Comparative Experimental study between RCC, Bituminous Mix and Modified Bituminous Mix

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ABSTRACT: India is a rapid urbanizing country. In the advancement in country's economy, roads have contributed a lot. To match the increasing population of India, roads which are safe and reliable to public access are to be constructed. The most common material used in the road construction is usually RCC which is the combination of ordinary concrete with the reinforcement to increase its compressive and tensile strength to a great extent. With the passage of time the bituminous roads came into existence which are used in road construction because it is easy to produce, reusable, non-toxic and a strong binder. Howsoever, the roads have been made so far but the problem of roads having potholes, cracking, etc. are yet to be resolved. To overcome this problem the usage of scrap tires with bitumen on roads can be greatly effective. There are tonnes of tire waste generated which can be reused on the earth's surface as a great substitute for concrete.

Keywords: crumb rubber, asphalt mixture, stability, binding strength, elasticity

1. INTRODUCTION

Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. Traditionally soil, stone aggregate, sand, bitumen, cement etc. are used for road construction.

Natural material being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, by which the pollution and disposal problems may be partly reduced. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of waste tires in road making in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low volume roads in different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximize the use of solid wastes in different layers of the road pavement. Post construction pavement performance studies are to be done for these waste materials for construction of low volume roads with two major benefits: (i) it will help clear valuable land of huge dumps of wastes: (ii) it will also help to preserve the natural reserves of aggregates, thus protecting the environment.

Rubber tires are user friendly but not eco-friendly as they are non-biodegradable generally. The practice of disposing waste tires in landfills and open burning is becoming unacceptable because of rapid depletion of available landfill sites and clear environment respectively. The conventional bituminous mix includes stone aggregate and 3 to 5 percent bitumen by weight of the aggregate. The scrap tire rubber can be incorporated into bitumen, often abbreviated as modified bitumen and granulated or ground rubber or crumb rubber can be used as a portion of the fine stone aggregate. The use of waste in hot bituminous mixes enhances pavement performance, protect environment and provide low cost and quieter roads.

Crumb rubber is recycled rubber produced from automobiles and truck scraped tires. During the recycling process of these crumb rubber, steel and tire cord are removed, and tire rubber are produced with a granular consistency. In India, over 15 million waste tires are generated annually. Not only are these tire mounds eyesores, they are also environmental and health hazards. The little pools of water retained by whole waste tires create an ideal breeding ground for mosquitoes. Aside from the persistent annoyance, mosquitoes have been shown to spread various dangerous diseases. Equally hazardous are tire fires, which pollute the air with large quantities of carbon smoke, hydrocarbons, and residue. These fires are virtually impossible to extinguish once started. Currently, the 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 cases, tend to float back up to the surface. Land filling waste tires has also become more and more expensive as landfill space has decreased. Asphalt acting as a binder for aggregates is a very important ingredient affecting the life cycle and travel comfort on roads.

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 longer lasting asphalt mixes. This has been a very important development in the last 3 decades and has led not only to huge saving by delaying the maintenance cycles of the road but also its importance has been felt in countries where aggregates and asphalt are in short supply. Natural asphalt is a naturally occurring hydrocarbon mineral that is high in asphalt and high in the Nitrogen. When crumb rubber is added to asphalt it dramatically increases the asphalt's viscosity, lowering penetration while increasing the softening point. The chemically treated crumb rubber and besides have been designed to rapidly blend into asphalt. The addition of rubber gives the additional binding strength, increasing elasticity and softening point of the asphalt. Carbon present in rubber acts as an anti-oxidant and prevents asphalt from ageing and oxidization.

2. Previous investigation:-

In the present study various physical tests were done on aggregate evaluate the mechanical properties such as strength, toughness, hardness, water absorption capacity etc. the obtained results were then compared with the allowable limits as per MORTH,2013 specification shown in table. All the results were found within the allowable limits of bituminous concrete mix.

