Utilization of Waste Tyre Rubber – CRMB in the Construction of Economic Bituminous Road

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Abstract- *The purpose of this research is to discover a good mix proportion for the rubberized bitumen. Flexible pavements through bituminous surfacing are extensively used in India. The high traffic intensity in terms of commercial vehicles, more loading of trucks and significant variation in daily and seasonal temperature of the pavement has been accountable for earlier development of distress symptoms. Investigation in India and out of the country have exposed that the properties of bitumen and bituminous mixes can be improved to assemble the essential requirements. Use of Crumb Rubber i.e. the rubber obtain from the waste tires of vehicles, is used in the construction of flexible pavement. In the present study, a challenge has been made to use crumb rubber customized bitumen which is blended at specified temperatures. Marshall's mix design was carried out by varying the modified bitumen content at constant optimum rubber content and consequent tests have been performed to find out the different mix design characteristics and for conventional bitumen (VG-30) also. This has resulted in much improved characteristics when compared with directly run bitumen, due to improved strength of customized Bitumen it is one of the upcoming essential construction materials for flexible pavements. This study will have a positive impact on the environment as it will decrease the volume of rubber waste to be disposed of by burning and land filling. It will not only add value to rubber waste but will grow a technology, which is eco-friendly.*

Modified binders are modern construction materials with improved performance interrelated properties. The details of premium properties of modified binders for their use in flexible pavement are describe in this study. Modification of bitumen with crumb rubber reduces permanent deformation, increase resistance to thermal cracking besides endorsement adhesion of binder to aggregates. In this research we have used of crumb rubber powder in different proportions with VG-30 bitumen, aggregate and cement as a filler to perform necessary tests on all materials.

I. INTRODUCTION

The purpose of study is to give solution for utilization of rubber obtained from unused tires and improving the quality and properties of bitumen mix by addition of waste rubber in binder of bitumen work like VG-30 grade bitumen.

Following main things will be taken in to consideration during study.

1. To enhance in elastic recovery. Lower value of elastic recovery will cause cracking under stress.
2. To increase the Marshall stability of mix. lesser value of Marshall Stability will cause less durable & life of road surface
3. To increase the softening point of mix. Lower value of softening point will cause bleeding on road surface and decrease the strength of layer.
4. To decrease the penetration value of mix. Higher value of penetration cause lesser in their temperature inclination resistant characteristics.

Scope of work

This study will provide a stable bitumen mix, by which the bitumen work execute is more durable, less expensive, low maintenance cost and have longer span of life. This will also decrease the time and cost incurred in reconstruction of early failure of road layer due to conventional bitumen mix with the help of this study, we discover a solution to improve the important properties which are necessary for good quality of bitumen mix the main properties are as follows.

1. Reduced reflective cracks.
2. Enhanced adhesion with the aggregates.
3. Increase in elastic recovery, thereby improving resistance to cold climatic conditions and resistance to cracking below stress.
4. Improved age resistance properties - by adding rubber to the plain bitumen, the life of the bitumen increase because the ageing process slows down by the addition or rubber to the bitumen.
5. Does not require changes in road laying practices.
6. Highly durable and reliable economical solution for raveling, undulations, rutting, bleeding, shoving and potholes problems.

7. Lesser Penetration thereby making harder grade of asphalt, giving additional strength to the road and reduces water damage.
8. High stiffness modulus leading to advanced resistance to deformation and wear and tear.
9. Increase of Softening Point, thereby giving it protection against hot climatic conditions.
10. 10. Improved adhesion aggregates and binder in that way giving better strength, stability and longer life.
11. Higher cohesiveness & Improved fatigue resistance.

