An Experimental Investigation on Flexible Pavement with Partial Replacement of Bitumen by Using Waste Plastic (Biomedical Wastes and Bags)

B.Surya[#1], R.Praksh[#2], S.Ranjithkumar[#3], S.M.Saravanan[@4], Dr.M.Sivaraja[*5]
[#1,#2,#3]*UG Scholar, N.S.N. College of Engineering and Technology, Karur, Tamilnadu, India*
[@4]*HoD/Civil, N.S.N. College of Engineering and Technology, Karur, Tamilnadu, India*
[*5]*Principal, N.S.N. College of Engineering and Technology, Karur, Tamilnadu, India*

Abstract: Nowadays the major problem is dumping of bio-medical waste in Tamil Nadu by Kerala government. It penetrates into the soil and affects the surrounding groundwater and also creates health issues like dengue fever to the surrounding people and improper management of these wastes is hazardous and dangerous to human health and ecological system. To save our environment from this problem we make use of bio-medical waste plastic in bitumen pavement. This project involves the utilization of waste plastic in bituminous mixes to solving disposal problems and environmental pollution. That takes a proactive approach to minimize the effect of rutting, cracking and another failure in the flexible pavement. Waste plastic materials can improve desired properties of bituminous mix for repair and construction of flexible pavements. The plastic waste which is cleaned and cut into a size such that it passes through 2.3mm sieve. The plastic waste when mixed with bitumen improves desired mechanical properties in particular road mix. Bitumen is used as a binding material in construction of flexible pavement, when waste plastic is mixed with bitumen it increases its water resistivity capacity and stability. Laboratory test has shown Plastic mix bitumen act as a better binding material. Marshal stability test is considered to simulate with field conditions. The objective of this work is to suggest the optimum percentage of bitumen that can be replaced by plastic waste. The approach is to find the replacement of the conventional material used in flexible pavement.

INTRODUCTION

Generation of waste plastic is increased day by day. Mainly the biomedical waste is created major problem to the society. The bio-medical wastes enumerate the huge amount of toxic agent from the syringes to the environment. Because the syringes contain the blood with the micro level it is not visible to the naked eye. The micro-organism is multiple into huge amount by the action of bacteria. The microbes a lot of diseases to the human beings. The microbes are also penetrated into the soil and spread into groundwater and affect the properties of groundwater. Generally, we are thinking the groundwater is pure which doesn't affect form any pollution but it is wrong. Because the soil does not have the property to control and filter the microbes due to this the many of the diseases are spread into the environment to overcome this entire problem we planned to reuse of biomedical waste plastic and waste plastic bags in bituminous mixes. The waste plastic has the good binding properties in its molten state. It has helped in finding out a method of safe disposal of waste plastic. Generally, the plastics are considerably non-biodegradable so that can be used as a modifier in bitumen and to enhance their strength. New methods of pavement design are being developed to improve the performance of roads. New materials are being used to replace the old ones to improve the durability, strength, aesthetics, and economy. One of the promising ways is to use plastics in bituminous road construction industry. Initially, the shredded plastic waste is mixed in hot aggregate and the plastic modified mix is prepared using 10%, 15%, 20%, 25%, and 30%plastic by weight of bitumen. The mix proportion is obtained from highway department. The variation Marshall Properties for the mixes containing different amount of plastic waste are studied.

MATERIAL USED

Bitumen

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water prolongs properties and relatively low cost. Bituminous materials consist of bitumen which is a black or dark-colored solid or viscous cementations substances consists chiey high molecular weight hydrocarbons derived from the distillation of petroleum or natural asphalt has adhesive properties, and is soluble in carbon disulfide. Tars

are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

Aggregate

Crushed stone obtained by crushing of hard granite that could pass through IS sieve and contained only so much of fine material as permitted by the specification alone could be procured. 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 by-product of other manufacturing industries.

Filler

The material which passes through the sieve is termed as fine filler. Usually, the crushed aggregate is used as filler. The filler used for the experimental works was locally procured and conformed to grading zone II. Sieve Analysis of the filler was carried out in the laboratory. The filler was first sieved through 4.75mm sieve to remove any particle greater than 4.75 mm sieve and then was washed to remove the dust.

Waste plastic Bags

The use of plastic materials such as carry bags cups, etc. is constantly increasing. The consumption of plastics has increased from 4000 tons/annum (1990) to 4 million tons/annum (2001) and it is expected to rise 8 million tons/annum during the year 2009. Nearly 50 to 60% of the total plastics are consumed for packing. Once used plastic materials are thrown out. They do not undergo bio-decomposition. Hence, they are either land filled or incinerated. Both are not eco-friendly processes as they pollute the land and the air. Biomedical waste, also known as infectious waste or medical waste is defined as solid waste generated during the diagnosis, testing, treatment, research or production of biological products for humans or animals. Biomedical waste includes syringes, live vaccines, laboratory samples, body parts, bodily fluids and waste, sharp needles, cultures, and lancets.

