Application of Waste Tyre Rubber Crumbs in Strengthening of Bituminous Roads

Santanu Haldar, T. Senthil Vadivel, and Sukanta Das

Abstract In the World, India is considered as the second rapid mounting automobile industry and production of waste tyres is just a consequence of this. Tyres become scrap due to continuous frictional force between pavement surface and vehicle tyres. This continuous production and disposal of waste tyres creates several nuisances such as intensifying landfill areas, environmental contamination, and resulting health vulnerability. Hence, solid waste management may be a great option for those scrap tyres that can be used as a modifier in Crumbed Rubber Modified Bitumen (CRMB). Crumbed tyre rubber can be used as partial replacement to the total weight of Bitumen in road construction. Waste crumbed rubber has same properties as bitumen that possesses an improved skid resistance, fatigue cracking interruption, and augmented rut resistance. In this paper, it is seen that CRMB confirms greater softening point, lesser penetration value, and lower ductile value. Also strength properties of CRMB are evaluated by means of Marshall Stability test. The objective of this study was to use waste crumb rubber with neat bitumen that would diminish the costs of construction and as well as possessing improved physical properties in comparison of convention bitumen. At the end of experimental studies, it is observed that 12% addition of crumb rubber has the most suitability for blending with bitumen.

Keywords CRMB · Waste crumbed rubber · Softening point · Penetration value · Ductile value

1 Introduction

Generally, proper communication system in the form of pavement is a sign of a developed society or country. In India, most of the highways are flexible pavement where bitumen plays a vital role as the primary constituting material. The main function of bitumen is to adhere aggregate in their place and provide a better water sealant skid resisting surface for the ongoing vehicles. Globally, nearby 15 million

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tonnes waste tyres are produced annually and 1 million tonnes out of that are supplied by India [1]. Generally, they are dumped in a place causing landfill occupancy, creating breeding of mosquitoes.

Environmental Protection Agency (EPA), in the year 1990, approximated that in the same year, 78% of the waste tyres, were either accumulated in a place, illicitly deserted, or a land filled [4, 5]. Few of the states burnt those tyres but the problem for this was, after burning it apt to float back on the surface again. Disposal by burning technique also results harmful fumes that go in the atmosphere, originating large amount of hydrocarbons, carbon smoke, residues, causing environmental pollution, and health risk concurrently [2].

So, instead of disposal, solid waste management of the waste tyres may be a great option where reuse of the waste happens in form of partial replacement of bitumen because rubber also possesses same properties as bitumen. Besides of that, in addition of crumbed rubber into conventional bitumen causes hiking in viscosity, lowering the value of penetration, and rising the bitumen softening point [3]. The addition of rubber offers bonus binding strength, escalating flexibility of the bitumen [6]. Moreover, carbon in the rubber inhibits oxidation and protects bitumen from ageing [8].

2 Literature Review

There are several sorts of research had been done by quite a few students, professors, and researchers to examine the behaviour of crumb rubber replacement in typical bitumen to augment the engineering properties of bituminous pavement.

Nabin Rana Magar examines the performance of CRMB for varying its percentages with neat bitumen. Greater percentage of crumb rubber significantly augments penetration and softening point of bitumen. 0.3 to 0.15 mm is recommended as the finest size to be used for crumb rubber amendment for commercial fabrication of CRMB [2].

Nuha S. Mashaan illustrated the convenience of using asphalt mix with crumb rubber modifier. The modifier can use in hot mix asphalt in order to get better counteraction to rutting and fabricate pavement with superior resilience. It is then diminishing distresses reasoned in pavement with hot mix asphalt. Hence, the road user would assure more secure and smooth roads [3].

Senthil Vadivel et al. highlighted on existing traditions associated to the reclaim of waste tyre rubber and discover latest potential use. The progress of new construction material by means of recycled waste tyre is significant to both the construction and rubber industry. Widespread investigation has been carried out to scrutinize the applications of wasted tyre rubber which used as reinforcement in under reinforced beams. 14 beams were cast with 2 numbers of 15 $\times$ 25 mm sized scrap tyre rubber as reinforcement as an alternative of steel in tension zone. Flexural behaviour of different aged tyre reinforced concrete beam was tested in this regard. It was observed that all the test specimens performed in a ductile manner. Based on the experiment

dimensions, flexural stiffness, the ultimate strength, and ductility were measured and compared. The test outcomes also point towards that strength and stiffness of the beam are equivalent to Reinforced Concrete beams [4].

