PERFORMANCE EVALUATION OF BITUMINOUS CONCRETE USING CRUMB RUBBER AND RECYCLED POWDER FILLER

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ABSTRACT

The disposal of rubber waste from various industries is a major issue in the current situation. Because these materials are not biodegradable, they pollute the atmosphere in the surrounding area. The majority of materials used in road construction are bitumen, cement, sand, dirt, and stone aggregate. Natural resources are getting harder to find. Additionally, it is becoming more expensive to extract high-quality natural material. It is advised that alternate materials be used while building highways in order to address this issue and potentially lessen pollution and disposal issues. By recycling waste materials, the use of crumb rubber for asphalt reinforcement is seen as a clever way to promote sustainable development. It is also thought that crumb rubber modifier (CRM), a different kind of polymer, may be able to enhance the performance characteristics of hot mix asphalt. The goal of adding recycled powder filler and crumb rubber modifier (CRM) to asphalt mixtures is to enhance the bitumen's characteristics. Therefore, the goal of this study is to assess how bituminous mix behaves when various waste items are introduced, as well as how well this mixture performs. The characteristics of CRM binder as a function of percentages were examined in a lab setting for this study. The optimum modification level has been evaluated considering un-aging and aging criteria for five CRM contents such as 5%, 10%, 15%, 20% and 25% by weight of the bitumen. The following testing methods were used to evaluate the binder: ductility, flash and fire point, penetration, and softening point tests. For the bituminous mixture: The Marshall Test has been carried out. The findings highlight the potential benefits of utilizing steel crumb rubber in bituminous mix designs, including enhanced sustainability and reduced environmental impact, while maintaining or even improving pavement performance.

Keywords: Crumb rubber modifier (CRM), Marshall test, Powder filler, sustainability, sustainable development, asphalt.

INTRODUCTION

Bituminous mix design using crumb rubber is a waste product of tires, into the mix to enhance the performance and sustainability of asphalt pavements. This approach aims to utilize crumb rubber as cost-effective alternative of bitumen material, while also reducing its environmental impact. The mix design process typically includes selecting appropriate proportions of aggregates, crumb rubber and bitumen, along with additives if necessary, to achieve desired engineering properties such as stability, durability, and resistance to deformation. The key steps in this process involve aggregate characterization, gradation analysis, volumetric analysis, and performance testing to ensure the resulting mix meets specific project requirement and performance criteria. By incorporating crumb rubber, limestone powder and glass powder in bituminous mix design, we engineer can potentially improve pavement performance and contribute to sustainable construction practices.

Materials Used:

Bituminous mixture consists of aggregate, filler, crumb rubber, glass powder, limestone and finally binder that can bind all of this material together and also to give the mixture its durability. The properties of each material and their function in the bituminous mixture are described in the following sections.

Aggregate

Aggregates are granular mineral particles; the aggregate used should be strong, tough, durable, and has the ability to be crushed into bulky particles without many flaky particles. In addition to gradation requirements, the aggregate is also required to possess the strength to carry and transmit the applied loads. There are four types of aggregate gradation namely, well-graded, gap graded, open graded and uniform graded. Some typical terms are used in describing the aggregates depending on their sizes. Coarse aggregate (gravel size) is the aggregate particles mainly larger than 4.75mm. Fine aggregate is defined for aggregate particles between 4.75mm and 0.075mm while filler is used to describe particles that are smaller than 0.075mm.

Bitumen

Bitumen refers to a group of naturally occurring, solid or semi-solid hydrocarbons. It is commonly found in crude oil and is also known as asphalt or tar..Formation: - Bitumen is formed from the remains of plants and animals that lived millions of years ago. These organic materials were buried by sediment and subjected to high pressure and temperature, leading to the formation of petroleum reservoirs.

Composition: - Bitumen is composed primarily of hydrocarbons, which are organic compounds made up of hydrogen and carbon atoms. It also contains smaller amounts of sulfur, nitrogen, oxygen, and trace minerals. The specific composition can vary depending on its source.

