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Behavior and Performance of Asphalt Concrete Modified by Crumb Rubber

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ABSTRACT- In our country, the increase in the production of wastes has posed a great challenge for humanity. India is the leading producer of waste rubber and if any kind of method that makes it possible for us to reduce the ill effects of it on the environment and human life is to make use of it in the best possible way. Waste rubber, being a non biodegradable material has found a better place in case of embedding useful and effective properties in bitumen thus enhancing the performance of bituminous concrete. So researchers found its use in the case of bitumen and in this paper we would be analyzing the performance and behavior of bitumen modified with rubber. Some of the main features of road pavement construction would be studied; such features are: - stability, stiffness, fatigue, resistance, rutting and so on.

KEYWORDS- Stiffness, Crumb Rubber, Asphalt, Concrete,Pavement.

I. INTRODUCTION

Roads are considered as the lifelines of human development in case of economical as well as social aspects. Roads are constructed with a view to provide safety and a smooth experience for the riders in a very economical manner[1]. The main constituents of road construction are bitumen, aggregates, binders, filler materials etc. These materials as whole build up the road in a very systematic manner. But the whole construction process could be made furthermore effective and more economical as compared to the present scenario of road construction[2].

This made various engineers to think about the alternative sources of construction since the natural materials are very limited in nature[3]. So, it was found that crumb rubber could easily provide a substantial assistance in case of road construction, being used as an alternative material or we can say as a filler material. Crumb rubber is generally obtained from the automobile or truck tires and ultimately shredded into smaller pieces[4].

Rubber (a non-biodegradable material), whether natural or synthetic, when disposed of could create various environmental as well as health issues[5]. So in spite of disposing It off, we can put it to work in road construction. This can be achieved by shredding the used tires leaving behind a by-product known as crumb rubber[6]. Millions of tons of waste rubber is being produced in India thus posing a great threat to the environment and ultimately to human health but parallel creating an opportunity for the intellectuals to think about the future of roads by making use of these wastes in something really important[7]. Crumb rubber being a waste material can be used in asphalt concrete in case of road construction making it possible to minimize the adverse effects on the environment and on the other side supporting and modifying the trend used in road construction[8].

Crumb rubber, when treated with the asphalt, can prove to be a useful product as it enhances the properties of asphalt itself.[9]At different stages of its use, asphalt binder modification is possible. Asphalt pavement design requirements will be outlined in this paper and a significant analysis will be given and addressed on the use of crumb rubber in asphalt modification. It also provides a study of the impact of CRM on the road pavement's rigidity, rutting and fatigue resistance[10].

II. MATERIALS AND METHODOLOGY

Materials

- Bitumen
- Crumb Rubber
- Aggregates
- Bitumen

It is a black, sticky and highly viscous liquid or semi-solid form of petroleum. The words "asphalt" and "bitumen" also describe both organic and artificial versions of the material interchangeable. It is soluble in Carbon disulphide and in soluble in water. Around 85% of the manufactured asphalt is used as the binding agent for roads of asphalt concrete. It is also used in other paved areas like airport roads, parking lots and footways. Asphalt concrete is usually produced by adding coarse or gross materials including salt, gravel and broken asphalt, which acts as the binding agent. Asphalt is also produced. Substances such as polymers reused (e.g. rubber pipes) can be applied to the asphalt in order to change the quality of the asphalt, in compliance with its planned use. In roofing applications where waterproofing qualities are invaluable, an additional 10 percent of global asphalt production is applied. The other 5% of asphalt is primarily used in different building materials for concrete and ventilation purposes.

Types of Bitumen:

A. Based Upon Penetration Grade

The fundamental assumption of penetration scoring includes of the higher the blade, the less viscous the asphalt becomes. This depth of penetration (although only roughly) is empirically related to asphalt binding. High-penetration

binders (called "soft") are therefore used in cold climates, whereas low-penetration binders (called "hard") are used in warm climates

Industrial Grade Bitumen:

This grade is formed by blowing air into the hard bitumen usually beyond 80 degree Celsius. This grade is also known as Blown bitumen

Cutback: It is also known as liquid bitumen. It is prepared by mixing bitumen with solvents, that are used for preparation of cutback are white spirit, gasoline,naphtha, kerosen etc.

Table 1: AASHTO M 20 and ASTM D 946 Penetration Grade

Penetration grade	Comments
40-50	Hardest grade
60-70	Typical grade used in U.S
85-100	
120-150	Penetration grade
200-300	Softest grade used for cold climates

B. Bitumen Emulsion

It is the mixture of water, bitumen and emulsifiers. Emulsifiers help bitumen to mix with the water. They are used for maintenance and repair work. It can be used during wet weather.

Crumb Rubber: Scrap tyres are being generated and accumulated in large volumes causing an increasing threat to the environment. So these are used for engineering purposes in the form of crumb rubber. Crumb rubber is actually the granular rubber which is derived from the automotive waste tyres. Crumb rubber is obtained by removing the steel present in the tyres during the crushing process. Crumb rubber is produced in two ways Mechanical Grinding and Cryogenic Grinding.