Senthil Vadivel and Thenmozhi aimed on using waste tyre rubber crumbs as a replacement of fine aggregate in concrete combinations. Shredded rubber crumbs with the proportion of 2, 4, 6, 8, and 10% by weight used as an alternative of fine aggregate in casting of total 90 cubes, cylinders, and beam specimens and the experimental outputs compared with total 18 conventional specimens. Properties of fresh and hardened concrete such as tensile strength, compressive strength, workability and flexural strength were recognized and it was concluded that waste tyre rubber of 6% substitution with fine aggregate will offer safest and optimal alternative in concrete combinations [5].

Mashaan et al. presented that addition of crumb rubber with neat bitumen decreases bitumen penetration value and consequent increase in softening point value which also indicates the resulting mix as stiffer and viscous material [6].

Justo et al. stated that the usage of crumb rubber changes the properties of bituminous mixture with his assistance Shankar and Mohd. Imtiyaz. They used the rubber content up to 12 tonnes and proper practical values were obtained from the several applications of CRMB. The temperature was also mentioned there for proper blending of bitumen mix. They have used 60/70 grade bitumen to get optimum binder (bitumen) content [7].

Becker et al. revealed that the mix characteristics are largely influenced by addition of rubber content into bituminous mix. Rubber content in greater extent enhances the mixing property but up to a certain limit of addition should be carried out to get proper one. Crumb rubber replacement effects in penetration, softening point, and ductility [8].

Abedlrahman and Carpenter determines the varied percentage of crumb rubber with blending temperature for the preparation of CRMB mix. He mentioned the temperature as 175 °C and 40–45 min as the time of mixing. This research was so much helpful to get sense about the blending temperature where the bitumen can be mixed properly to get proper mixture without any hesitation [9].

Based on the above literature, the current study was intended to:

- Use crumb rubber as a partial substitution of bitumen and make the process of construction economically viable.
- Achieve a greater strength and stiffness of the entire paving mix in order to carry a greater load coming from the moving vehicles.

3 Materials Used

Here in this chapter, selection of materials and their specifications used for this study are discussed below:

Fig. 1 40 mess crumb rubber collected from Kharagpur

3.1 Crumbed Rubber

Scrap tyre rubbers are the key constituent of Crumbed Rubber modifier and this scrap tyre is mainly ordinary and synthetic rubbers and it contains carbons. Types of rubber vary with the type of vehicle, for e.g. truck tyres having ordinary rubbers mainly whilst the automobile tyres contain synthetic rubbers [2]. The composition of classic mass of crumb rubber modifier available in present marketplace is generally homogeneous in nature. Standard car tyres have ordinary rubber, synthetic rubber, steel cord, carbon, bead wire, oils, chemicals, waxes, pigments etc.

Crumb rubber fabricating corporations are mainly situated in various states of India like, Hyderabad, Kerala, Tamil Nadu, Gujarat, Maharashtra, Rajasthan, Telangana, Delhi etc. But in West Bengal, it is very hard to find such a corporation like this. "Tri Rubber Republic of India Inc." assisted during ingathering of crumb rubber by informing about the concern material that is available at Kalaikunda, DewanmaraAyma, Kharagpur, Province—721304. Collection of 40 mess (0.42 mm or 420 micron) crumb rubber (Fig. 1) was done from the reference place.

3.2 Bitumen

Bitumen is an extremely viscous, highly sticky, black colour semi solid or liquid product existing in natural deposits. Mainly it is a side-product of the partial distillation of crude petroleum. It is well known for its adhesive and waterproofing properties and using comprehensively for the construction of Flexible Pavements. It is an amalgamated substance which is the mixture of hydrocarbon and integrated elements which comprise sulphur, calcium, iron, and hydrogen.