Crumb Rubber

Crumb Rubber is a granular material made from recycled rubber, typically from discarded tires. The tires are shredded into small pieces, resulting in granules that can vary in size. In the process, most of the steel wires and reinforcing fibers or fluff of the recycled tires are removed. The fine grinding is done by either the ambient method or the cryogenic method. The crumb rubber is often sieved and separated in categories based on gradation to meet the requirements of a particular application or agency. This difference in particle surface texture results in the ambient particles having higher surface area than the cryogenic crumb rubber.

Fig. 1

Limestone Powder

Limestone powder, also known as limestone fines or limestone screenings, is a by-product of limestone processing. It's created when limestone rock is crushed into smaller fragments during quarrying or mining operations. This fine powder consists mainly of calcium carbonate, the primary component of limestone. Limestone dust is often used in construction and landscaping as a filler material or as a component in concrete and asphalt mixes.

Fig 2

Glass Powder: -

Glass powder is a versatile material with a range of applications, particularly valued for its sustainability benefits when derived from recycled glass. High-quality glass powder is defined by its uniform particle size, purity, and appropriate chemical composition.

Fig 3

Physical tests on aggregate

The following tests were conducted in order to determine the physical properties of aggregates.

- Specific gravity
- Water absorption
- Aggregate impact test
- Aggregate crushing test
- Shape test
- Los-angeles abrasion test

RESULTS

Softening Point Test of Bitumen

The grade of bitumen on which test are performed is VG-30. Method of test according to IS 1205-1978.

Table 1

	% of Crumb Rubber (CR) with respect to weight of bitumen sample.	**Mean Temperature**
Temperature at which sample touches the bottom plate	0 %	43.5 °c
	5 %	50.5°c
	10 %	52.5°c
	15 %	53.5°c
	20 %	55.5°c
	25 %	56^0 c

