	6.5 Million Tonnes 6.5 Kg Per capita

Drawbacks of Bitumen

Temperature Effect: At high temperature bleeding of road occurs reducing performance of road.

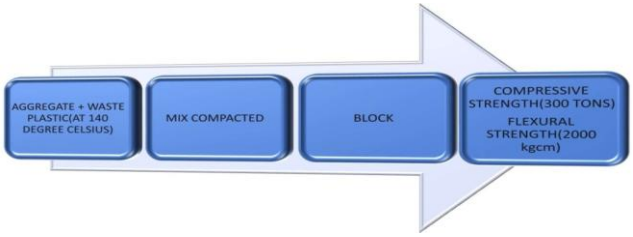
Oxidation Effect: Due to oxidation bitumen may led to cracking & crazing phenomenon.

Water Effect: Due to water, bitumen strips off from the aggregate forming pothole on roads as being water repellent material. Reducing life of roads.

High Cost - Being petroleum product it costs much higher.

Waste plastic as a binder

The molten plastics waste exhibits good binding property. Various raw materials like granite stone, ceramics etc. were coated with plastics and then molded into a stable product. On cooling, it was tested for compression and bending strengths. Dr R Vasudevan found that the values of the compression strength and bending strength increases with above formulation shows that the plastics can be used as a binder.



PCA AND PCA WITH BITUMEN

Characteristics of plastic-coated aggregate (used for flexible pavement)

Moisture Absorption and Void Measurement

For the flexible pavement, hot stone aggregate (170℃) is mixed with hot bitumen (160℃) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and viscoelastic property. The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

Soundness Test

Soundness test is intended to study the resistance of aggregate to weathering action. The weight loss is attributed to the poor quality of the aggregate. The plastic-coated aggregate, did not show any weight loss, thus conforming the improvement in the quality of the aggregate.

Aggregated Impact Value

A study on the effect of plastic coating was extended to study on the aggregate impact value. Aggregate was coated with 1% & 2% plastics by weight and the plastic-coated aggregate was submitted to Aggregate Impact Value test and the values were compared with values for non coated aggregate.

Los Angel's Abrasion Test

The repeated movement of the vehicle with iron wheeled or rubber tire will produce some wear and tear over the surface of the pavement. This wear and tear percentage of an aggregate is determined with the help of Los Angeles abrasion study. Under this study the percentage of wear and tear values of the plastic-coated aggregate is found to be in decreasing order with respect to the percentage of plastics. When the Los Angeles abrasion value of plain aggregate value is compared with the Plastic- coated aggregate the values are less for polymer coated aggregate.

IMPROVED CHARACTERISTICS OF PLASTIC-COATED AGGREGATE (PCA).

By using the waste plastic as coated material to the aggregate, properties of aggregate were improved with different percentage of waste plastics.

It showed better values than conventional aggregates. By this the poor quality of aggregate will be improved by using plastic as a modifier and can be used in construction.

The water absorption property has decreased and by this their will be less porosity and provide better resistance to water and stagnation.

Plastic coated aggregate exhibit good nature in abrasive charge and in impact test

PLASTICS COATED AGGREGATE WITH BITUMEN

The hot plastic coated aggregate was mixed with 80/100 bitumen at 170º. The bitumen polymer coated aggregate mix was subjected to test like stripping test, bitumen extraction test and Marshall Value determination test.

% of Plastics	Moisture Absorption	Soundness	Voids	Aggregate Crushing Test	Los Angeles Abrasion	Aggregate Impact Value
Nil	4%	5%	4%	18%	22.8%	20.85%
1%	1%	NIL	2.2%	19%	19.2%	19.20
2%	1%	NIL	1%	17%	17.7%	18.50
3%	0.5%	NIL	NIL	NA	NA	NA
5%	0.35%	NIL	NIL	NA	NA	NA
10%	0.12	NIL	NIL	NA	NA	NA

EXPERIMENTAL ANALYSIS

Marshall stability

Marshall stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/minute. The test load is increased until it reaches a maximum. Beyond that, when the load just starts to decrease, the loading is ended and the maximum load (i.e. Marshall stability) is recorded. During the loading test, dial gauge is attached which measures the specimen's plastic flow owing to the applied load. The flow value refers to the vertical deformation when the maximum load is reached

% of Plastics Waste added in the mix	% of Bitumen added in the mix	Marshall Stability Value (kg)	Flow value (mm)	M/Q (kg/mm)
0.00	5	1050	4.10	304
0.25	5	1910	4.70	406
0.50	5	2450	4.75	515

Observations:

The use of a PCA increase the MSV of the mix

As the percentage of the waste coated increase the MSV is also increased

Higher percentage of plastic result in lesser compatibility with bitumen and lesser bonding resulting in lower MSV.

The use of PP and PE also gives better MSV results.

The waste plastic available as foams or films can also be used.

The use of optimum percentage of plastics was arrived using mathematical modelling and it is found to be 10% of bitumen used.

The flow value and the void films with bitumen are within the tolerance value.

The MSV of PCA – bitumen mix is compared with PMB mix. It was observed that the value of the PCA bitumen mix are 50% to 60% higher than that of the PMB mix, showing that the binding is higher in the case of PCA bitumen mix.