Table 1 Tests on Bitumen

Sl. No.	Tests	Used apparatus	Reference
1.	Penetration	Standard Penetrometer	IS: 1203-1978
2.	Softening Point	Ring Ball Apparatus	IS: 1205-1978
3.	Ductility	Ductility Test Apparatus	IS: 1208-1978
4.	Flash & Fire Point	Cleveland Flash & Fire Point Apparatus	IS: 1209-1978
5.	Specific Gravity Test	Specific Gravity Bottle	IS:1202-1980

For this study, VG 30 bitumen was collected from Debra—Patashpur Road where construction of 2 lane was happening. Here the grade of bitumen was declared by the supplier, which is later cross checked by experimental procedures.

4 Methods

The testing methodology for this study has embraced with a number of tests to investigate the results on amalgamation, bitumen with crumb rubber substituted hydrocarbon and aggregate-bitumen united material (Table 1).

4.1 Preparation of CRMB

In this part, scrap tyre rubber is integrated into asphalt paving mixes where the aspect temperature was kept at150–160 °C to make the mix.

5 Tests, Results, and Discussions

Generally, observations were started with measuring properties of aggregates and bitumen. Before preparation of CRMB, physical properties of crumbed rubber like specific gravity and moisture content checked (Table 2). Then change in properties of bitumen with application of crumbed rubber modifier was investigated. During this observation, initially 65 gm bitumen was taken and then partial application of

Table 2 Crumb rubber properties

Sl. No.	Crumb rubber properties	Tested value
1.	Moisture content	0.69%
2.	Specific gravity	1.02

crumb rubber modifier applied for 4, 8, 10, 12, and 14% of crumbed rubber. Changes in the properties were noted for each application.

5.1 Specific Gravity Test of Normal Bitumen

The specific gravity is very much influenced by the chemical formation of binder. It is defined as the ratio of the densities of any material to some other material where one is considered as the standard. For solids and liquids, water is considered as the standard one. Standard temperature is maintained at 27 ± 0.10 °C. The specific gravity confirmation is accomplished by supporting IS: 1202-1980. Test result for VG 30 bitumen was obtained as 1.02 and as per the mentioned IS code the range given as 0.98–1.30. Hence the test result is within satisfactory limit.

5.2 Penetration Test

Penetration test is one of a measurement of consistency of bitumen. Grading of bitumen is decided by seeing the penetration of a regular needle vertically beneath the surface of bitumen under specified circumstance of ordinary load, period, and temperature (Fig 2). The penetration test is carried out as per IS: 1203-1978.

It can be concluded from Table 3, penetration value of normal bitumen was 66.67 mm which is reducing continuously with addition of percentage of crumb rubber (Fig. 3).

5.3 Softening Point Test

Bitumen suddenly does not change its state from semi solid to liquid, it progressively becomes softer with rise of temperature and then ultimately start flowing. The objective of this experiment is to determine a lowest temperature at which bitumen conquers a specific extent of softening. Ring and Ball test apparatus is used to find Softening point of Bitumen and CRMB. The experimental method is based as per IS: 1205-1978 (Fig. 4) (Table 4).

For various percentage of CRMB (0, 4, 8, 10, 12, and 14%), softening point is investigated and it is observed in Fig 6 that softening point is increasing continuously with the mounting percentage of crumbed rubber. Generally lower temperature susceptibility is indicated by the higher softening points and it is more acceptable in hot climate regions (Fig. 5).

