Investigation on the Use of Crumb Rubber and Bagasse Ash in Road Construction

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Abstract. The naturally occurring materials like aggregates, sand, bitumen, etc. are depleting day by day due to its extensive usage in various civil infrastructural and building construction projects. On the other hand, the disposal of industrial and domestic waste in an eco-friendly way is a thrust area for researchers and has ample scope for its utilization as an alternative to the conventional exhausting natural materials. A number of researchers have already reported the potential use of various waste materials in road construction. The present study is an attempt to report the obtained results from extensive literature review upon the use of waste materials like tyre rubber, bagasse ash, in road construction. Furthermore, as a sustainable construction method, the experimental investigation on studying the effects of adding scrap rubber and bagasse ash as a partial replacement to bitumen and filler in the bituminous mixes respectively done by using the Marshall stability testing machine. The results obtained from the comparative study showed that scrap rubber can be used in road construction as a partial alternative to bitumen but the additions of bagasse ash lower done the strength & quality of the bituminous mix. So it is concluded that scrap rubber can be effectively used in the road construction as an alternative to bitumen but the use of bagasse ash is not been recommended in bituminous layers.

Keywords: Scrap rubber · Partial replacement · Bagasse-ash

1 Introduction

As the amount of cars in India is increasing quickly, tire waste becomes a significant environmental fear. Crumb rubber is a material generated when used tires are destroyed and commuted. Nearly 60% of waste tyres current are disposed of through urban and rural regions. This creates numerous conservation problems, including air pollution

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(owing to the burning of tyres) and artistic pollution that causes serious health-related problems. These are abiotic, disposable goods that cause environmental pollution to these materials. This creates numerous conservation problems, including air pollution (owing to the burning of tyres) and artistic pollution that causes serious health-related problems. These are abiotic, disposable goods that cause environmental pollution to these materials. In contemporary years, rubber waste by-products are being used with excellent concern in many developing nations in highway building. Practical, commercial and environmental criteria are used to select these materials in road construction. Millions of tons of rubber waste are manufactured in India every year. Using these materials in road construction can effectively reduce the issues of pollution and disposal. Caring for the bulk trick of these waste in India, it was considered necessary to examine these products and create requirements to boost the use of rubber waste in highway manufacturing, where greater financial returns could be feasible. These materials should be used in road construction in each and every part of our country.

The use of crumb rubber, which is the reprocessed tire rubber, as an additive in asphalt mixture is considered a sustainable construction method. The addition of crumb rubber to the bitumen binder enhanced the physical properties of rubberized bitumen binder as indicated by the reduction in penetration and ductility. There are two fundamental procedures in asphalt blend for adding crumb rubber, wet and dry procedures. Crumb rubber is added to asphalt in a wet method, allowing the reaction of rubber and asphalt. The primary method of the moist method is rubber swelling.

In the dr phase, before adding bitumen, Crumb rubber is blended with the warm aggregate. Adding tire rubber to asphalt mixtures using a dry method could enhance the characteristics of permanent deformation resistance at elevated temperatures and cracking at low temperatures. As specified, the rubberized asphalt mixture with the wet process could achieve the desired Volumetric parameters. The aim of this research was to explore the impact of using the wet method to add crumb rubber to asphalt mixtures.

Sugarcane bagasse ash is the sugarcane refinement's natural product. It is the fiber remaining to create juices after the method of extraction that comes from sugar cane. When the juice was extracted from sugarcane, the amounts of product volumes in sugar factories render it a waste product Sugarcane bagasse ash is the natural product of sugarcane refinement. After the extraction technique that comes from sugar cane, it is the fiber that remains to produce juices. The quantities of product quantities in sugar mills make it a waste product when the juice was extracted from sugar cane.