PRELIMINARY INVESTIGATION

TESTS ON BITUMEN

Penetration test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25 C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred

Result

The penetration value of sample bitumen is 23.5mm

Ductility test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. The dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured into the mold assembly placed on a plate. These samples with molds are cooled in the air and then in a water bath at 27^{o} C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mold with an assembly containing sample is kept in the water bath of the ductility machine for about 90 minutes. The sides of the molds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of a breaking of the thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, a rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS.

Result: The Ductility value of sample bitumen is 64cm

Flash and fire point test

At high temperatures depending upon the grades of bitumen, materials leave out volatiles. And these volatiles catch fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade. BIS defined the flashpoint as the temperature at which the vapor of bitumen momentarily catches fire in the form of flash under specified test conditions. The fire point is defined as the lowest temperature under specified test conditions at which the bituminous material gets ignited and burns.

Result: The temperature at which the flame application that causes a bright flash 177.5°c and temperature at which the sample catches fire 220°c.

Softening point test Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5^0C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature. Trial 1 2 Temperature when the ball touches bottom, °c 47 48.5 Average 47.75°c Softening point of bitumen 47.75°c

Result

The Softening value of sample bitumen is 47.75°c

TESTS ON AGGREGATE

Specific gravity

The specific gravity is important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Initially dry the pycnometer and weigh it with its cap (W1) and then take about 200gm of oven dried aggregate passing through 10mm sieve into the pycnometer and weigh again (W2) and add sufficient de-aired water to cover the aggregate and screw on the cap. After that shake the pycnometer well and remove entrapped air if any. After the air has been removed, fill the pycnometer with water completely and then thoroughly dry the pycnometer from outside and weigh it (W3). clean the pycnometer by washing thoroughly and fill the cleaned pycnometer completely with water up to its top with cap screw on and weigh the pycnometer after drying it on the outside thoroughly (W4).

Calculation Dry weight of pycnometer (W1) = 0.635 kg 200g coarse aggregate + dry weight of pycnometer (W2) = 0.835 kg Pycnometer + coarse aggregate + water (W3) = 1.570 kg Empty pycnometer + water (W4) = 1.445 kg

Specific gravity (G) = (W3-W4)/ ((W2-W1)-(W4-W3)) = (1.570-0.635)/((0.835-0.635)-(1.445-1.570)) = 2.5

Abrasion test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (IS: 2386 part-IV). The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as the abrasive charge. After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

Result: The average value of los angles abrasion test is 28.3%

Impact value the aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal diameter 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as a percentage of aggregates passing sieve (W1) to the total weight of the sample (W2).

Calculation Empty weight of cylinder = 1.875 kg Weight of aggregate in cylinder (W1) = 2.475 kg 2.36mm retained (W2) = 0.485 kg Aggregate impact value = (W1/W2) ×100 = (0.485/2.475)×100 = 19.59% Result The impact value of aggregate is 19.59%

MIX DESIGN

MIX PROPORTION

12.5mm aggregate - 70g

10mm aggregate - 312g

4.7mm aggregate - 84g

2.6mm aggregate - 204g

Filler - 480g

Bitumen - 70g

DETAILS OF MIX PROPORTIONS

The following represents the details of mix proportion for the conventional mix, conventional mix with 25%, 30%, 35%, and 40% replacement of plastic waste.

The specimen is in the size of the cylinder with dimension (7.5 × 10) cm. The size of the mould is the standard size which is used in the Marshall Stability test. In this project totally 15 cylinders are made

QUANTITY OF MATERIAL USED

The quantities of materials like Bitumen, Aggregate, and Filler are required for the casting 3 cylinders in each mixing ratio are clearly explained

CASTING

The strength of the pavement was determined by using Marshall Stability test machine with the cylinder of size 7.5cm × 10cm. Initially, oil applied in the mould to ease of demoulding before casting.

MIXING

Thorough mixing of materials is essential for the production of uniform course. The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency. The mixing was done by hand mixing. In which initially the Bitumen is heated to the temperature 120^{o}c to 140^{o}c then the aggregate, filler, and plastic waste are mixed thoroughly with adequate temperature and mix them properly for a good mixture.

CASTING AND COMPACTION

After mixing, the molds are filled immediately by pouring the bituminous mixture inside manually by using a trowel with three layers. Compaction process is adopted for expelling the entrapped air from the mixture. In the process of mixing, transporting and placing of concrete air is likely to get entrapped. Compaction is done here is manual with the hammer of weight 4.54 kg in the way of dispersing the homogeneous mix to avoid entrapment of air. 75 blows on each side of the mould by using the hammer of weight 4.54 kg dropped should be vertically from a height of 45.7 cm.