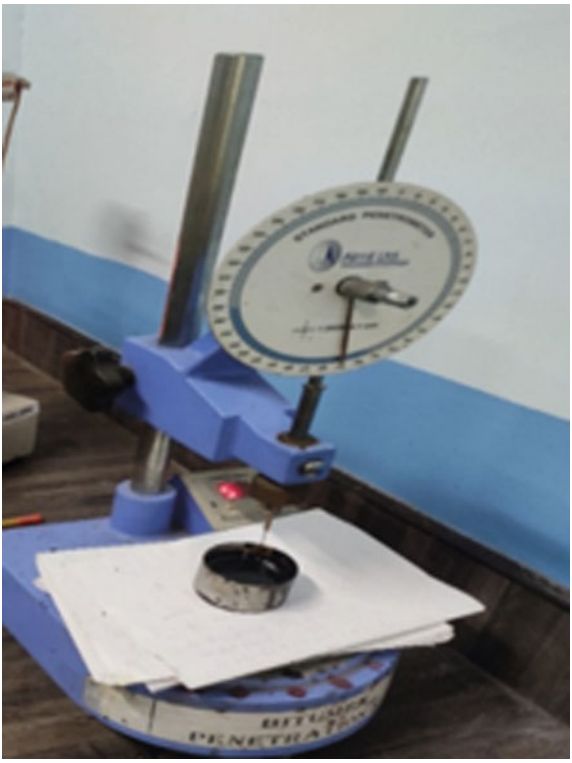

Fig. 2 Bitumen penetration test

Table 3 Penetration test and results

% of Crumb rubber modifier (%)	Readings during	Trials			Average penetration value in mm	Permissible value as per IS: 1203-1978
		1	2	3		
0	Initial	0	0	0	66.67	60–70
	Final	68	65	67		
4	Initial	0	0	0	54.66	
	Final	50	54	60		
8	Initial	0	0	0	49.33	
	Final	44	48	56		
10	Initial	0	0	0	38.67	
	Final	33	37	47		
12	Initial	0	0	0	19	
	Final	18	19	20		
14	Initial	0	0	0	15	
	Final	16	14	15		