1.1 Dense Bituminous Macadam (DBM)

For use as a base course and/or binder course, the dense bituminous macadam (DBM) is currently specified. Two DBM gradations are specified in section 505 of the 2013 MORTH specifications: Grading 1 has an NMAS (nominal maximum aggregate size) of 37.5 mm and Grading 2 has an NMAS of 25 mm MORTH composition of DBM Grading 1 and 2. The specified percentage of fine aggregates is the same in both gradings (28–42%), the main difference is only some large aggregate particles (25–45 mm size) are the same in both gradations. The use of large stone mix (37.5 mm or bigger NMAS) has several drawbacks such as segregation and elevated permeability. These disadvantages outweigh the "marginal" gain instability if any; over a mixture of

25 mm NMAS. As Grading 1 is extremely permeable, it must be closed or overlaid before rainy season otherwise water will penetrate it and harm the fundamental course of WMM. experienced Indian highway technicians recommend this but the alternatives are merely to completely prohibit the problematic DBM Grading 1 and use only the DBM Grading 2. On many national highways in India deteriorated DBM grading 1 in the reduced lift of the complete DBM, which was disintegrated owing to drying, could not be recovered intact by coring. Based on the previous debate, in the flexible pavement, problematic DBM Grading 1 should not be used (Table 1).

Table 1. Grading dense bituminous macadam as per morth

Grading	1	2
Nominal aggregate size*	37.5 mm	26.5 mm
Layer thickness	75–100 mm	50–75 mm
IS Sieve 1 (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	95–100	100
26.5	63–93	90–100
19	–	71–95
13.2	55–75	56–80
9.5	–	–
4.75	38–54	38–54
2.36	28–42	28–42
1.18	–	–
0.6	–	–
0.3	7–21	7–21
0.15	–	–
0.075	2–8	2–8
Bitumen content % by	Min 4.0**	Min 4.5**
mass of total mix		

2 Aims and Objectives

To study the use of flexible pavement bagasse ash in DBM along with partial replacement of bitumen by Crumb rubber by wet mixing method. Finding an alternative method for eco-friendly disposal of Crumb rubber and bagasse ash. To find an appropriate alternative in flexible pavements to conventional materials with cost reduction & improvement in strength & other parameters. Using waste material in flexible paving without growing unit costs and without sacrificing durability. Using software to verify the suitability of waste products in the flexible pavement.

3 Materials and Methods

3.1 Bitumen

The bitumen used in the 60/70 grade of penetration in this inquiry. As per IS code (India), the bitumen used in the bitumen investigation characteristics was verified. Table 2 shows the properties. To determine the optimum content of asphalt, bitumen content as per minimum MoRTH is 4.5 specified table 500-10 as per grading 2 bitumen content was varied 4.0%, 4.25%, 4.5%, 4.75%, 5% by weight of asphalt blend. For each proportion, three samples are conducted too much. On the basis of the Marshall Stability Test, the optimum bitumen content was determined, corresponding requirement specification. Higher content of crumb rubber and bagasse ash had a powerful impact on the reduction of bitumen penetration and ductility.

Table 2. Physical properties of bitumen

Sr. no.	Tests conducted	Test results	Specifications	IS codes
1	Specific Gravity	1.02	0.97–1.02	IS-1202
2	Flashpoint, °C	270	220 °C	IS-1209
3	Penetration test	65	50–90	IS-1203
4	Softening point test, °C	49	Min 55 °C	IS-1205
5	Ductility test	51	Min 40	IS-1208

4 Crumb Rubber

The fast growth of the automotive sector and a greater standard of living of individuals in India, the number of cars raised significantly, India facing the environmental issue of large-scale waste tires disposal. How to handle the enormous amount of waste tires in India has become an urgent environmental issue. Every year, tens of millions of tires are discarded throughout the Middle East. Because tires have a long life and are non-biodegradable, disposal of waste tires is a challenge. The traditional technique of managing waste pneumatics was storage or illegal dumping or landfilling, all of which are a short-term solution.

The world's disposal of waste tires has three main methods to cope with such things as landfills, burning & recycling. Scrap tire (recycled tire rubber) applied to pavement can be the best way to reduce large quantities of waste tires while at the same time improving the engineering properties of asphalt mixtures.