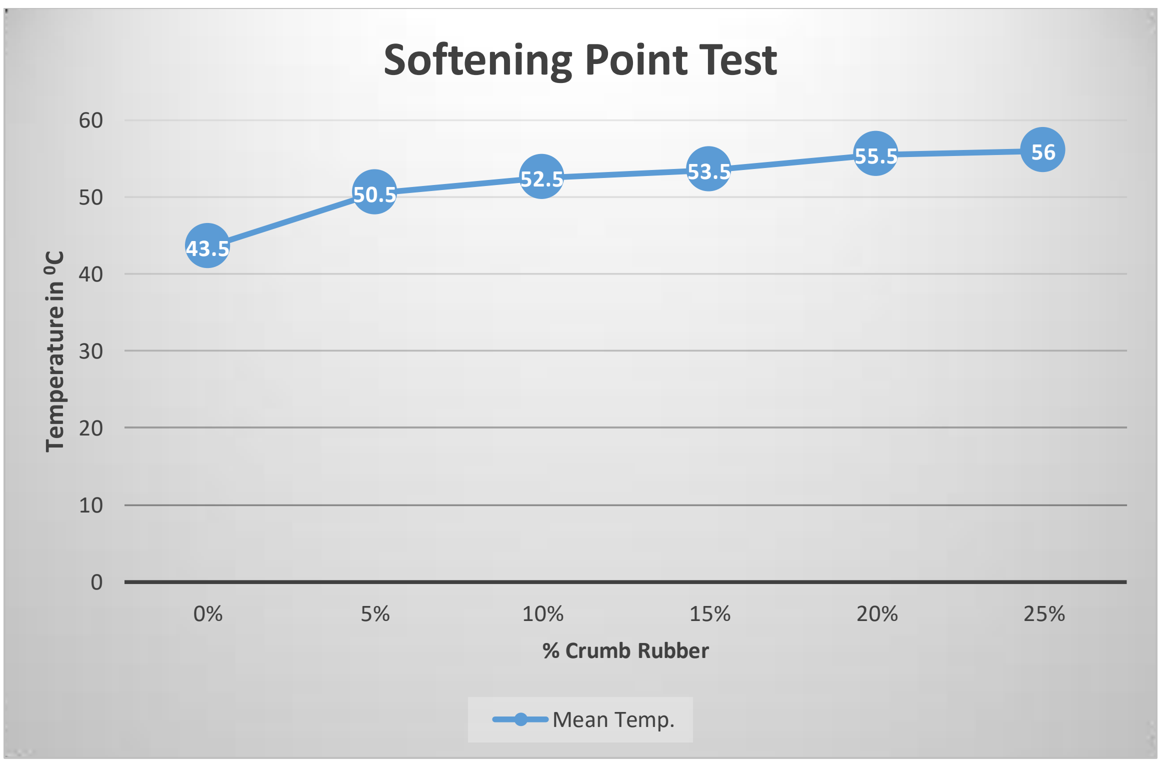

Fig 4

Remarks:

It is observed that as the percentage of plastic waste (low density polymer) is increased with respect to the weight of bitumen the softening point of the bituminous plastic waste (LDP) mix sample increases.

Flash and fire point of bitumen

The grade of bitumen on which test are performed is VG-30. Method of testing is then according to IS 1209-1978.

Table 2

% of Crumb Rubber (CR) with respect to weight of bitumen sample.	Flash point	Fire point
0 %	246.66°C	261.66°C
5 %	266.66°C	286.66°C
10 %	283.33°C	316.66°C
15 %	291.66°C	330°C
20 %	303.33°C	336.66°C
25 %	305^{0}C	340^{0}C