II. METHODOLOGY OF WORK

General

The Detailed laboratory experiments were conducted on all the material, namely aggregate, conventional bitumen (VG-30) and Crumb rubber modified bitumen to find out their individual properties i.e. impact, shape test, and Penetration, Softening point, specific gravity, Ductility. By using the Marshall Mix design characterization of conventional bituminous mix (VG-30) for bituminous concrete (BC) were carried out and comparison was prepared for conventional bitumen mix properties with crumb rubber modified bitumen. Finally the detailed analysis was carried out for development of strength for flexible pavement. Comparative assessment was prepared between conventional bituminous mix and Crumb rubber modified bituminous mix for bituminous concrete (BC). Materials used in the current investigation are described as follows:

a. VG-30 Bitumen: Bitumen is obtainable in a variety of types and grades. The grades of bitumen used for pavement construction work of roads and air-fields are called paving grades and that are used for water proofing of structures, industrial floors, etc. are called industrial grades. The paving bitumen existing in India is classified in two categories – A type from Assam petroleum and S-type from other sources. The common tests to evaluate the grade of paving bitumen are penetration test, ductility test and the softening point test and the specific gravity tests are also required. In this work, we have used S-type, VG-30 grade bitumen.

b. Crumb rubber Modified Bitumen: CRMB is produced by wet process, in which powdered crumb rubber is mixed in hot bitumen and the mixture is agitated mechanically until there is a “reaction” between the bitumen and crumb rubber. It is highly durable and reliable economical solution for raveling, undulation, rutting, bleeding, and shoving and potholes problems. For this work, crumb rubber was procured from discarded heavy vehicle tires from Bharat tires-remolding (Bhopal).

c. Aggregate: Aggregate forms the major part of the pavement structure and it is the leading material used in pavement construction. Aggregates which are used in the surface course have to resist the high magnitude of load stresses and wear and tear due to abrasion. Such aggregates should acquire sufficiently high resistance to crushing. The aggregates further require being hard enough to resist the wear due to abrasive action of traffic. wanted characteristics of an aggregate are-high specific gravity indicating less porous material, however some porosity is required for enhanced binding, desirable angular shape assessed I by sieve analysis and then by flakiness and elongation indices.

d. Filler: Ultra-tech cement was mixed as filler. Then 2% percent cement was added to the aggregate.

PHYSICAL REQUIREMENT OF BITUMEN FOR B.C.

Specific Gravity of Bitumen

Specific gravity of semi-solid bitumen road tars, creosote and anthracite oil are determined as per IS: 1202 – 1978. Specific gravity is the ratio of mass of a given volume of bitumen to the mass of an equal volume of water and both taken at a recorded/specified temperature.

Apparatus used -The apparatus necessary to determine specific gravity of bitumen Specific gravity bottles of 50ml capacity, Water bath, and thermometer – Range 0oC to 44oC,Graduation 0.2oC.

Penetration of Bitumen

The penetration is a measure of hardness or softness of bitumen binder, which is effected by adding up crumb rubber to bitumen binder; it decreases as rubber content is increased. This test is performed as per IS: 1203 – 1978. Penetration of a bituminous material is the distance in tenths of mm, that of a standard needle, which would be penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

Apparatus used - The apparatus required such as Penetrometer, Water bath and thermometer – Range 0oC to 44oC, Graduation 0.2oC.

Softening point of Bitumen

The viscosity referred as the fluid property of the bitumen, and it is a gauge of flow resistance. The potential of the resultant paving mixes. During compaction or mixing, the low or high viscosity has been demonstrated to result in lower stability values. The softening point refers to the temperature at which the bitumen attain a particular degree of softening.

Softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen are determined as per IS: 1205 – 1978. Softening point is the temperature at which the substance attains a particular degree of softening under particular condition of the test.

Apparatus used – The Ring and ball apparatus and Thermometer – Low Range -2 to 80oC, Graduation 0.2oC – High Range 30 to 200oC, Graduation 0.5oC.

Ductility of Bitumen

The ductility of distillation residue of cutback bitumen, blown type bitumen and other bituminous products is determined as per IS: 1208 – 1978. The principle is that the ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled separately at a specified speed and a specified temperature.

