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AN EXPERIMENTAL STUDY OF WASTE TYRES IN ROAD CONSTRUCTION

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Abstract - *Roads make a crucial contribution to economic development and growth which brings important social benefits. They are of vital importance in order to make a nation grow and develop. In addition, providing access to employment, social, health and education services makes a road network is crucial in fighting against poverty. The importance of roadways enhances the growth rate of the vehicle which seems to be the backbone of a economically developing country. As a result, amount of waste tyres is also increasing. The increasing consumption of waste tire has generated severe problems such as environmental pollution and health hazards. The study focuses on the use of powdered- rubber as a replacement to the total weight of bitumen. The design period of highways and urban roads are expected to be 10 – 20 years but regrettably they fail due to heavy loading and distress even before their life span. To take away this problem, powdered-rubber obtained from shredding of scrap rubber can be used as a modifier. It would be used as a cheap and environmentally friendly modification process. The expectations of the study is to develop of bitumen with powdered-rubber that would minimize the cost of bitumen and providing better physical properties compared to the convention bitumen based on the tests were conducted.*

Key Words: *Keywords – Waste Tyre, Powdered Rubber , Modified Bitumen , Road Construction , Replacement to Bitumen.*

1. INTRODUCTION

This document is template. Rapid industrial and population increase has resulted in increasing the various types of waste material. Among the various waste materials generated this study encourages the use of powdered rubber obtained from waste tyres as a modifier. In India, over 15 million waste tires are generated annually. Not only are these tire mounds eyesores, they are also environmental and health hazards. Hazardous are tire fires, which pollute the air with large quantities of carbon only large scale methods to use waste tires are through burning for electric power generation production of cement in cement kilns, energy to run pulp and paper mills, and recycling at tires-to-energy facilities. In 1990, the Environmental Protection Agency (EPA) estimated that out of the 242 million waste tires generated that year, 78% of the tires were either stockpiled, a land filled or illegally dumped. While some states burn waste tires this is only a temporary solution because of the tires, in many case tend to float back up to the surface. land filling waste tires has also become more and more expensive as landfill space has decreased. It has been an established fact that normal bituminous course end up with the following problems:

i. increasing traffic on road / overloading of vehicles leading to undulations, rutting, cracking deformations, potholing, and shortening of the life of asphaltic pavements.

ii. High range of temperature causing pavements to become softer in summer and brittle in winter

iii. Rains/water causing extensive stripping problems in asphaltic pavements.

To overcome the above problems in the entire world it has become a regular practice to use modifier as additives to strengthen the asphalt for making long lasting asphalt mixes. This has been a very important development in the last 3 decades and has led not only to huge saving, but also its importance has been felt in countries where aggregates and asphalt are in short supply.

Rubber can be used as a modifier in a form of powder in bitumen to enhance its strength. Waste tire use for industrial application by burning emits Green House Gases and thereby contributes to global warming and climate change. Accidental fires caused in stockpiled sites can rage for months releasing toxic fumes. The oily residue left after tire fire is difficult to eliminate from the environment. According to a GOI report of "National Highways Development Project", road network of India is growing at an annual rate of 4% since 1951 while the vehicles are increasing at a much faster rate of around 12% per annum. This higher rate of increment of vehicles on the roads as compared to the rate of construction of roads, has resulted in the formation of transverse and longitudinal cracks, potholes and subgrade deformation in flexible pavement. Problem worsens due to inefficient maintenance of the pavement. Improvement in bituminous mix design can be one of the possible solutions to this problem. The benefits of modified asphalt can also be analyzed keeping financial aspect in mind.

II. EXPERIMENTAL METHODOLOGY A. Materials used

(a)Coarse Aggregates

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stress occurring to the wheel loads on the pavement and on the surface course they also have to resist wear due to abrasive action of traffic. Therefore the properties of the aggregates are of considerable significance to the highway engineers. In our present study we use aggregates of size less than 25 mm. The required aggregates sizes are chosen according to fulfill the gradation. This document may be used as a template for preparing your Transactions/Journal paper. You may type over sections of the document, cut and paste into it, and/or use mark up styles.