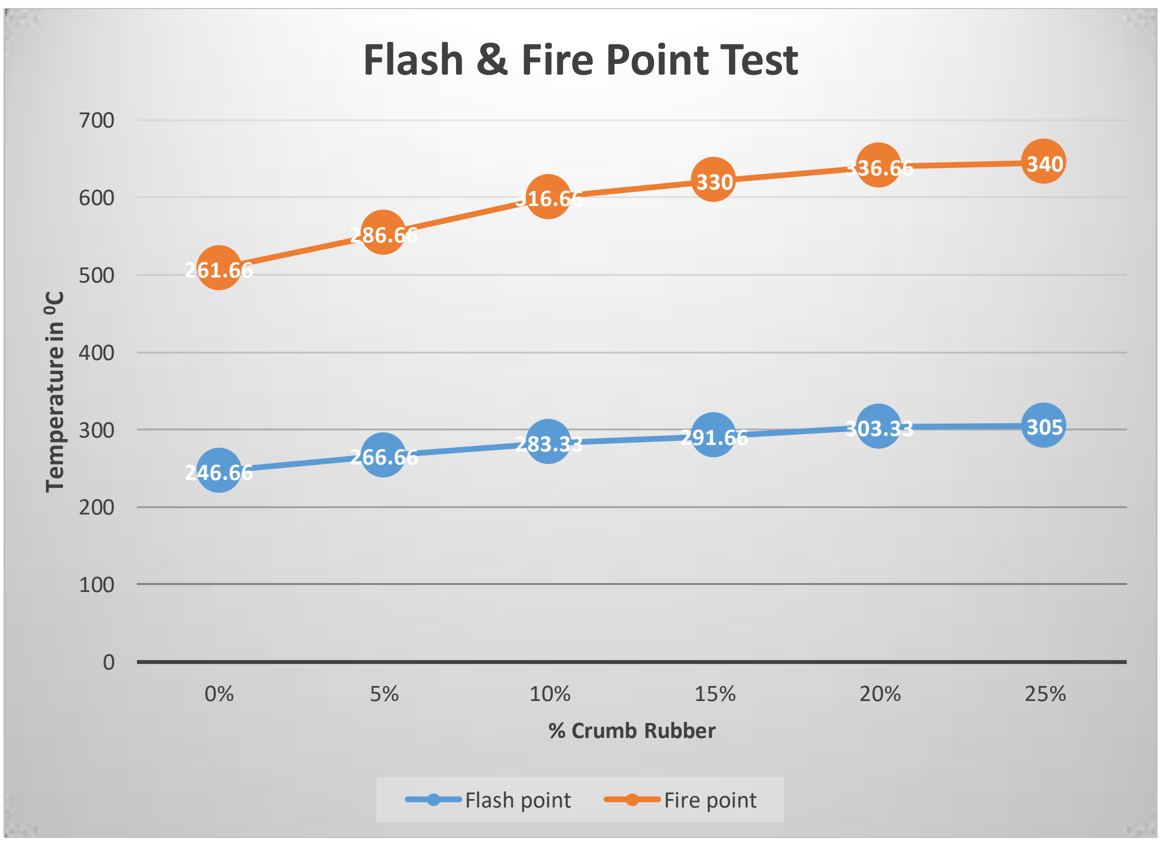

Fig 5

Remarks:
Flash and fire point of bitumen sample increases with increase in the percentage of Crumb Rubber (CR) with respect to the weight of bitumen used.

Penetration test of bitumen

Table 3

Method of test is according to IS- 1203-1978. Grade of bitumen used vg-30. **% of Crumb Rubber (CR) added with respect to the weight of bitumen sample**	**Penetration 1/10th mm**
0 %	88.67 mm
5 %	76.33 mm
10 %	**67.33 mm**
15 %	59.66 mm
20 %	52 mm
25%	50 mm