CONCLUSION

In this chapter, a detailed conclusion for the discussed results of the various characteristics studies of the PMB is given. The conclusion mainly focuses on whether the polymer chosen can be used for the modification of bitumen.

Process – both the dry and the wet process can be effectively used for the preparation of PMB. The advantage of using dry process is that it is in situ and can be used easily with available techniques. In dry process, the PMB formed is in situ and its structure is imaginary in nature and also in dry process, with waste plastics modification only is tried. But, in wet process, the formation of PMB is very effective.

Softening Point- As per the observations on softening point, the PMB shows high value compared with the unmodified bitumen. This observation is concludes that PMB can be used in pavement applications. The increase in softening point will also increase the resistance against rutting- a permanent deformation of flexible pavement (Noor et al 2011). Hence it is concluded that, when PMB shows higher softening point, it indicates lower temperature susceptibility (Mathews &Rao 2006) and it makes the bitumen to be used in higher temperate regions.

Penetration Point - The results of Penetration values of PMBs suggests that, when the PV decreases, the stiffness of the polymer modified bitumen increases. This results in the increase of the load bearing capacity of the sample. The observations concludes that the increase in stiffness will make the PMB less temperature susceptibility and less sensitive towards permanent deformations like rutting and ravelling.

Penetration index- From the present study it is concluded that the PI values of all the PMBs are above standard value due to the increased and decreased values of SP and PV respectively. Both higher SP and lower PV indicate the increase in the stiffness of the PMB which infers

PMB with less temperature susceptible and increased resistance towards permanent deformations.

Ductility – Form the observed ductility values of all PMB except the WP it is concluded that the addition of polymer does not impart notable changes in the ductile nature of the PMB. Hence it is concluded that the polymers impart elasticity to the bitumen and make it elastic enough for pulling even at high percentages. But in the case of WP modified bitumen there is a different observation, showing poor ductile nature even at 5 % modification. This behavior is due to heterogeneous nature of PMB in which the plastic will start separating from the bitumen layer and form two different phases.

Marshall Stability Test- From the results obtained, it is concluded that the MSV of the PMB is more when compared with the MSV of unmodified bitumen. The values also suggest that there is an increase in the MSV of all the PMBs with respect to their increment in the percentage. The maximum value of MSV is obtained for Waste plastics PMB- 2400 Kg at 7

%. The value of all the PMBs at 7 % is more than 2000 kg which is a very positive result. The normal MSV for a road mix is 1000 kg as per IRC standards. Thus, it is concluded

that the addition of polymer to the bitumen increases the MSV.

Viscosity studies of PMB concludes that the observed value shows that the polymer mixed with the bitumen plays a major role in changing the viscous nature of the unmodified bitumen. Non Newtonian behavior is observed in all the PMBs. This behavior is a result of the influence of the polymer in the bitumen constituents. Polymer modification increases the dynamic viscosity of the binder at low temperature regions and decreases the kinematic viscosity at high temperature regions thus the improved viscous properties of the PMB exhibits low thermal stability at the service temperatures and decreased viscosity at high temperatures provides easy processing and application of PMB in pavement. In this part it is concluded that the resistance to permanent deformations of the pavement is reduced due to the improvement in the viscous properties of the modified bitumen.

FTIR study of all PMB concludes that the bitumen mainly consists of Saturates, Aromatics Resins, and Asphaltenes. When the bitumen is functioning in the pavements, hydrocarbon groups present in the chain start oxidizing due to the interaction of bitumen with the atmospheric oxygen and moisture. This reaction results in the decomposition of the continuous chain which reduces the binding nature of bitumen, as a result of oxidation. In the case of PMBs, polymers influence the basic chain of the bitumen by imparting changes as discussed. This can prevent oxidations in the PMB due to the oxidizing stability nature of the polymers. Hence it is concluded that the PMB prepared can perform for a longer period in the pavement by reducing the extent of oxidation of the hydrocarbons present in the bitumen chain.

The aim of developing a PMB is to make the binder to perform well at all workable temperature levels with different loading parameters. The present study on PMB shows positive results in their empirical tests like SP, PV and PI. This concludes that the PMB shows less temperature susceptibility and lower deformation due to cracking. The thermal studies concluded that the modified binder shows an increase in the temperature stability and decreased crystalline nature of the PMB which results in decreasing the extent of permanent deformations like rutting, fatigue cracking and low temperature cracking. FTIR study is quiet interesting study when compared with other studies. IR spectrum obtained show that there is a change in the chemical structure of the bitumen chain and further studies in this area will be much interested in finding the molecular level rearrangements present in the bitumen composition. The viscous study also shows improved results and the resistance to permanent deformations of the pavement is reduced, due to the improvement in the viscous properties of the modified bitumen. The morphological study also supports the conclusion with a clear morphological picture of the bitumen polymer blend and its distribution without any phase separations.

FUTURE SCOPE

The characterization methods of the PMB are needed to be normalized since the PMB behaves differently when compared with the unmodified bitumen. Laboratory findings need to be carried out to the field of application

The present study is mainly focuses on the binder nature and discusses less about the mixer properties. Studies on enhancing the adhesion of the binder with the aggregate is need to be studied.

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