(b)Bitumen

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stress occurring to the wheel loads on the pavement and on the surface course they also have to resist wear due to abrasive action of traffic. Therefore the properties of the aggregates are of considerable significance to the highway engineers. In our present study we use aggregates of size less than 25 mm. The required aggregates sizes are chosen according to fulfill the gradation.

(c)Powdered Rubber

Powdered-rubber is recycled powder from an automotive and truck scrap tires. During the recycling process, steel and tire cord (fluff) are removed, leaving tire rubber with a granular consistency. Continued processing with a granulator or cracker mill, possibly with the aid of cryogenics or by mechanical means, reduces the size of the particles further. The particles are sized and classified based on various criteria including color. Powdered-rubber is sized by the screen or mesh through which it passes in the production process. Powdered-rubber of size lesser than 90micron mesh is used as a modifier in the present-day study.

Collection process

In case of large scale requirements, the powdered rubber is collected from tire refinery plants, where the End Life Tires (ELTs) are shredded into minor pieces which are in powder form. Powdered rubber is sized by the screen or mesh through which it passes after the buffering process.

Figure – 1: Buffering Machine

B. Material Testing

(1)Test on aggregate

Aggregates play a vital role in pavement construction. Aggregates influence, to a great extent, the load transfer capability of pavements. Hence it is essential that they should be thoroughly tested before using for construction They are tested for strength, toughness, hardness, shape and water absorption. . Not only that aggregates should also possess proper shape and size to make the pavement act monolithically.

Some the test that are carried out in order to decide the suitability of the aggregate for use in pavement construction follows:

(1.1) Crushing Test

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by IS:2386 part-IV and used to determine the crushing strength of aggregates crushing value provides a relative measure of resistance to crushing under gradually applied crushing load.

The test consists of subjecting the specimen of aggregate in standard load conditions.

Figure -2: Universal Testing Machine

Dry aggregates passing through 12.5 mm sieves and retained on 10mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tamped 25 times with a standard tamping rod. The test sample is weighed and placed in the test cylinder each layer being tamped again. The specimen is subjected to a compressive load of 40 ton gradually applied at the rate of 4 ton per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weigh of passing material (W2) is expressed as percentage of the weight of the total sample (W1) which is the aggregate testing value.

Aggregates passing through 12.5 mm and retaining on 10 mm sieve

Aggregate crushing value = (W1/W2) x 100

= 5.8%

Similarly; Aggregates passing through 10mm sieve and retained on 4.75 mm sieve

Aggregate crushing value = (W1/W2) x 100

= 13%

(Value obtained as per the test conducted)

A value less than 10 signifies an exceptionally strong aggregate while above 35 would normally be regarded as weak aggregate.

(1.2) Impact test

A 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 number of blows. Metal hammer of weight 13.5 to 14 kg is arranged to drop with a fall of 38 cm by vertical guides and the test specimen is subjected to15 number of blows. The crushed aggregate is allowed to pass through 2.36 mm sieve. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1).

Figure – 3: Impact Testing Machine

Aggregates passing through 12.5 mm and retaining on 10 mm sieve

Aggregate impact value = (W1/W2) x 100

= 25%

Similarly; Aggregates passing through 10mm sieve and retained on 4.75 mm sieve

Aggregate impact value = (W1/W2) x 100

= 34%

(Value obtained as per the test conducted) Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. For bituminous macadam the maximum permissible value is 35%. For Water bound macadam base courses the maximum permissible value defined by IRC is 40%.

(1.3) Specific gravity and water absorption

The specific gravity and water absorption of aggregates are 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. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used. One is apparent specific gravity and bulk specific gravity.

Aggregates passing through 12.5 mm and retaining on 10 mm sieve Specific gravity value = 2.57

Similarly; Aggregates passing through 10mm sieve and retained on 4.75 mm sieve

Specific gravity value = 2.67

(Value obtained as per the test conducted)

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9.

The difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a saturated surface dry condition, with all permeable voids filled with water. The difference of the above two is Mw.

Aggregates passing through 12.5 mm and retaining on 10 mm sieve

Water absorption = (MW/MD) x 100

= 1.41%

Similarly; Aggregates passing through 10mm sieve and retained on 4.75 mm sieve

Water absorption = (MW/MD) x 100

= 1.40%

(Value obtained as per the test conducted) Water absorption value ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

(2) Test on bitumen

(2.1) 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 and locking in any position.

Figure – 4: Penetrometer

The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25oC. It may be noted that penetration value is largely influenced by any inaccuracy specified temperature of 25oC. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, the size of the needle, weight placed on the needle and the test temperature. A grade of 60/70 bitumen means the penetration value is in the range 60 to 70 at standard test conditions.

(2.2) Softening point test

Softening point denotes the temperature at which the bitumen attains a particulars degree of softening under the specification of test. The test is conducted by 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 5oC per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below.

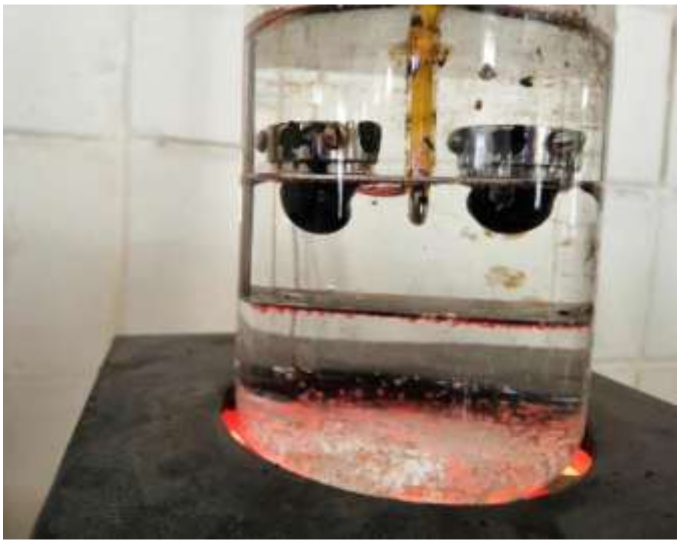

Figure – 5: Ring and Ball Apparatus

(2.3) 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.

Figure – 6: Ductility mould

The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples within the moulds are cooled in the air and then in the water bath at 270C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould containing with the assembly containing sample is kept in the water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of the breaking of thread is the ductility value which is reported in cm.

(2.4) Viscosity test

Viscosity denotes the fluid property of the bitumen and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting pavement mix. Low or high viscosity during compaction or mixing has been observed to result in lower stability values.

Figure – 7: Viscometer setup

At high viscosity, it resists the comp active effort and thereby resulting mix is heterogeneous, hence low stability values. And at low viscosity it will lubricate the aggregate particles. Orifice type viscometers are used to find the viscosity of liquid binders. The viscosity expressed in seconds is the time taken by the 50 ml bitumen to pass through the orifice of the cup, under standard test conditions and specified temperature.

C. Mixing

(1) Mixing of powdered rubber with bitumen

In preparing the modified binders, about 400 gm of the bitumen was heated to a fluid condition in a 1liter capacity metal container. For the blending of crumb rubber with bitumen it was heated to a temperature of 1600 C and then crumb rubber was added. For each mixture sample 0%, 5%, 10%, 15%, and 20% of crumb rubber by weight is used. The blend is mixed manually for about 3-4 minutes. The mixture is then heated to 160oC and the whole mass was stirred using a mechanical stirrer for about 50 minutes. Care is taken to maintain the temperature between 1600 C to 1700 C. The contents are gradually stirred for about 55 minutes. The modified bitumen is cooled to room temperature and suitably stored for testing.