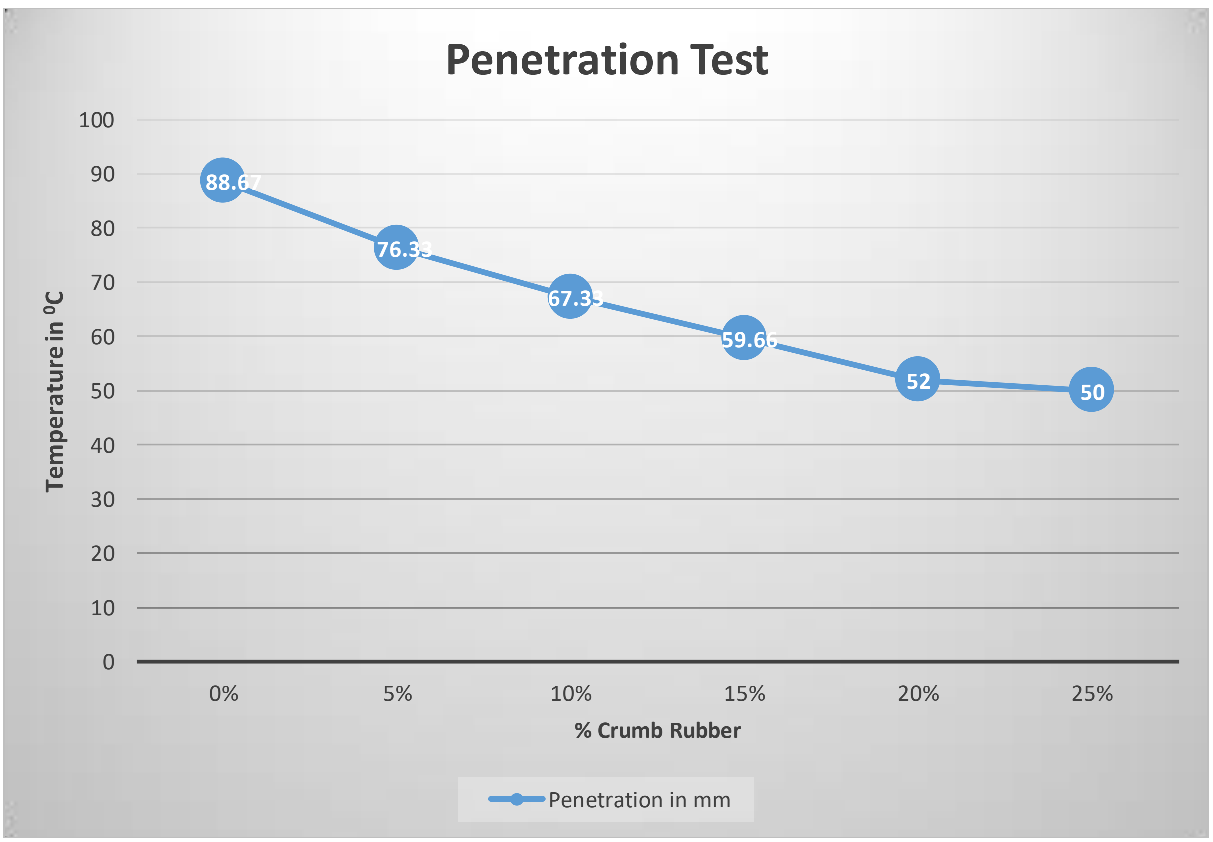

Fig 6

REMARKS
In the bitumen sample as the percentage of plastic waste (LDP) is increased with respect to the weight of bitumen, the penetration value of the bitumen sample is reduced.

Ductility test of bitumen

Table 4

Method of testing according to IS 1208-1978. Bitumen sample used vg-30. **% of Crumb Rubber (CR) added with respect to the weight of bitumen sample.**	**Ductility in cm**
0 %	93.33 cm
5%	89 cm
10 %	82.67 cm
15 %	**73.33 cm**
20 %	63.66 cm
25%	58.33 cm