Marshall Method of mix design was adopted to carryout mix design for Bituminous Concrete Mix prepared using Polymer Modified Bitumen. Marshall Stability and Indirect Tensile Strength tests were conducted on Bituminous Concrete Mix prepared using Polymer Modified Bitumen by varying mixing and compaction temperatures. For the selected mixing and compaction temperatures Indirect Tensile Fatigue test was conducted at 25oC by varying stress level.

3. Materials and methods :-

Aggregates offer good compressive and shear strength; along with this they provide good interlocking facility with sufficient permeability. Aggregate mainly consisting of both coarse and fine aggregates. Coarse aggregate of 19 mm to 2.36 mm and fine aggregates of 2.36 mm to 75 µ were used.
The test results are presented in table 1.

Table 1: Physical Properties of Aggregates

Sr.No.	Types of test	Test methd	Result	MORTH,2013 specifications
1	Aggregate impact	IS-2386 PartIV	9.56%	<27%
2	Los angeles abrasion	IS-2386 Part I	25.00%	<35%
3	Aggregate crushing	IS-2386 Part I	24.05%	<30%
4	Water absorptin	IS-2386 PartIII	0.8%	<2%
5	Specific gravity (Coarse aggregat) (Fine aggregat)	IS-2386 PartIII	2.77% 2.50%	2-3%

Bitumen is a binding agent. At normal temperature they are in the form of semi-solid, it is heated until liquefied before blending it with the aggregates. In this study Polymer Modified Bitumen PMB-70(SBS) is used as binder. All the basic fundamental test and also the thin film oven test were carried out at specified temperature (153°C) on the bitumen sample as per the requirement. The test results were satisfying the requirements as per IRC-SP 53 2002. The results are presented in table 2.

Table 2: Physical properties of bitumen :-

Sr.No.	Types of test	Test methd	Result	BIS-73:2006 Specifications
1	Penetrtion test, mm (25°C,100g,5sec)	IS:1203-1978	42.6	50-70
2	Softening point test(°C)	IS:1205-1978	42.3	Min.47
3	Ductility test, cm (25°C)	IS:1208-1979	49.33	>40
4	Specific gravity test (27°C)	IS:1202-1978	1.026	Min.99
5	Viscosity(135°C)	IS:73-2013	172	>150

According to standard Marshal design method designated as ASTM D 1559-89, 15 numbers of samples each of 1200 gm in weight were prepared using five different bitumen contents (from 4 - 6% with 0.5 % incremental). Also number of samples are prepared for different proportion of crumb rubber (5, 7.5, and 10) and for different sizes of crumb rubber as shown in below table

SIZE OF CRUMB RUBBER	SIEVE SIZE
Size 1	2.36mm-1.18mm
Size 2	3.25mm-2.36mm

3.1 Procedure for Mix Design

- Select aggregate grading.
- Determine the proportion of each aggregate size required to produce the design grading.
- Determine the specific gravity of the aggregate, mineral filler and bitumen.
- Prepare the trial specimens with varying bitumen contents.
- Determine the specific gravity of each compacted specimen.
- Perform stability tests on the specimens.
- Calculate the percentage of voids, and percent voids filled with Bitumen in each specimen.
- Select the optimum binder content from the data obtained.
- Evaluate the design with the design requirements.

4. Marshall Method of Mix Design

4.1 Bituminous mix design

The mix design determines the optimum bitumen content. Suitably designed bituminous mix will withstand heavy traffic loads under adverse climatic conditions and also fulfil 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:

•Sufficient binder to ensure a durable pavement by providing a water proofing coating on the aggregate particles and binding them together under suitable compaction.
•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 binder in the mix.

•Sufficient flexibility to withstand deflection and bending without cracking. To obtain desired flexibility, it is necessary to have proper amount and grade of bitumen.

•Sufficient voids in the total compacted mix to provide space for additional compaction under traffic loading.

•Sufficient workability for an efficient construction operation in laying the paving mixture.