During compaction, the strokes should be distributed in a surface of the mixture, and should not forcibly strike the bottom of the mould. After the top layer has been compacted, a strike off the bar is used to strike out the excess.

DEMOULDING

The cylinder specimens are demoulded after 24 hours from the process of molding. Then the process must be delayed for another 24 hours care should be taken not to damage the specimen during the process because, if any damage is caused, the strength of the concrete may get reduced. During the process of demoulding, the bearing wall should always be kept between the extracting tools. Then extract the mould by using extractor and collar kidding with a hammer. After demoulding, the specimen is marked with a legible identification, on any of the faces by using paint.

CURING

After demoulding of the specimen, the mould should be kept in the water having the temperature of 60^{o}c for 20 minutes for curing take place with an identification mark

MARSHALL STABILITY RESULT ANALYSIS

The suitably designed bituminous mix will withstand heavy traffic loads under adverse climatic conditions and also fulfill the requirement of structural and pavement surface characteristics. The objective of the design of bituminous mix is to determine an economical blend through several trial mixes. The gradation of aggregate and the corresponding binder content should be such that the resultant mix should satisfy the following conditions. (i) Sufficient binder to ensure a durable pavement by providing a waterproofing coating on the aggregate particles and binding them together under suitable compaction. (ii) Sufficient stability for providing resistance to deformation under sustained or repeated loads. This resistance in the mixture is obtained from aggregate interlocking and cohesion which generally develops due to a binder in the mix. (iii) Sufficient flexibility to withstand deflection and bending without cracking. To obtain desired flexibility, it is necessary to have proper amount and grade of bitumen. (iv) Sufficient voids in the total compacted mix to provide space for additional compaction under traffic loading. (v) Sufficient workability for an

efficient construction operation in laying the paving mixture. There are three principal bituminous mix design methods in general use. They are Marshall Method, Hveem Method and Super pave Method. Marshall Mix design is the widely used method throughout India. In this method load is applied to a cylindrical specimen of bituminous mix and the sample is monitored till its failure as specified in the ASTM standard (ASTM D1559). For the present work, the bituminous mix is designed using the Marshall Method and arrived at the volumetric properties.

MARSHALL MIX DESIGN

This test procedure is used in designing and evaluating bituminous paving mixes and is extensively used in routine test programmers for the paving jobs. There are two major features of the Marshall method of designing mixes namely, density – voids analysis and stability – flow test. Strength is measured in terms of the 'Marshall's Stability' of the mix following the specification ASTM D 1559 (2004), which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60°C. In this test compressive loading was applied to the specimen at the rate of 50.8 mm/min till it was broken. The temperature 60°C represents the weakest condition for a bituminous pavement. The flexibility is measured in terms of the 'flow value' which is measured by the change in diameter of the sample in the direction of load applied between the start of loading and at the time of maximum load. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The associated plastic flow of specimen at material failure is called flow value. The density-voids analysis are done using the volumetric properties of the mix, which will be described in the following subsections.

RESULT ANALYSIS

It is evident that the presence of plastic waste in the SMA mixtures effectively improves the stability values, which will result in an improvement of mixture toughness. This result indicates that the mixture using plastic waste would result in higher performance than using the control mixture. Variation of Marshall Stability and flow value with different plastic waste contents indicates that the stability of plastic waste stabilized mixtures increases initially, reaches a maximum value and then decreases with increasing plastic waste content. The bituminous mixture is an inconsistent, non-uniform, multi-phased composite material consisting of aggregates and sticky bitumen. Therefore, excessive plastic wastes may not disperse uniformly, while coagulate together to form weak points inside the mixture. As a result, stability decreases at high plastic waste contents.

CONCLUSION

From the experimental test results, the partial replacement of bitumen on the flexible pavement by using waste plastic bags and biomedical waste plastic gives the better performance in workability and strength properties which is found out through Marshall Stability test. If we are applying this in real life surely the biomedical waste those which affect the problem to the environment like impure drinking water, health issues, etc.., will automatically reduce. Using of waste plastic in flexible pavements shows the good result when compared with conventional flexible pavements. The optimum use of plastic can be 15%, 20%, 25% and 30% of bitumen based on Marshal Stability test. This has added more value in minimizing the disposal of plastic waste bags and biomedical waste plastic are the eco friendly technique and also minimizing the emission of toxic reagent and spreading of bacteria from the biomedical waste. The flow value goes increasing and the % air voids in the mix decrease continuously with the addition of the plastic waste in the mix. The uses of waste plastics in the manufacture of roads help to consume a lot of waste plastics. Through this investigation, it gives the better solution to the problem occurs in Tamil Nadu. The dumping of biomedical waste in the environment will be minimized through this process. From the experimental analysis, it is concluded that plastic waste mix, which is 15%, 20%, 25%, and 30% replacement of Bitumen, is found to be the most preferable.

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