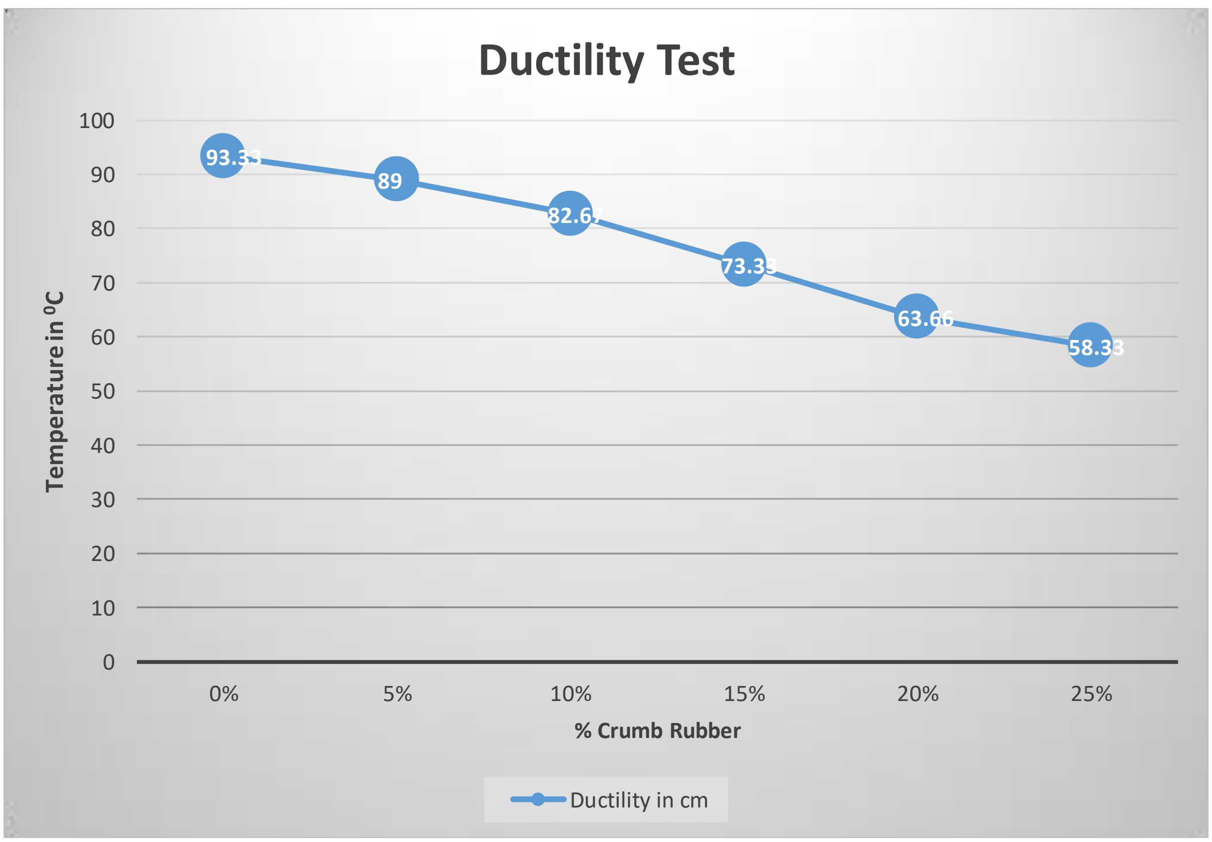

Fig 7

Remarks:

Ductility of the bitumen sample decreased as the percentage of Crumb Rubber (CR) added to the bitumen sample is increased.

Marshall stability test of bitumen

Bitumen used VG-30. Method of testing is according to ASTM D-1559.

Table 5

Results of 3% Glass Powder filler for Varying Percentage of CR

% of Crumb Rubber (CR) added with respect to the weight of bitumen mix sample.	Stability in kN	Flow in mm
0 %	16.87KN	5.63mm
5%	16.98KN	5.55mm
10 %	17.35KN	5.41mm
15 %	17.22KN	4.27mm
20 %	16.97KN	3.83mm
25 %	16.89kN	3.71mm

Table 6

Results of 3% Limestone filler for Varying Percentage of CR

% of Crumb Rubber (CR) added with respect to the weight of bitumen mix sample.	Stability in kN	Flow in mm
0 %	16.87kN	5.63mm
5%	17.38KN	5.47mm
10 %	18.45KN	5.34mm
15 %	18.22KN	4.90mm
20 %	16.57KN	4.07mm
25 %	16.47kN	3.94mm

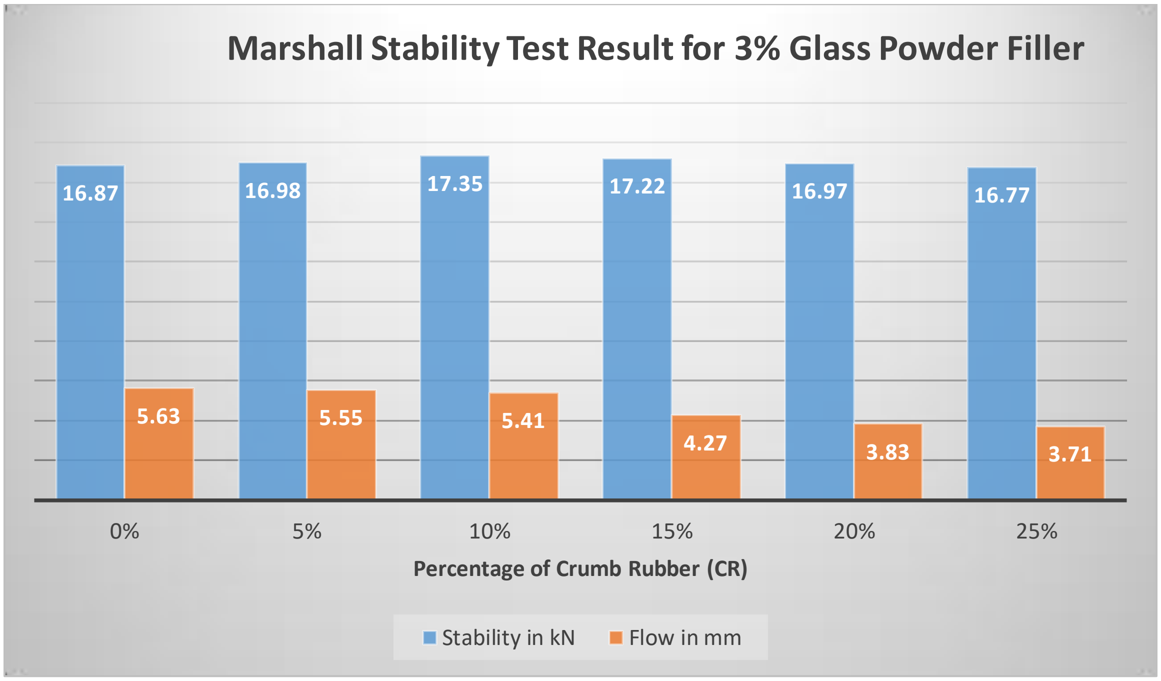
Marshall Stability Test Result for 3% Glass Powder Filler
16.87
5.63
16.98
5.55
17.35
5.41
17.22
4.27
16.97
3.83
16.77
3.71
0%
5%
10%
15%
20%
25%
Percentage of Crumb Rubber (CR)
Stability in kN
Flow in mm

