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# Impact of Crumb Rubber as Mineral Filler on Bituminous Concrete Mix

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**Abstract:** Disposal of scrap tyres has become a challenging problem these days and can be a potential reason for health hazard. One of the by-products of the scrap tyres shredding process is Crumb Rubber. Fillers are the materials that have size less than 75 $\mu$ . An attempt has been made to study the effect of crumb rubber as a mineral filler in bituminous mixes. Crumb rubber at 3.5%, 5%, 6.5% and 8% by the weight of the total mix has been used.

Marshall Stability and flow test were performed and Optimum bitumen content was determined followed by retained stability test on the samples that meet the minimum stability criteria of 900kg. it was found that Crumb rubber performed poorly as a filler material and could meet the minimum stability criteria at 5% filler content at 5% and 6% bitumen content only. Only 5% Crumb rubber at OBC of 4.60% could meet the minimum stability criteria.

Further 5% crumb rubber could not retain its stability on moisture exposure. Hence use of crumb rubber as a filler in bituminous mixes is unadvised.

**Keywords:** Crumb Rubber, Marshall stability, Retained Stability, Optimum Bitumen Content, Fillers.

## I. INTRODUCTION

Transportation infrastructure is the backbone of any economic activity. This has a special importance for developing countries like India where road network forms one of the primary systems for moving goods and services and thereby supporting economic activities.

Since the country witnesses all kinds of seasons in various parts of the country especially monsoon, requirement of an all-weather road network system should not come as a surprise. At the same time construction of all-weather roads can be a challenging and costly task.

This calls for better understanding and incorporating scientific and practical approach along with proper construction practices so as to achieve the required aim of an efficient road network system. Since the surface course is the topmost layer, it is the one subjected to not only a high amount of stress but also wear and tear. Therefore, whether a road functions in all weathers will be heavily dependent on the structural strength and integrity of the surface course. Any pavement layer consists of aggregates of different sizes and properties.

Coarse aggregates, fine aggregates, fines and binder which is almost exclusively bitumen, are mixed together in right proportion to form wearing course. The decision to use different materials and their proper proportioning comes under the domain of an extensive and scientifically engineered process of mix design.

Those materials that pass the 75  $\mu$ m sieve are known as fillers. Researches have shown that fillers directly or indirectly affect the mixing and workability characteristic along with the required optimum bitumen content (OBC). Fillers have been instrumental in affecting the strength, durability and other performance characteristics of a mix. Conventionally, various materials like lime, cement, stone dust etc. have been used as fillers.

But the growing awareness about using waste or recycled materials especially in the construction industry has paved way for various non-conventional materials to be used as fillers in road construction. In many cases they have served as a viable and economical substitute for conventional materials especially at local levels where their availability is not a problem. Land disposal of scrap tires has been a challenging task for engineers.

They serve as breeding grounds for mosquitoes and rodents.[1] Hence potential use of crumb rubber in road construction should be studied to see whether it can serve as a material in road construction.

## II. OBJECTIVES

- A. Study the impact of Crumb rubber as a mineral filler on the Marshall Stability, flow, OBC and other volumetric parameters
- B. To study its impact on moisture susceptibility of the mix.

### III. MATERIALS AND CHARACTERIZATION

The following materials along with their physical and mechanical properties have been used in the study:

#### A. Coarse and Fine Aggregate

Coarse and Fine aggregates were obtained from a local crusher with the following properties:[2][3]

Table I Aggregate Physical Properties

Type of aggregate	Material Properties	Test Procedure
Coarse Aggregate	Absolute Specific Gravity: 2.63 Apparent Specific Gravity: 2.72 Water Absorption: 1.2%	IS:2386 (Part 3)-1963
Fine Aggregate	Specific Gravity: 2.71	IS:2386 (Part 3)-1963

Table II Aggregate Mechanical Properties

Aggregate Property	Sample 1	Sample 2	Average Value	Test Procedure
Aggregate Impact Value	13.25%	12.70%	13.00%	IS:2386 (Part 4)-1963
Aggregate Crushing Value	22.06%	20.86%	21.46%	IS:2386 (Part 4)-1963
Los Angeles Abrasion value	20.66%	22.02%	21.34%	IS:2386 (Part 4)-1963

#### B. Bitumen

VG-10 Grade of bitumen has been used throughout the study. Bitumen used was VG-10 Grade obtained from Delhi Bitumen Sales, sector 7 Chandigarh.[4][5]

Table III Test on Bitumen

Test	Sample 1	Sample 2	Average	Test Procedure
Penetration Test	87.32	87.05	87.17	IS 1203-1978
Softening Point	44.51°C	45.60°C	45.06°C	IS 1205-1978
Specific Gravity	1.02	1.02	1.02	IS 1202-1978
Ductility (cm)	82	86	84	IS 1208-1978

#### C. Filler

Crumb Rubber has been used as mineral filler. It was obtained from Ludhiana, Punjab. Specific gravity of crumb rubber was 0.82.