D. Test on modified bitumen

The following test are conducted to note down the properties and performance of bituminous mix, in which four of them are already mentioned above in the test on bitumen.

(1) Penetration test

(2) Softening point test

(3) Ductility test

(4) Viscosity test

(5) Marshall stability test

Bituminous concrete mix is commonly designed by Marshall method. In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at a rate of 5 cm per minute. The test procedure is used in the design and evaluation of bituminous paving mixes. The test is extensively used in routine test programme for the paving jobs. There are mainly two features of the Marshall method of design mixes namely,

i. density-void analysis ii. stability-flow test

The Marshall stability of the bituminous mix specimen is defined as a maximum load carrying in kg at a standard test temperature of 60˚C when load is applied under specified test conditions.

The Flow value is the total deformation that the Marshall test specimen undergoes at the maximum load, expressed in mm units.

For performing the Marshall test, 1200 g of aggregate consisting of different aggregate fractions is taken. The aggregate sample is then heated to a temperature 175 to 190˚C and the bitumen to a temperature 121 to 138˚C. The mix was thoroughly mixed at a temperature 154 to 160˚C and was placed in a Marshall mould preheated in an oven. Collar is placed and specimen is compacted by a rammer with 75 blows. The prepared specimen was allowed to cool at room temperature for 20 to 25 minute. By using a mechanical sample extractor the specimen was extracted from the mould and the dimensions of the specimen are measured. From these measurements the volume of the specimen was calculated and also weight of water is determined. The Marshall test was then conducted and the load and the flow values at failure were recorded. The conventional Marshall graphs were plotted and the optimum bitumen content was determined.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

(1) Penetration test

The experimental result on bitumen modified by the addition of crumb rubber at 5%,10%,15% and 20% of the weight of the bitumen.

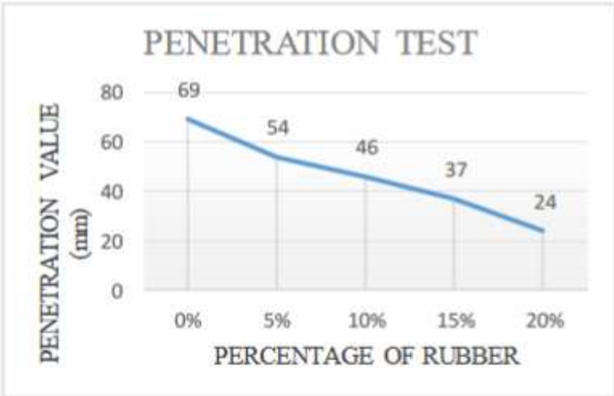

Chart – 1: Variation in penetration value

It is observed that penetration value decreases with the addition of rubber-content. Bitumen with lower penetration value makes harder grade of bitumen which provides additional strength and to the pavement and protects it from water damage.

(2) Softening point test

The experimental result on bitumen modified by the addition of crumb rubber at 5%,10%,15% and 20% of the weight of the bitumen.

It is observed that softening point increases gradually as the rubber-content increases. The softening points of bitumen are almost linear with the addition of crumb-rubber. This shows that the bitumen become less susceptible to temperature changes as content of crumb-rubber waste was increased.

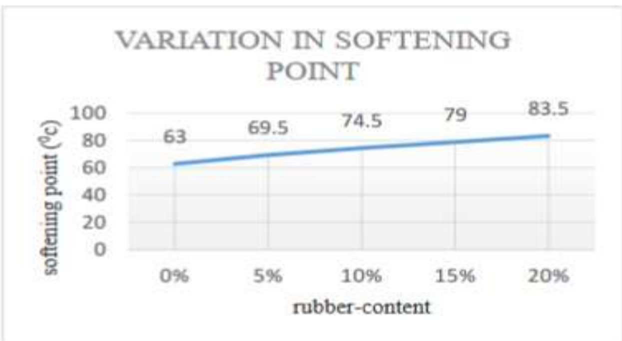

Chart – 2: Variation in softening point

(3) Ductility test

The experimental result on bitumen modified by the addition of crumb rubber at 5%,10%,15% and 20% of the weight of the bitumen is represented by the following graph.