Crumb rubber is a word used in automotive and truck scrap tires for recycled rubber. There are two significant technologies for mechanical processing of the ambient crumb rubber and cryogenic processing of the two procedures, the cryogenic method is more costly but it generates smoother and lower crumbs.

This article uses a moist method to present experimental studies on recycled asphalt mixtures modified by tire rubber. The advantages of wet alteration are the extensive and controllable interaction between rubber and bitumen that enables elevated binder quality to be obtained.

Waste tyre at Karad near NH4

Crumb rubber

4.1 Ambient Mechanical Grinding

The breaking up of a scrap tire occurs at or above ordinary room temperature during the ambient mechanical grinding process. Ambient grinding is a multi-step technology that utilizes whole or pre-treated shredded car or truck tires, or sidewalls or treads. Sequentially separate the rubbers, metals, and fabrics. Pneumatics pass through a shredder that breaks the tires into chips.

The chips are fed into a granulator which, while removing steel and fiber in the process, breaks them into tiny pieces. Any remaining steel and fiber are separated magnetically By combining shaking displays with wind seams. In secondary granulators and high-speed rotary mills finer rubber particles can be acquired by further grinding. Ambient grinding is the manufacturing method most crumb manufacturers are using. The machines most frequently used in ambient crops for fine grinding are:

(1) Secondary granulators
(2) High-speed
(3) rotary mills
(4) Cracker mills

4.2 Cryogenic Grinding

Cryogenic grinding refers to grinding scrap tires with liquid nitrogen or commercial refrigerants at temperatures near minus 80 °C. Cryogenic processing uses pretreated car or truck tires as feedstock, most often in the form of chips or granulates produced in the environment using fluid nitrogen or commercial refrigerants to embitter the rubber, processing takes place at very low temperatures. It can be a four-phase scheme that involves an original decrease in size, refrigeration, separation, and friction. The material enters a freezing chamber where liquid nitrogen is used to cool it from −80 to −120 °C, below the stage where rubber stops acting as a flexible material and can readily be crushed and broken.

In a hammer mill, fibers and metal are readily segregated due to their brittle state. The granulate then moves through a sequence of magnetic screens and seals to remove the last remains of impurities. This method needs less power than others, producing much finer quality rubber crumb.

Paravitasri Wulandari et al. (2016) demonstrated the usefulness of crumb rubber as an additive in asphalt concrete mixture, which is recycled tire rubber, as an additive in a warm blend of asphalt is regarded a sustainable method of building. Crumb rubber adding crumb rubber to the proportion tends to boost asphalt mixture strength and quality. Modified blend required less asphalt content to improve stability and reduce inflow crumb rubber.

N. S. Mashaan et al. evaluated the addition of crumb rubber to the bitumen binder to enhance the physical characteristics of the rubberized bitumen binder as demonstrated by decreased penetration and ductility and increased elastic recovery, thereby enhancing the elasticity of the rubberized binder and enhancing its ability to withstand deformation. The higher concentration of crumb rubber has a clear effect on the rheological properties of rubberized bitumen with increased complex modulus, storage modulus, loss modulus, and reduced angle of phase. The addition of crumb rubber in bitumen positively marks the rutting factor, thus, improving the rutting resistance of the rubberized pavement mix. As proved, the high correlation coefficient values are reasonably indicative of an adequate level of consistency on the effect of crumb rubber satisfied on the physical and rheological properties of the rubberized binder.

Davide Lo Presti concentrated on the conduct of the road pavement technology of Rubber Modified Bitumen (RTR-MBs). Indeed, the several assistances to asphalt pavement efficiency and general infrastructure sustainability are so evident that it is highly recommended to consider RTR-MBs techniques as a first alternative to the binders presently used in road pavements. The High Viscosity wet process technology, which has been commonly demonstrated to provide several advantages, enables highway developers in specific to decrease pavement layer thickness owing to rubberized bitumen's demonstrated characteristics.