#### IV.METHODOLOGY

##### A. Specification of the Mix

Grading-I as per MORTH 2013[6] has been adopted with the following specifications:

Table IV Grading-I as per MORTH specifications 2013

GRADING	1
Nominal Aggregate Size	19mm
Layer thickness	50mm
IS Sieve (mm)	Cumulative % by weight of the total aggregate passing
26.7	100
19	90-100
13.2	59-79
9.5	52-72
4.75	35-55
2.36	28-44
1.18	20-34
0.6	15-27
0.3	10-20
0.15	5-13
0.075	2-8

##### B. Marshall Mix Sample Preparation and Testing

The samples were prepared as per the Marshall Mix Design test (ASTM D 1559. 1989) [7]. Oven dried aggregates along with the filler (Dried at 175-190 Degree Celsius) with weight equal to 1200 grams were mixed with the required amount of Bitumen heated till 130-140 degrees. The mixture is thoroughly mixed till the temperature reaches between 150-160 Degree Celsius. 75 blows were given to each face. The Marshall samples were left to cool in air for 24 hours. Then their weight in air, weight in water and saturated surface dry weight are measured. Then they were kept in water bath at 60 degrees for 30-40 minutes. After this they were tested in the Marshall Stability Machine at a constant loading rate of 50 mm/minute. The stability and flow values were noted.

##### C. Retained Stability Test

The Retained stability test requires two measurements:

- 1) Marshall Stability value of the first sample kept at 60 degrees in water bath for 30-40 minutes called the UNCONDITIONED SPECIMEN
- 2) Marshall Stability value of the similar sample kept at 60 degrees in water bath for 24 hours called the CONDITIONED SPECIMEN

Retained Stability is the ratio of Marshall stability of the conditioned sample to the unconditioned sample expressed as a percentage.

#### V. EXPERIMENTAL SETUP

##### A. Stage I: Sample Preparation And Testing: Marshall Mix Design And Testing Method

Preparation of Crumb Rubber filled samples were done at:

- 1) 4%,5%,6% and 7% Bitumen Content, each at 3.5% Filler content
- 2) 4%,5%,6% and 7% Bitumen Content, each at 5.0% Filler content
- 3) 4%,5%,6% and 7% Bitumen Content, each at 6.5% Filler content
- 4) 4%,5%,6% and 7% Bitumen Content, each at 8.0% Filler content

In the preparation of crumb rubber samples, the crumb rubber was first mixed with aggregates and then was charged with bitumen. Filler content is the percentage weight of the filler by the total weight of the mix.

##### B. Stage Ii: Determination Of Obc And Other Mix Design Parameters

After testing the samples, OBC were determined for samples at each filler content corresponding to 4% air void content [8]. The various other mix design parameters were evaluated. Mix design parameters were also evaluated corresponding to the OBC.

### C. Stage III: Retained Stability Test

Retained Stability tests were performed as per the procedure for those filler contents at their OBC's who satisfied the minimum Marshall Stability criteria of 900kg as per MORTH.