4.2 Sample preparation

Total of 1200gm of aggregates and filler put together is heated to a temperature of 160 to 170°C. Bitumen is heated to a temperature of 121 to 145 °C with the trial percentage of bitumen (say 4% by weight of the mineral aggregates). Then the heated aggregates and bitumen are thoroughly mixed at a temperature of 154 - 170°C. The mix is placed in a preheated mould and compacted by a hammer having a weight of 4.5 kg and a free fall of 45.7 cm giving 75 blows on either side at a temperature of 130 to 145°C to prepare the laboratory specimens of compacted thickness 63.5±3 mm. In this study three samples were prepared for each percentage of bitumen ranging from 4.00% to 6.00% with interval of 0.5% to obtain better result.

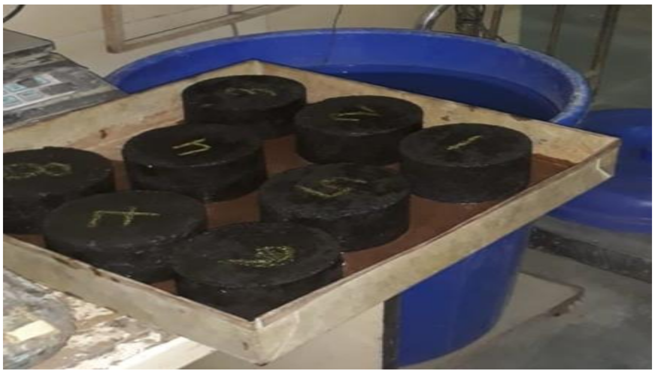

Figure 1: Marshall specimens for different bitumen percentage

4.3 Determination of marshall stability and flow

The load is applied at the constant deformation rate of 51 mm per minute and load and deformation readings are closely observed. The maximum load reading and the corresponding deformation of the specimen at failure load are noted. The maximum load value expressed in kg is recorded as the "Marshall Stability" value of the specimen. The vertical deformation of the test specimen corresponding to the maximum load, expressed in mm units is recorded as the "Flow value". The specimen is removed from the test head and the test is repeated on other specimen. in mm units is recorded as the "Flow value". The specimen is removed from the test head and the test is repeated on other specimen.

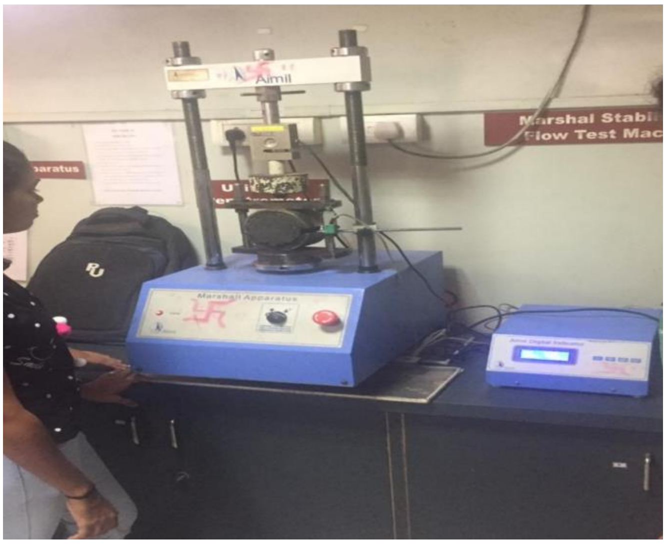

Figure 2: Testing of mould in marshall test equipment

Stability flow and volumetric analysis results of BC samples for non-modified and modified mixes:

	Composition	Marshall stability 60°C	Marshall flow 60°C	Bulk density	Air voids	Voids in mineral aggregates
Units		Kg	mm	g/cc	%	%
Test methods		ASTM:D 1559	ASTM: D 1559	ASTM:D 2726	ASTM:D 3203	ASTM:D 1559
4	100%B	850	2.25	2.44	5.91	14.46
4.5		920	2.47	2.49	3.34	13.11
5		1050	2.88	2.49	2.64	13.46
5.5		985	2.97	2.49	2.35	14.15
6		880	3.48	2.48	2.13	14.90