C. *Mechanical Grinding*

It is a multi-step grinding in which the scrap tyres are first broken down into chips by a shredder at or above the room temperature and the steel is separated out. Then the chips are fed into the granulator which further breaks the chips into smaller particles and remaining steel and fibres are removed, to attain finer rubber particles further grinding is done by secondary granulators and rotary mills.

D. Cryogenic Grinding

This process is carried out under low temperatures near minus 80oC. This temperature is achieved by the liquid nitrogen or commercial refrigerants which make the tyre chips brittle and are easily crushed.

Aggregates: Aggregates constitute to the important and the most building structure of the pavement.The main function of the aggregates is to bear the load and stress and apart from that they impart water resisting property to the pavement. Aggregates are primarily used in the construction of cement concrete pavement, bituminious concrete pavement and other kinds of pavements.

Table 2: various Tests on Coarse Aggregate

Table 2: Properties of Aggregates

Test on aggregate	Coarse aggregate
Water Absorption	0.36%
Specific Gravity	2.72
Aggregate Crushing Value	24.3%
Los-Angeles Abrasion Value	32%
Aggregate Impact Value	21%

E. Tests Before the Preparation of Specimen

After formulating various kinds of values related to the aggregates (coarse and fine),we finally move on to the binder part.The binders should be prepared in such a way that they should be befitting the properties of the desired binder used for road construction. The mixing of the crumb rubber modified bitumen should be done keeping in view the compatibility and feasibility scenario in order to make the mix most suitable in case of road construction.

The first step includes heating bitumen upto 150°C and for that bitumen pans have to be heated for about 9-10 minutes then another step is to mix the crumb rubber and bitumen thoroughly.Crumb rubber percentages of 4%,6%,8% and 10% are added into the pans and are therefore mixed thoroughly.

Preparation Of Sample:

Aggregates and fillers are taken in a pan as per the requirements and are mixed together and then heated to a temperature of 180-190°C

Then crumb rubber and the bitumen already mixed thoroughly, are added to the prepared mixture of aggregates and fillers

Presently, the necessary amount of first preliminary level of bitumen (state, 5 % by weight of mineral totals) is added to the warmed totals and the entire blend is mixed consistently and homogenously. This is proceeded for 15-20 minutes till they were appropriately blended which is plainly observed from the uniform shading all through the blend.

The blending temperature for 80/100 evaluation bitumen might be around 154º C.Then the blend was moved to a throwing mold so as to get a compacted bituminous blend example of thickness 63.5 ± 3 mm.

Then the compaction of the blend is done by Marshall hammer by giving about 75 number of blows on each side of the sample thus each sample receives about 150 number of blows.

Then these samples are kept separate and then the bitumen content is added in the percentages of 0.5 and so on and the above procedure is repeated.

III. RESULTS AND DISCUSSIONS

A. Mixing of Crumb Rubber with Bitumen

First Crumb Rubber is blended with Bitumen, bitumen is heated to a temperature of 160oC and then Crumb Rubber is added. Then the blend is manually mixed for 3-4 minutes. This mixture is then heated to 160 ° C, and the entire mass was stirred for about 50 minutes using a mechanical stirrer. The temperature between 160 °C and 170 °C should be preserved. The contents are stirred for approximately 55 minutes gradually.

The tests that are conducted are as follows:

B. Penetration Test

This test is done in order to find out or predict the hardness as well as softness of the bitumen. In this the depth is being measured in tenth or (0.01) mm. The standard needle is being used and is allowed to penetrate vertically in about 5 seconds. This is done by using penetrometer and it consists of needle assembly and in this the weight of bar is 100gm. The consistency is being determined in this process. IS Code: The code used for the penetration test of bitumen is IS 203-1978.
Table 3 shows the Variation of Penetration on the Addition of different percentages of crumb rubber to the bitumen

Table 3: Variation of Penetration on the Addition of different percentages of crumb rubber to the bitumen

Sample	Penetration Value (1/10th of mm)
Bitumen	75
B+4% CR	48
B+6%CR	55
B+8%CR	68
B+10%CR	85

C. Ductility Test

The ductility test gives the measure regarding the tensile properties of the bitumen. The tensile properties mean the ability of the bitumen to deform under the loading. When the ductility value is not good, crack is likely to occur. .Table 4 shows the variation of Ductility on the addition of different percentages of crumb rubber to the bitumen

Table 4: Variation of Ductility

Sample	Ductility value(cm)
Bitumen	75
B+4% CR	19
B+6%CR	18.5
B+8%CR	17.4
B+10%CR	17.2

D. Softening Point Test

Softening point is defined as the temperature at which a particular degree of softness is being attained under given set of conditions. In this higher is the softening point, low is the temperature susceptibility. Mainly the softening point of bitumen is 25 to 75.IS Code: The code used for softening point is IS 1205-1978. Figure 1 shows the graph depicting the variation of softening point.