## VI. RESULTS AND DISCUSSIONS

### A. Effect of Crumb Rubber as a Filler

Table V Effect of Crumb Rubber

	Filler Content (%)	Bitumen Content (%)	Marshall Stability (Kg)	Flow (mm)	Air Voids (%)	VMA (%)	VFB (%)	Bulk Density (Kg/m <sup>3</sup> )	OBC (%)
Crumb Rubber	3.5	4	221.20	2.01	5.28	14.03	62.35	2252.8	4.04
		5	227.50	2.28	4.04	14.86	72.76	2253.6	
		6	409.50	2.41	2.91	15.74	81.52	2252.7	
		7	393.10	2.70	1.93	16.77	88.48	2248.6	
	5.0	4	743.47	1.57	5.02	13.52	62.82	2194.9	4.60
		5	982.20	1.97	3.42	14.02	75.58	2205.4	
		6	938.84	2.19	2.65	15.08	82.37	2197.1	
		7	800.80	2.60	2.23	16.65	86.61	2182.1	
	6.5	4	612.20	2.05	4.39	12.72	65.46	2148.6	4.34
		5	756.20	2.26	3.26	13.60	76.00	2149.3	
		6	318.50	2.83	2.35	14.60	83.90	2145.8	
		7	252.00	3.26	1.46	15.58	90.65	2142.3	
	8.0	4	101.20	2.98	4.06	12.17	66.64	2098.3	4.00
		5	122.85	3.36	3.12	13.12	76.31	2095.9	
		6	240.29	3.87	2.31	14.25	83.77	2091.4	
		7	129.58	4.28	1.45	15.17	90.43	2088.3	
	MORTH Specifications (5 <sup>th</sup> Revision)		900 (Min)	2-4	3-5	11-13 (Min)	65-75	----	5.2 (Min)

Table IV shows the Marshall Stability test results for Crumb rubber as a filler. From the results it is quite clear that Crumb rubber fails to perform as a filler material at almost all filler and bitumen contents. Only 5% crumb rubber at 5% and 6% Bitumen content is able to meet the minimum stability criteria with relatively lower values. 8% Crumb rubber registered exceptionally lower stability values indicating the higher amounts of crumb rubber progressively make the sample weak.

Table VI Effect of Crumb Rubber at its OBC

From the table VI it can be seen that only 5% Crumb rubber is barely able to meet the minimum stability criteria at OBC of 4.6%.

Crumb Rubber at its OBC	Filler Content (%)	OBC	Stability (Kg)	Flow value (mm)	VMA (%)	VFB (%)	Density (g/cc)
	3.5	4.04	227.50	2.27	14.86	72.76	2253.6
	5.0	4.60	905.00	2.21	13.70	71.00	2202.0
	6.5	4.34	682.10	2.10	13.20	69.40	2148.6
	8.0	4.00	101.20	3.00	12.20	67.00	2098.0



### B. Effect of Crumb Rubber at its OBC

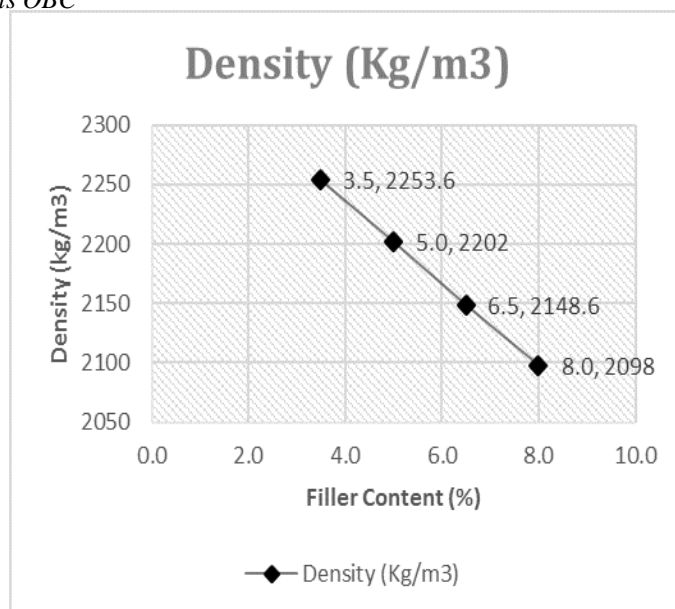


Figure 1 Density Trend for Crumb Rubber at Different Filler Contents

From the Figure 1 it can be seen that Crumb rubber samples exhibit particularly low and decreasing densities as the CR mixtures tend to swell or rebound after compaction affecting the mix volumetric. Adjustment with the aggregate gradation has to be made since the CR particles swell and we have to make space for them. This can be done by reducing the amount of screenings of like sized materials like the fines.[8]