	Composition	Marshall stability(60°C)	Marshall flow(60°C)	Bulk density	Air voids	Voids in mineral aggregates
Units		Kg	mm	g/cc	%	%
Test methods		ASTM:D 1559	ASTM:D 1559	ASTM:D 2726	ASTM:D 3203	ASTM:D 1559
Size 1	97.5%B+2.5%CR					
4		1121.7	2.41	2.42	6.56	15.29
4.5		1246	2.58	2.4	6.73	16.41
5		1403.3	2.93	2.39	6.78	17.4
5.5		1633.3	3.33	2.39	6.09	17.73
6		1080	4.13	2.38	5.96	18.55
Size 2	95%B+5%CR					
4		1177	2.2	2.4	6.96	15.88
4.5		1270	2.63	2.4	6.88	16.8
5		1437	3.07	2.41	5.71	16.76
5.5		1643	3.65	2.41	5.26	17.32
6		1113	4.27	2.4	4.69	17.78
Size 3	92.5%B+7.5%CR					
4		1215	1.963	2.47	4.37	13.79

4.5		1365	2.27	2.5	2.74	13.36
5		1596.67	2.573	2.49	2.29	14.02
5.5		1796.67	3.11	2.49	1.5	16.4
6		1203.33	3.546	2.46	2.04	15.83

	Composition	Marshall stability(60°C)	Marshall flow(60°C)	Bulk density	Air voids	Voids in mineral aggregates
Units		Kg	Mm	g/cc	%	%
Test methods		ASTM:D 1559	ASTM:D 1559	ASTM:D 2726	ASTM:D 3203	ASTM:D 1559
Size 1						
4	97.5%B+2.5%CR	989.33	2.5	2.41	7.22	15.9
4.5		1057.3	3.17	2.42	6.2	15.9
5		1156	3.33	2.43	5.14	16
5.5		1360	3.84	2.46	3.41	15.4
6		900	4.3	2.45	3.06	16
Size 2						
4	95%B+5%CR	996.7	2.08	2.42	6.49	15.46
4.5		1131.3	2.42	2.45	4.92	15.05
5		1253.7	2.53	2.43	4.98	16.11
5.5		1386.7	2.84	2.43	4.33	16.51
6		921.3	3.11	2.45	3.04	16.36
Size 3						
4	92.5%B+7.5%CR	1083.3	2	2.42	6.45	15.66
4.5		1186.7	2.1	2.45	4.57	15
5		1324.7	2.3	2.44	4.25	15.74
5.5		1416.7	3	2.44	3.72	16.28
6		987	3.2	2.44	3.11	16.76

5. Conclusions

By using the crumb rubber in bituminous mixture helps to utilize the crumb rubber waste increasing the strength and performance of the roads and providing better adhesion between the asphalt and the aggregate, reducing the cost and further developing a technology, which is eco- friendly.

The study was performed with three content of crumb rubber (5%, 7.5% and 10% by weight of binder) and four different sizes varying from 1.18mm – 3.25mm for modified mix by dry process.

From the observations, results and analyses, the following conclusions are deduced:

References

1)Niraj D Baraiya suggested addition of waste tyres reduce thermal cracking and permanent deformation in hot temperature region and also decreases the sound pollution.

2)R Vasudevan et al stated rubber coated aggregate bitumen makes better material for pavement construction as mix shows higher Marshall stability value.

3)Huffman found that after thoroughly mixing crumb rubber with asphalt binder and allowing it to blend for periods of 45 to 60 minutes, new material properties were produced.

4)Prof. Justo et al (2002), observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the crumb rubber additive up to 12 percent by weight.

5)Shankar et al (2009), crumb rubber modified bitumen (CRMB55) was blended at specified temperature which resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%).

6)Mohd. Imtiyaz (2002) concluded that the mix prepared modifiers shows: higher resistance to permanent deformation at higher temperature.