Rokade's report on the use of LDPE and CRMB indicates that the Marshall Stability value, which is Semi-Dense Bituminous Concrete's strength parameter, showed an increasing trend and the maximum values increased by about 25% by adding LDPE and CRMB. Not only has this research favorably enhanced the waste plastics and tyres in the road construction industry, but it has also effectively enhanced the significant boundaries that will ultimately lead to better and longer highways.

Plastics-waste is covered over aggregate in the altered method (dry process). This enables to bind bitumen better to the plastic-waste covered aggregate owing to enhanced bonding and enhanced contact region between polymer and bitumen. The coating of the polymer also decreases the voids. This prevents trapped air from absorbing moisture and oxidizing bitumen. Weidong Cao (2007) concentrated on the characteristics of recycled tyre rubber modified asphalt mixtures using dry process Testing of three kinds of asphalt mixtures holding distinct carbon content (1%, 2% and 3% by weight of complete blend) and a control combination without rubber.

Based on the outcomes of rutting trials (60 C), indirect tensile tests (10 C) and variance analysis, the inclusion of recycled tire rubber in asphalt mixtures using dry processes could improve the engineering characteristics of asphalt mixtures, and the rubber content has an important impact on the Performance of continuous elevated temperature deformation resistance and low temperature cracking (Table 3).

Table 3. Tests on crumb rubber modified bitumen (crumb-60)

Sr. no.	Test conducted	Test results	Specifications	IS code
1	Specific Gravity	1.03	0.97–1.02	IS-1202
2	Flash point,° C	290	220 °C	IS-1209
3	Thin film oven test			
(A)	Penetration value before conducting TFOT mm	35	30–50	IS-1203
(B)	Reduction in Penetration value after conducting TFOT %	14.28	Max up to 35%	IS-1203
(C)	Loss in mass by heating %	0.075	1	IS-9382
(D)	Increase in softening point, °C, Max	1.00	6 °C	IS-1205
4	Separation Test			
(A)	The softening point before the test, °C	62.00	Min 60 °C	IS-1205
(B)	Softening point after test, °C		The difference in softening point, Max 3 °C	IS-1205
	Top portion	61.00		
	Bottom porion	60.30		

5 Bagasse Ash

Sugarcane Bagasse Ash Sugarcane bagasse is the sugarcane refinement natural product. It is the fiber left to make juices after the process of extraction that comes from the sugar cane. Sugarcane is one of the non-wood fibers species that are heterogeneous, hygroscopic and have a big percentage of very thin-walled cells. When the juice was extracted from sugarcane, the amounts of product volumes in sugar factories make it a waste product. It usually utilizes furnaces as a fuel in the same sugar mill that generates about 8–10% of ashes. Sugarcane bagasse is a natural fiber that is widely used in the construction industry such as banana fiber and softwood pulp. The fiber can be split into two high-E components, asbestos fibers, carbon fiber and glass, and low-E fibers consisting of two components of natural and synthetic fibers. The bagasse is commonly used as a fertilizer and biofuel product because it is crushed in ethanol every 10 tons of sugarcane; almost three tons of moist bagasse is produced by a sugar factory. Because bagasse is a by-product of the cane sugar sector, the manufacturing amount in each nation is consistent with the amount of sugar cane generated.

The high moisture content of bagasse, typically 40–50%, is detrimental to its use as a fuel. In general, bagasse is stored prior to further processing. For electricity production, it is stored under moist conditions, and the mild exothermic process that results from the degradation of residual sugars dries the bagasse pile slightly. For paper and pulp production, it is normally stored wet in order to assist in the removal of the short pith fibers, which impede the papermaking process, as well as to remove any remaining sugar.