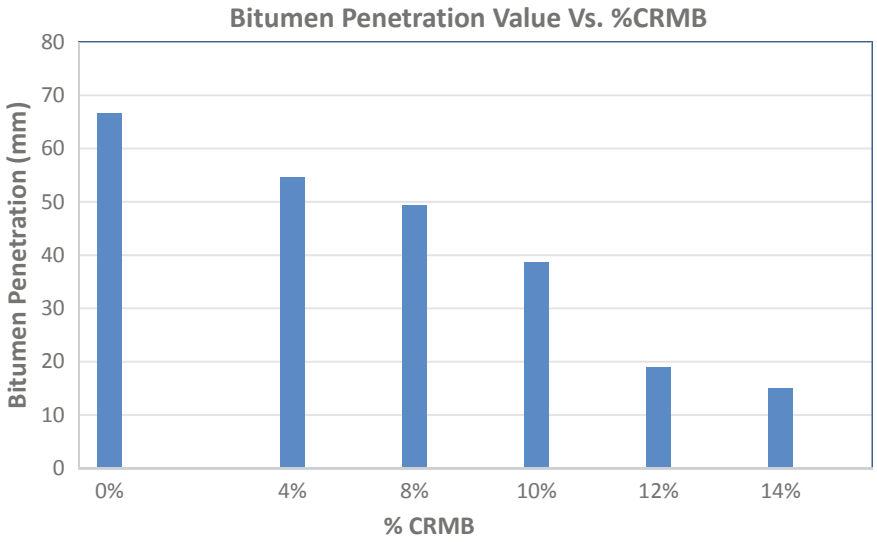

Fig. 3 Relationship between penetration (mm) and % CRMB

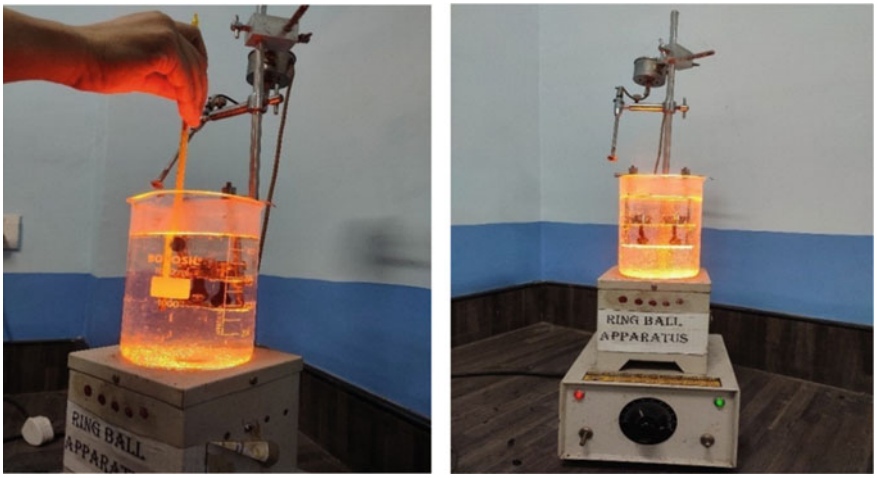

Fig. 4 Ring and ball apparatus for measuring softening point of Bitumen

5.4 Ductility Test

Bituminous material is deliberated ductility through presenting a distance in cm at which the test sample starts lengthen prior to breaking when the standard briquette specimen of the material is dragged away from each other by maintaining a particular

Table 4 Softening point test and results

% of CRMB (%)	Temp. (°C) Reading I	Temp (°C) Reading II	Average Value of Softening Point (°C)	Permissible Limit As per IS:1205-1978
0	47	47.8	47.40	40–55 °C
4	50	51.5	50.75	
8	53	53.2	53.10	
10	55	55.4	55.20	
12	59	60.5	59.75	
14	62	60.8	61.4	

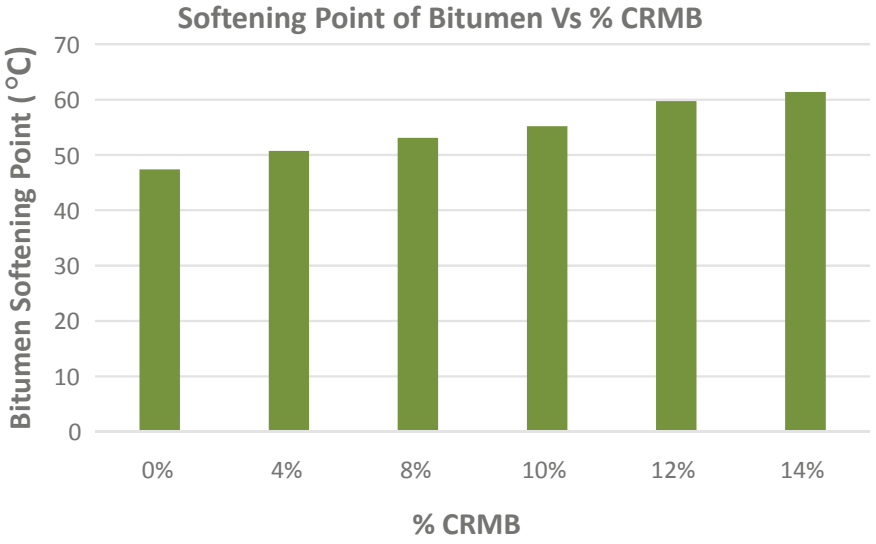

Fig. 5 relationship between softening point versus % CRMB

steady speed of 50 mm/min at a specified temperature. The ductility test was carried out based on IS: 1208-1978.

Ductility test was carried out for both neat bitumen and for CRMB as well. It was seen that, ductility value is decreasing (Table 5, Fig. 7) with hike in crumb rubber modifier percentage and that indicates subsequent conversion into stiffer material.

Fig. 6 Ductility test

Table 5 Ductility test and results

% of CRMB (%)	Sample Reading in cm			Average Ductility Value in cm	Permissible Limit as per IS:1208-1978
	Reading 1	Reading 2	Reading 3		
0	76	77	75	76	75 cm
4	68	72	69	69.67	
8	57	59	58	58.00	
10	52	55	53	53.33	
12	49	52	50	50.33	
14	40	41	43	41.33	