Fig 7

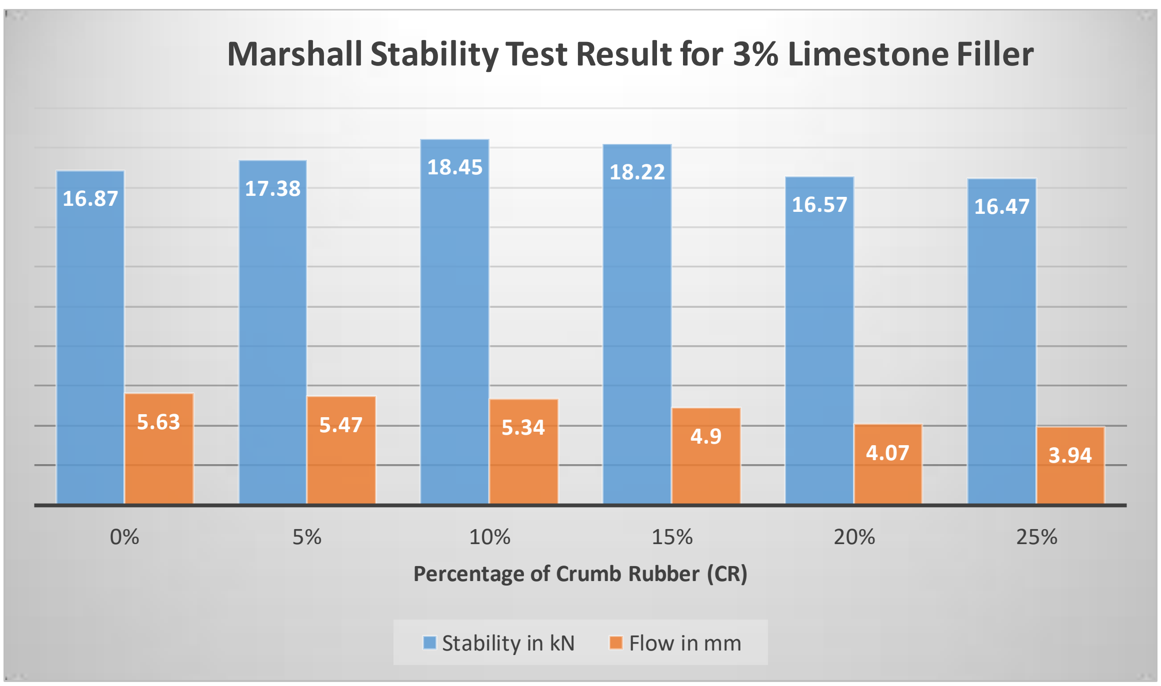
Marshall Stability Test Result for 3% Limestone Filler
16.87
5.63
17.38
5.47
18.45
5.34
18.22
4.9
16.57
4.07
16.47
3.94
0%
5%
10%
15%
20%
25%
Percentage of Crumb Rubber (CR)
Stability in kN
Flow in mm