M. Zulfikri, M. Zainudin et al. was discovered to be 0.34% ash content focused on Optimum Sugarcane Bagasse. The quantities of SCBA used were 5.63% from 0.1 to 0.5% by weight of the upper limit OAC filler. The study results showed that modified mixtures using SCBA are effective in increasing the Marshall stability, flow, and resilient module by 0.6%, 4.9%, and 17.4% of ordinary HMA respectively. Compared to unmodified mixtures, the VTM is also greater, and this would affect the rutting strength of these mixtures. Air void content of 4.94% for the altered sample is sufficient to provide room for asphalt expansion to prevent bleeding or flushing cabin in order to improve rutting susceptibility and decrease pavement skid resistance. The use of SCBA as a filler in HMA was therefore discovered to be appropriate for use in road pavements and as an alternative material to profit from environmental and financial elements.

Due to the HRS combination with a variety of filler-containing 60%, David D.M. Huwae noted that Bagasse-ash is the ideal composition compared to the others (20%, 40%, 80%, and 100%). The outcome shows that Bagasse-ash is appropriate as a filler based on testing of a variety of Bagasse-ash and cement content (Marshall-stability test 1205,040 kg; flow test 4,427 mm; Marshall-Quotient 273,717 kN/mm; VMA 20,249%; VFA 74,206% and VIM 5,223%). Using Bagasse-ash as a filler can both reduce the need for cement fillers and provide a relatively elevated economic value as well as overcoming current waste.

5.1 Application of Bagasse Ash

5.1.1 Fuel

Bagasse is often used in sugar mills as a primary source of energy. When burned in quantity, it produces enough heat energy to supply with energy to spare all the needs of a typical sugar mill. To this end, cogeneration, the use of a fuel source to supply both heat energy used in the mill and electricity, typically sold on the consumer electrical grid, is a secondary use for this waste product.

5.1.2 Pulp, Paper, Board and Feed

In many tropical and subtropical nations, Bagasse is widely used as a wood replacement for pulp, paper, and board manufacturing such as India, China, Colombia, Iran, Thailand, and Argentina. It generates pulp with physical characteristics that are well suited for generic printing and writing documents as well as tissue products but is also commonly used in the manufacturing of boxes and newspapers. It can also be used to make plywood or particle board-like panels, called bagasse boards, and is regarded as a useful replacement for plywood. It is widely used to make partitions and furniture.

5.1.3 Aggregates

The aggregates used in laboratory research are composed of crushed rock, crushed gravel or other difficult material held on the 2.36 mm sieve. They shall be clean, difficult, and durable, cubic in form, free of dust and soft or friable matter, organic or other harmful matter. 20 mm, 12 mm, 6 mm and dust aggregates used in this research. Tests on aggregates were performed to assess the fundamental physical characteristics along with aggregate gradation (Tables 4, 5, 6).

Bagasse ash

Testing laboratory experiments on both plain and altered binders were performed to evaluate their characteristics and to verify that they fulfill the IS requirements. Tests have shown that the characteristics are within IS boundaries.

Table 4. Chemical composition of Bagasse ash

Item	Percentage (%)
Carbon	10.91
Silica (Sio2)	72.33
Magnesium	0.58
Calcium	0.63
Aluminum (Al203)	3.24
Ferrum	0.85

Table 5. Test on aggregates

Sr. no.	Properties tested	Unit	Results	Specification limits for bituminous concrete (BC) as per MoRTH(2001)
1	Los Angeles abrasion value	(Percent)	16.76%	30% (max)
2	Combined flakiness and elongation indices	(Percent)	14.00%	30 (max)
3	Water absorption	(Percent)	1.30%	2 (max)
4	Specific gravity (CA)	(g/c m^3)	2.68	2–3
5	Specific gravity (FA)	(g/c m^3)	2.66	2–3
6	Aggregate impact value	(Percent)	13.60%	24 (max)

Table 6. Blending of aggregates

Proportioning of materials	25 mm	20 mm	12 mm	6.3 mm	Dust	Total
		0.270	0.230	0.190	0.310	1.000

5.2 Marshall Stability Test

The Marshall specimens are ready to grade the DBM grade 2 mixes for the acquired mixture gradation. The samples are ready in accordance with ASTM D6927-06 (Bituminous Mixtures Standard Test for Marshall Stability and Flow). The samples were casted using standard VG 30 binder and Modified Binder Crumb Rubber (CRMB 60). Bagasse ash was used as a partial substitute for the filler to prepare the samples. The bagasse ash used in both standard and crumb rubber modified blend as partial filler substitute was varied from 1% to 3% and the corresponding optimum bitumen content was acquired from Marshall Stability test outcomes. It was noted that 7.5% o can be substituted by bagasse ash, which provides maximum stability and requires marshall values for both simple and altered DBM mixes as per MoRTH.