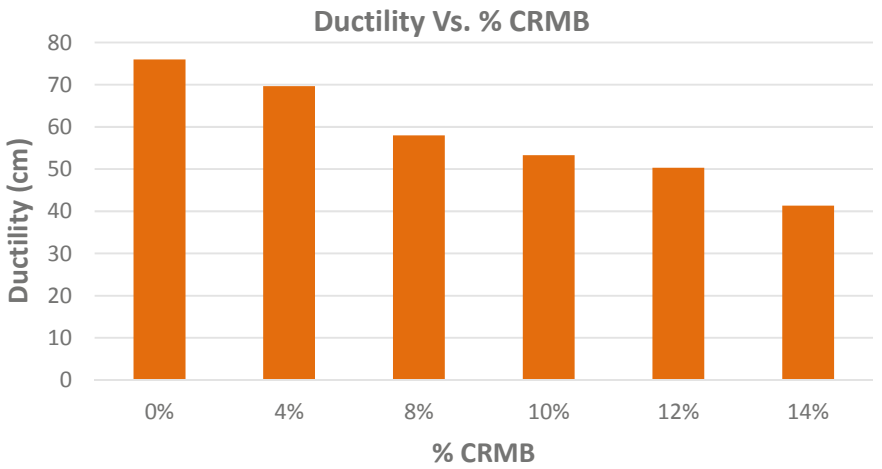

Fig. 7 Relationship between Ductility and % CRMB

Table 6 Flash point and fire point test and results

% of CRMB (%)	Flash point (in °C)	Fire point (in °C)
0	180	220
4	190	210
8	210	235
10	220	250
12	235	265
14	260	280

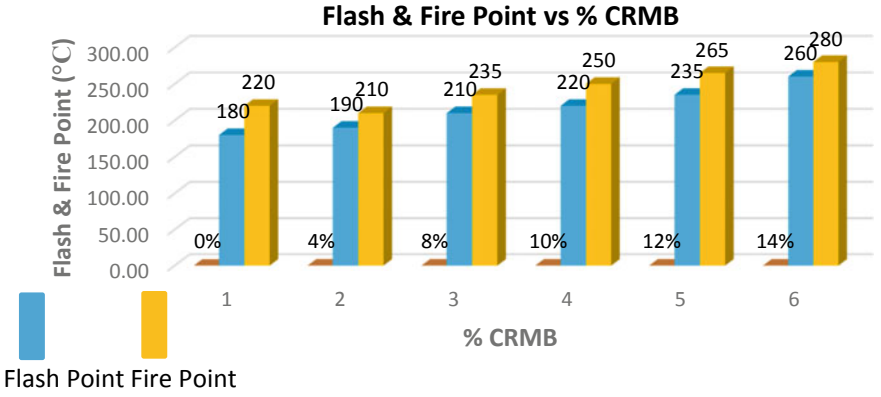

Fig. 8 Relationship between flash point and fire point versus % CRMB

5.5 Flash Point and Fire Point Test

These tests are considered as the safety check carried out on bituminous materials and it is a deciding test of determining the minimum temperature from which bituminous materials can protect from fireplace risks all through its applications.

Flash point is the minimum temperature at which bituminous material tends to get spark on the experimental sample. Fire Point is the least temperature at which the material gets lit and be on fire under mere circumstance of check. The experiment was carried out by following IS1209-1981 (Table 6) (Fig. 8).

With continuous inclusion of crumb rubber modifier, flash point and fire point of the material getting increased. This indicates employing of CRMB gives the preventative process after a little longer time than the normal bitumen.

6 Conclusion

Seeing the experimental results following statements can conclude:

- Neat bitumen becomes harder with successive addition of crumb rubber modifier. Its penetration value decreases, softening point and flash point and fire point increases. It implies crumb rubber modifier provides benefit in form of additional strength to the road.
- From the ductility test result we can conclude that the addition of rubber waste will make the bitumen harder. Addition of crumb rubber up to 12% gives a good result (50.33 cm), because ductility value less than 50 cm is not suitable for the construction of roads [10].
- So, we can conclude that application of crumb rubber is so much effective and useful in the formation of strengthen roads. The durability of the crumb rubber modified bituminous road is also increased than that of bituminous road up to a certain replacement of crumb rubber with bitumen.
- On the other hand, we can use this research further as economically effective as the price of crumb rubber is low with respect to the bitumen or hydrocarbon materials. Hence, if we substitute the required bitumen with the crumb rubber for making a bituminous road, cost optimization also happens there.

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