Apparatus used –

Ductility Machine: Conforming to specification given in IS: 1208 – 1978 and mould.

Thermometer: An ASTM 63oC thermometer or any other type of standard thermometer of equivalent range.

Scissors: the conventional scissors capable of cutting modified bitumen at the test temperature.

Scale: Any transparent scale of measuring ductility with ±1 mm accuracy.

Elastic Recovery of CRMB

The elastic improvement of modified bitumen is evaluated by comparing recovery of thread after conditioning specimen for 1 hour at specified temperature and the specimen is elongated up to 10 cm deformation in a ductility machine. This is mainly intended to evaluate degree of bitumen modification and quality of modified bitumen. This is sample test performed as per IRC:SP: 53 – 2002 intended to optimize does of rubber additive in bitumen and assist in assessing quality of CRMB in laboratory.

Apparatus used -

Ductility Machine: The conforming to specification given in IS: 1208 – 1978 and mould.

Thermometer: An ASTM 63oC thermometer or any other standard thermometer of equivalent range.

Scissors: there is conventional scissors capable of cutting modified bitumen at the test temperature.

Scale: Any transparent scale of measuring elastic recovery with ±1 mm accuracy.

3.2.6 Marshall Stability of Bitumen mixture

The Marshall Stability of bituminous mixture is determined as per ASTM D 1559. Marshall Stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on lateral surface. It is the load carrying capacity of the mix at 60oC and is measured in kg.

The apparatus required to determine Marshall Stability of bituminous mixture are :

i) Marshall stability apparatus
ii) Balance and water bath

PHYSICAL REQUIREMENTS FOR COARSE AGGREGATE FOR BITUMEN CONCRETE (BC)

Sieve analysis of aggregate

The Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. Sieving of the aggregates is done as per IS: 2386 (Part I) – 1963. In this test different sieves as standardized by the IS code were used and aggregates passed through them and residue of various sized particles on different sieves was determined.

Equipment used- A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm.and balance or scale with an accuracy to measure 0.1 percent of the weight of the test sample.

Aggregate Impact Test

This test was performed to determine the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV) – 1963.Due to traffic loads the road stones are subjected to the pounding action or impact and there is prospect of stones

breaking in to smaller pieces. A test designed to calculate the toughness of stone i.e. the resistance of the stones to fracture under repeated impacts is called impacted test, for road stones.

Apparatus used - These apparatus are used for determining aggregate impact value of coarse aggregates are Impact testing machine conforming to IS: 2386 (Part IV) - 1963 &IS Sieves of sizes – 12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end, Oven capable of maintain constant temperature between 100 to 110oC and a balance of capacity about 500 gm to weight to the accuracy of 0.1gm.'

Specific Gravity and Water Absorption of aggregate tests

The specific gravity of an aggregate is measured to be a measure of strength or quality of the material. Aggregate having low specific gravity is in general weaker than those with higher specific gravity values. The specific gravity test helps in identification of stone. Water absorption gives a proposal porosity & density of rocks. Stone having more water absorption are more porous in nature and are normally considered unsuitable, unless they are found to be acceptable based on strength, impact and hardness tests.

Apparatus used -This test helps to determine the water absorption of coarse aggregates as per IS: 2386 (Part III) – 1963. A wire basket, of not more than 6.3 mesh or a perforate, electroplated or plastic coated, with wire hangers for suspending it from the balance, Water-tight container for suspending the basket in it, Dry soft absorbent cloth – 75cm x 45cm (2 nos.), Shallow tray of minimum 650 sq.cm area, Air-tight container of capacity similar to the basket, Oven capable of maintaining constant temperature between 100oC to 110oC and a balance of capacity about 3 kg to weight precisely up to 0.5gm.

Flakiness & Elongation Index test of aggregate

The pavement construction flaky and elongated particles are to be avoided, mainly in surface course. If flaky and elongated aggregates are present in appreciable proportions, the strength of the pavement layer would be unfavorably affected due to possibility of breaking down under loads.