5.3 Preparation of Specimen

Aggregate fractions of sizes 25 mm, 20 mm, 12 mm, 6 mm and stone-dust (and bagasse ash) passing 2.36 mm and maintained in 75 µ is used as a gradation blend. For both simple and altered bitumen, specimens are cast. The mold's size is 1000 mm in diameter. Aggregates and Binder weight are calculated using Bulk Density from the Marshall Stability Test. For the VG-30 blend, the aggregates are preheated to 165 °C and the CRMB-60 mix to 185 °C. Binder is heated to the consistency of pouring. For the corresponding binder, the aggregates and the binder are blended in the pan and the temperature of the mixture is preserved as per IRC: SP:53. Bagasse ash is weighed while casting the blend with the filler and then added with aggregates to the pan. The blend for the necessary thickness is compacted using UTM well within the compacting temperature. After letting the specimen in the mold for 24 h, the specimen is de-molded and dimensions are measured to ensure the correct thickness.

5.4 Water Sensitivity Test

Marshall Moulds is ready for 7% air voids by compacting the samples on either hand for the comparable water sensitivity test. Indirect tensile strength and the proportion of conditioned to unconditioned specimen are screened for the unconditioned and conditioned samples.

Gradation variation after 10% Bagasse ash is one of the main variables for decreasing strength and keeping the blend temperature becomes hard as the bagasse ash percentage increases.

5.5 Optimum Asphalt Content

Asphalt content varied at 4.00%, 4.25%, 4.5%, 4.75% and 5% by weight of asphalt blend to determine the optimum asphalt content. For each variation in asphalt content, three samples were screened. The optimum asphalt content was determined in accordance with the requirement specification based on the mixed outcomes of the Marshall Test.

5.6 Marshall Stability and Optimum Binder at Varying Crumb Rubber Percentage in VG-30 BC Mix

As the percentage of Crumb rubber replacement increased from 1% to 3%, the stability and optimum binder content of the VG-30 BC mix is increased. Binder content at 3% crumb rubber at an optimum of 5% but greater than the control combination without crumb rubber.

5.7 Marshall Stability and Optimum Binder at Varying Bagasse Ash Percentage in CRMB-60 BC Mix

With the addition of bagasse ash for 10% substitute, stability has risen and after the strength has declined after 10% owing to multiple bagasse ash features. The gradation variation after 10% bagasse ash is one of the main variables for decreasing strength and keeping the mixture temperature becomes hard with the rise in the bagasse ash proportion.

5.8 Effect of Optimum Bagasse Ash on Gradation of Aggregates

The decrease in stability at 15% bagasse ash replacement and further was noticed from Marshall Stability test results, this can be explained by plotting a graph for 10% optimum bagasse ash replacement which clearly indicates the obtained gradation after the replacement is very close to deviating away from the desired mort&h DBM grade 2 gradation.

6 Results and Discussion

The conclusions of this study are defined as the following based on the outcomes of the laboratory investigation Crumb rubber is recommended as an additive in asphalt mixture. Adding a crumb rubber tends to boost asphalt mixture strength and quality. Increased stability and decreased flow are shown. Modified asphalt combination of crumb rubber required less asphalt content. However, the low content of asphalt improves air void in the blend and thus the permeability of blend improves the durability of asphalt blend. Therefore, due to the reduced asphalt content in crumb rubber-modified asphalt blend, there should be more concern about the durability of the asphalt blend. The use of SCBA as a filler in HMA was found suitable to be used for road pavement and as an alternative material that will benefit in environmental and economic aspects.

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