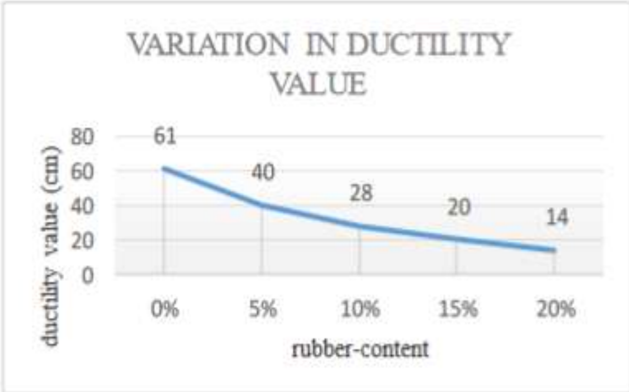

Chart – 3: Variation in ductility value

The ductility value decreases as the rubber content increases.

(4) Viscosity test

Viscosity test was done for normal bitumen and modified bitumen with 0%, 5%, 10%, 15% and 20% of rubber-content. There is a parallel increase between rubber-content and viscosity of bitumen. Addition of rubber makes the bitumen more viscous and harden, which would be helpful in obtaining stiffer bitumen asphalt.

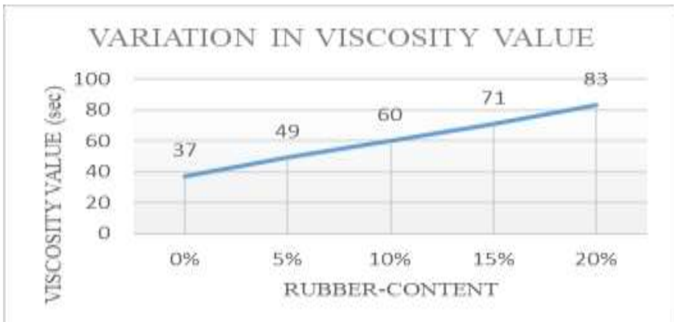

Chart – 4: Variation in viscosity value

(5) Marshall stability test

Here stability value increases with bitumen content initially and then decreases. Maximum stability value at 0% modifier is obtained at 5 % bitumen content (OBC).

The obtained maximum stability value is 19.47 kN. The Marshall stability value increases as the rubber content increases up to 20% modifier. Thus the maximum stability is obtained at 20% modifier which is the optimum modifier content. The maximum stability obtained is 23.44 kg which is 1.45 times greater than the plain bitumen.

V. CONCLUSION

The use of powdered-rubber as a modifier in bitumen can advance the properties of bitumen. The various studies conducted on the bitumen with different modifiers gives satisfactory results.

1. Penetration value test result shows that Penetration value decreased with the increased amount of the rubber waste added. Lower penetration value making a harder grade of asphalt, giving additional strength to the road and reduces water

damage. Lower Penetration thereby making a harder grade of asphalt, giving additional strength to the road and reduces water damage.

2. Softening point test shows that Softening Point increased with the increased amount of the rubber waste added. This showed that the bitumen becomes less susceptible to temperature changes as the content of rubber waste increased. Increase of Softening Point, thereby giving it protection against hot climatic conditions.

3. Ductility test result shows that the rubber waste added will harden the bitumen. The bitumen becomes more viscous and harden, which would be useful to obtain stiffer bitumen asphalt.

4. The biggest advantage of using rubberized bitumen is that the road life increases in comparison to the normal bitumen whereas the cost increase on the road.

5. In bituminous concrete pavement, powder- rubber gives the Marshall stability value of 23.44 kN for 5% bitumen by using 20% of powder rubber with bitumen mix which is greater than the Marshall stability value of conventional bitumen mix.

VI. ACKNOWLEDGEMENTS

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