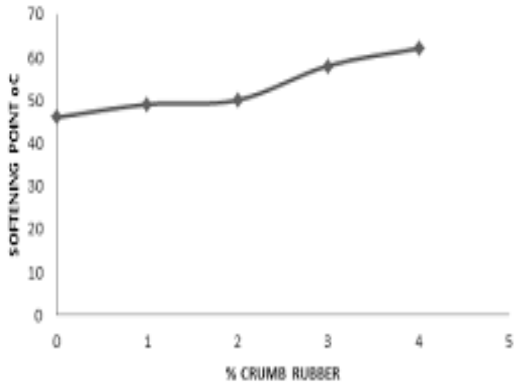

Figure 1: Graph depicting the variation of softening point with the addition of crumb rubber

Table 5 shows the Variation of Softening Point on the addition of different percentages of crumb rubber to the bitumen.Table 7 shows the Variation in Marshall Stability (S) and Flow Value (F) for SDBC with increase in bitumen

Table 5: Variation of Softening Point

Sample	Softening Point (ºC)
Bitumen (PB)	44
PB + 4% CR	47
PB + 6% CR	50.4
PB + 8% CR	52
PB + 10% CR	55.3

E. Viscosity Test

Viscosity is defined as the inverse of fluidity. It is defined as the measurement of the flow. The property allows the bitumen to spread, penetrate into the voids and also for coating purpose. For the orifice meter is used to find the viscosity of binder like the bitumen also various viscometers are used for the measurement of viscosity purpose. Viscosity has basically four grades VG10, VG20, VG30 and VG40.
IS Code: The code used for viscosity test is IS 1209-1978.
Table 6: Variation of Viscosity on the addition of different percentages of crumb rubber to the bitumen

F. Specific Gravity Test

This test deals with finding out the specific gravity of the bitumen. The specific gravity is defined as the measurement taking water as reference. It is also known as the ratio of the density of the substance to an equivalent amount of water. The specific gravity is measured by a device known as a Pycnometer.
IS Code: The code used for determining the specific gravity is IS 1202-1978.

Table 6: Variation of Viscosity

Sample	Viscosity(seconds) At 60º C
Bitumen (PB)	195
PB + 4% CR	231
PB + 6% CR	322
PB + 8% CR	409
PB + 10% CR	451

G. Marshall stability Test

A thermostatically controlled water bath maintained at 60 ± 1º C for about 30-40 minutes is used in which the samples are immersed. Marshall stability test is used to determine the mix ratio of bituminous pavements and to design and evaluate the mixes. Marshall stability is simply the determination of load carrying capacity of a specimen and some of the main features that are determined here are voids , flow value etc. So the design of bituminous mix can be best conducted by following some steps as explained below:The grade is selected to be used in the test and the aggregates are chosen for the mix.The proportion of each aggregate is determined along with the specific gravity of the compacted specimens.Then we carry out the stability tests.From the data collected above, we devise the optimum bitumen content.Fig.1 shows the Graph b/w Marshall stability and Bitumen content .

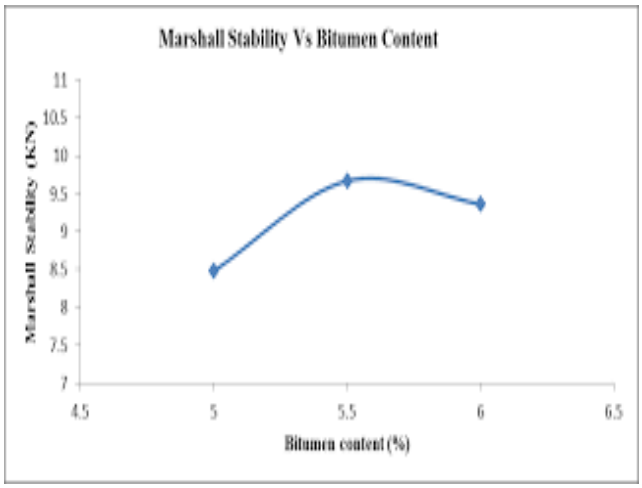

Figure 2: Graph b/w Marshall stability and Bitumen content

Table 7: Variation in Marshall Stability (S) and Flow Value (F) for SDBC with increase in bitumen

Bitumen content	Marshal stability value (S) kg	Flow value mm (F)
5	736.64	3.24
5.5	843.66	3.75
6	962	4.14

IV. CONCLUSIONS

- The main motto of the study and the work is to use the waste rubber (crumb rubber) in case of road construction in such a way that it should be safe for environment.
- A lot of tests are conducted that decide the utilization of crumb rubber as how well it could perform for the enhancement and stabilization of the bitumen. These tests are softening point test, penetration test, ductility test etc.
- Then by varying the percentages of crumb rubber, we analyze the behavior of the bitumen as a concrete mix like that in Semi- dense Bituminous Concrete (SDBC).
- After calculating different values such as Marshall Stability Value, Marshall Flow Value, percentage of voids etc through Marshall Stability Test, we can easily determine the quality and the performance of the concrete.
- The values of Marshall Stability are seen increasing as we increase the percentage of crumb rubber. That's how we can say that our mix is durable enough to resist the external forces.
- And it is also found that after the addition of crumb rubber more than 11%, the bitumen behaves negatively.

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