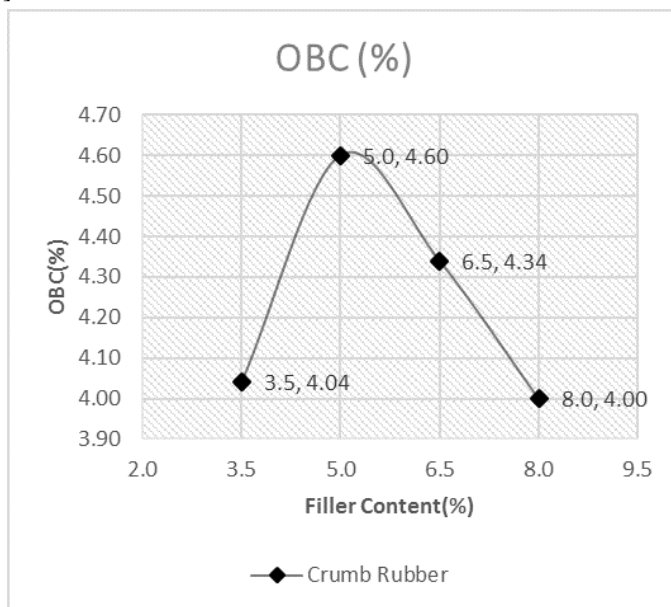


Figure 2 OBC Trend analysis for Crumb Rubber at Different Filler Contents

From the figure 2 it can be seen that although the OBC required for crumb rubber is low, it is below the minimum binder content requirement as per MORTH. The minimum bitumen is required to prevent the aggregates from being pulled out by the abrasive actions of moving vehicle on the carriageway [9]. Hence Crumb rubber is not able to perform against abrasive action of the traffic loading.

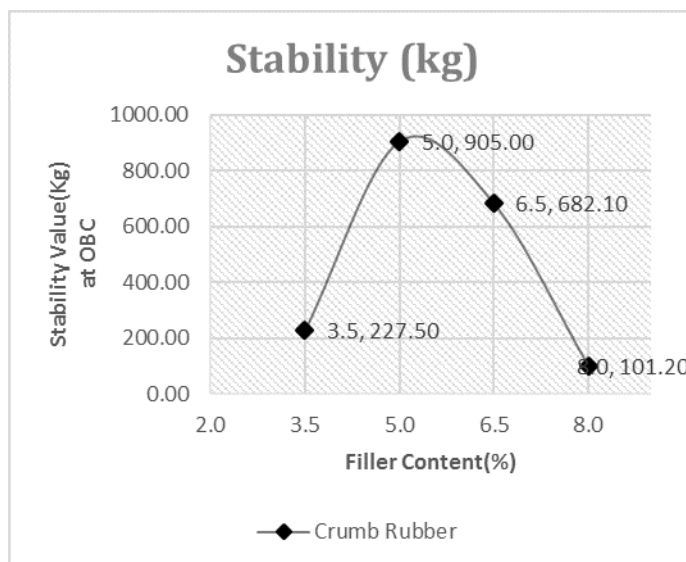


Figure 3 Stability Trend Analysis for Crumb Rubber at Different Filler Contents

From the Figure-3, it can be seen that Crumb rubber due to its lower overall density is not able to achieve compact mixes and therefore gets its low stability values.

### C. Retained Stability Test Result

Table VII Retained Stability Test

Retained stability of Crumb Rubber	Filler Content (%)				
	Contents (%)	3.5	5.0	6.5	8.0
	Value (kg)	-	617.2	-	-
	Percentage Stability Retained (%)	-	68.2	-	-

Table VII shows the results for retained stability test for various fillers at their OBC's. Retained stability tests were performed only for the fillers that satisfied the minimum Marshall stability criteria of 900kg at their optimum bitumen content. Crumb Rubber's retained stability value was unable to meet the minimum stability criteria of 75%. (MORTH) [10]. Hence Crumb rubber fails to keep the mix durable in the long run as it is very susceptible to moisture degradation.

## VII. CONCLUSIONS

- Crumb Rubber showed very poor performance as a filler (Only 2 values satisfied the minimum stability criteria). This should not be taken as an inherent weakness of the filler. This calls for studying the effect of adjustment in the gradation for Bituminous Concrete as Crumb Rubber has swelling tendencies and thereby require more space to fit. This can be done by making appropriate adjustment in the finer fraction of the gradation by reducing the amount of screenings of like sized materials. The effects then must be studied to make the final call for the use of crumb rubber in bituminous mixes
- CR, having the tendency to swell. Hence their use with open graded and gap- graded mix will be suitable. Hence it is suggested to make further studies on the use of CR in open and gap graded mixes.
- Crumb rubber fails to keep the mix durable in the long run as it is very susceptible to moisture degradation as it is unable to meet the minimum Retained Stability criteria of 75%.
- Use of Crumb Rubber exclusively as a mineral filler is unadvised. Although further studies are suggested to see if crumb rubber can be used in bituminous concrete by partially replacing the finer fractions with appropriate change in gradation.

## VIII. ACKNOWLEDGMENT

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