Apparatus used –

Flakiness- the apparatus consists of a standard thickness gauge, IS sieves 63, 50, 40, 31.5, 25,20,16,12.5,10 and 6.3mm and balance to weigh the aggregates.

Elongation- the apparatus consists of a standard length gauge, IS sieves 63, 50, 40, 31.5, 25, 20, 16, 12.5,10 and 6.3mm and balance to weigh the aggregates.

Maximum specific gravity of paving mixture

Gmm = Pmm / [(Ps/Gse)+(Pb/Gb)]
Gmm = Maximum specific gravity of paving mixture (no air void)
Pmm =Percent by weight of total loose mixture=100
Ps = Aggregate content, percent by total weight of mixture
Pb = asphalt content, percent by total weight of mixture
Gse = Effective specific gravity of aggregate
Gb = Specific gravity of asphalt
Void in mineral aggregate
VMA = 100-[(Gmb*Ps)/Gsb]
VMA= Void in mineral aggregate, percentage of bulk volume
Gsb = Bulk specific gravity of total aggregate
Gmb= bulk specific gravity of compacted mixture
Ps= aggregate content, percent by total weight of mixture
Air void in compacted:-
Va =100*[(Gmm - Gmb)/Gmm]
Va= air void in compacted mixture, percent of total volume

Void filled with asphalt
VFA= [100(VMA-Va)]/VMA
VFA = void filled with asphalt, percent of VMA
Va =air voids in compacted mixture, percent of total volume

III. EXPERIMENTAL WORK

GENERAL

The Bituminous Concrete (BC) mix was prepared using Marshall Method of bituminous mix design. The BC was prepared with conventional VG-30 grade bitumen, VG-30 grade bitumen added with varying percentages of Crumb Rubber. The details of the experimental programme are as follows.

Table - Detail of Sample Constitution and Crumb Rubber Percentage

Sample Constitution	**Sample Preparation**	**% Constituent of crumb rubber by Weight of Bitumen**
VG-30 Grade bitumen	Wet Process	

Bitumen + Crumb Rubber	Wet process	Crumb Rubber: 8% Crumb Rubber: 9% Crumb Rubber: 10% Crumb Rubber: 11% Crumb Rubber: 12% Crumb Rubber: 13% Crumb Rubber: 14%

SAMPLE PREPARATION FOR BITUMINOUS CONCRETE

Aggregate

According to MORT&H specification, aggregate for BC is prepared using 32% 20 mm,23% 10 mm,43% 6 mm & dust and 2% cement. Specific gravity and density of 20mm aggregate, 10mm aggregate, 6 mm aggregate, dust and cement is determined, which will be used later in result analysis. This aggregate mix was common for all types of samples.

VG-30 Bitumen

The above aggregate mix is blended with VG-30 bitumen using wet process. A detail description of wet process is given in the end of this section. Three each specimen was prepared by varying bitumen percent from 4.5%-5.5% with an increase of 0.25%, for each sample by the weight. Three samples for each specimen were repeated tested to obtain average value for various characteristics.

To prepare sample for Marshall Stability Mix Design, following design steps were followed-

1. The aggregate was selected.
2. To determine the proportion of each aggregate size essential to produce the design grading.
3. To determine the specific gravity of the aggregate combination and asphalt cement.
4. To prepare the trial specimens with varying bitumen contents.
5. To determine the specific gravity of each compact specimen.
6. To perform stability tests on the specimens.
7. To calculate the percentage of voids, and percent voids filled with Bitumen in each specimen.
8. To select the optimum binder content from the data obtained.
9. To evaluate the design with the design requirements.

To control the gradation of the test specimens, all aggregates were separated into various sized fractions and stored in metal buckets. The coarse aggregate, fine aggregate, and the filler material should be proportioned so as to fulfill the requirements of the relevant standards. The quantity of aggregate is taken so as to produce a batch, which will result in compacted specimen of 63.5 mm height and 1200 gm of aggregates and filler are necessary to produce the desired thickness. Now the aggregates are heated to a temperature of 175^0C to 190^0C. The compaction mould meeting and rammer are cleaned and kept pre-heated to a temperature of 100^0C to 145^0C. The bitumen is heated to a temperature of 120^0C-140^0C and the required amount of first trial of bitumen is added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with specified number of blows. The compaction was done by standard hammer of 4.5 kg weight falling from 45.7 cm height by giving 75 blows to each face. Now the sample was cured for 24 hours at room temperature before being extracted, using standard removal procedure. ultimately, the specimen is measured and weighed in air and water, for volume determination. The specimen is then noticeable and stored for stability and flow measurements. Three specimens each were prepared for BC Optimum Binder Content has been obtained by taking average of the bitumen contents at which the mix has maximum Bulk Density, maximum Stability and design Air Voids.

Crumb Rubber Modified Bitumen

The VG-30 grade bitumen mixed with varying percentages of Crumb Rubber was added from 8%-14% with an increase of 1%, the each sample by the weight prepare. For each percentage of crumb rubber mix, three samples were prepared and tested to get average values for various rheological characteristics. The results show that with CRMB, higher value of Marshall Stability and greater density can be achieved. All other parameters were also within the specifications of IRC: SP: 53-2002 and MORT&H.

IV. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Conclusions

The study on the use of CRMB reveals that the Marshall Stability value, which is the strength parameter of

BC, has shown increasing trend and the maximum values have increased by about 25 % by addition of CRMB. The density of the mix has also increased in the cases of CRMB when compared with VG-30 grade bitumen. This will provide more stable and durable mix for the flexible pavements. The serviceability and resistance to moisture will also be better when compared to the conventional method of construction. The values of other parameters i.e. Vv, VMA and VFA in the cases of CRMB have been found out to be, within required range of specifications. This study not only constructively utilizes the waste tires in road construction industry but it has also effectively enhanced the values of important parameters which will ultimately provide and long living roads.

Hence it is concluded that 12% of crumb rubber by weight of bitumen, is more suitable and recommended for execution of road pavement as bitumen's carpet.

CRMB roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with heavy distresses. This adversely affects the life of the pavements. The modified bitumen show better properties for road construction and rubber waste which otherwise are considered to be a pollution menace. It can find its use in CRMB & thus help in solving the problem of pollution. In the modified process (dry process) rubber-waste is coated over aggregate. This helps to have better binding of bitumen with the rubber-waste coated aggregate due to increased bonding and increased area of contact between rubber and bitumen. The rubber coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. The road can withstand heavy traffic and show better service life. This study has a positive impact on the environment as it will reduce the volume of rubber waste; otherwise It will not only add value to rubber waste but will develop a technology, which is eco-friendly.

Recommendation for future work

1. In most of the developing Countries like India, there is major scope for development of infrastructure. Large numbers of roads and link roads are still remains untouched and our Government had launched so many schemes for their construction. Water and sun cause equal damage to bitumen roads as heavy traffic load. Crumb rubber has a unique feature of delayed overlaying period owing to-

(i) Reduced oxidation,[due to presence of antioxidants]
(ii) Better repelling property.
(iii) Lower penetration

2. This Study give us solution for utilization of rubber from discarded tires. It will help to decrease land pollution, Disposal of material obtained from tires is a big problem for environment and fertility of land. Their reuse will not only head to economy in construction but also save our environmental balance.

3. The time period of next renewal of road may be extended by 50 percentage in case of surfacing with modified bitumen like CRMB as compared to normal period indicated for conventional bitumen like vg-30. For example, if normal renewal cycle is 4 years, this may be enhanced to 6 years in case of CRMB. Thus it is economical and eco friendly.

Scope for future work

1. Reduced bitumen %ge with increased rubber %ge [less than 5%] can be explored, to achieve economy.
2. This exploration with other grades [VG-10, VG-20 &VG-40] of bitumen can also be performed for economy.

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