Fig 8

Table 7
Results of 3% Glass Powder filler for Varying Percentage of CR

Properties	Stability in KN	Flow in mm	VMA (%)	Air Void (%)	VFB
0%, Crumb Rubber added bitumen	16.87kN	5.63mm	17.58	7.32	57.82
5% Crumb Rubber added bitumen	16.98KN	5.55mm	17.3	6.97	59.32
10% Crumb Rubber added bitumen	17.35KN	5.41mm	16.95	6.52	62.48
15%, Crumb Rubber added bitumen	17.22KN	4.27mm	16.22	6.05	64.55
20%, Crumb Rubber added bitumen	16.97KN	3.83mm	15.88	5.74	65.89
25%, Crumb Rubber added bitumen	16.89KN	3.71mm	15.68	5.44	66.84

Table 8

Results of 3% Limestone filler for Varying Percentage of CR

Properties	Stability in KN	Flow in mm	VMA (%)	Air Void (%)	VFB
0%, Crumb Rubber added bitumen	16.87kN	5.63mm	17.58	7.32	57.82
5% Crumb Rubber added bitumen	17.38KN	5.47mm	17.42	6.77	58.77
10% Crumb Rubber added bitumen	18.45KN	5.34mm	16.85	6.32	60.15
15%, Crumb Rubber added bitumen	18.22KN	4.90mm	16.32	6.15	62.88
20%, Crumb Rubber added bitumen	16.57KN	4.07mm	15.58	5.54	64.37
25%, Crumb Rubber added bitumen	16.47KN	3.94mm	15.18	5.14	65.47

Conclusion

1. The incorporation of crumb rubber affects the properties of the conventional bitumen. VG-30 bitumen which are generally used in flexible road construction. In the present research work, it was observed that the softening point of crumb rubber (CR) mix bitumen is increased by the increase of percentage of crumb rubber (CR) in bitumen from 5%, 10%, 15%, 20% and 25% respectively by 16%, 21%, 23, 27.5% and 28.73%.
2. In the present research work, it was observed that the flash and fire point of crumb rubber (CR) mix bitumen is increased by the increase of percentage of crumb rubber (CR) in bitumen from 5%, 10%, 15%, 20% and 25% respectively by 8.10%, 14.86%, 18.24% 22.97%, 23.65% and fire by 9.55%, 21.02%, 26.11%, 28.63%, 29.93%.

3. In the present research work, it was observed that the penetration value of crumb rubber (CR) mix bitumen is decreased rapidly by the increase of percentage of crumb rubber (CR) in bitumen from 5%, 10%, 15%, 20% and 25% respectively by 13.92%, 24.06%, 32.72%, 41.35% and 43.61%. Since the consistency of bitumen materials are measured by penetration test, the higher value of penetration represents softer consistency. In warmer area, lower penetration grade bitumen is preferred and in colder area, bitumen having high value of penetration is preferred.
4. It was observed that the ductility of crumb rubber (CR) mix bitumen is decreased rapidly by the increase of percentage of crumb rubber (CR) in bitumen from 5%, 10%, 15%, 20% and 25% respectively by 4.63%, 11.42%, 21.43%, 31.79% and 37.50%. Tensile properties of bitumen materials are measured by ductility test. Bituminous materials used in road construction should have sufficient ductility; otherwise the road surface would crack due to temperature variations or by the traffic load stresses which may cause the pavement to become pervious that can result in damage of the pavement structure. During day time, the pavement surface expands and during night time, pavement surface contracts. So, if the bitumen does not have sufficient ductility, cracking will occur in the pavement surface.
5. In the present research work, it was observed that the Marshall Flow value of crumb rubber (CR) with glass filler 3% dense bituminous mix of surface course is reduced and the Marshall Stability value is increased by the increase of percentage of crumb rubber (CR) in bitumen from 5%, 10%, 15%, 20% and 25% respectively by 1.42%, 3.91%, 24.16%, 31.97%, 34.10 and stability by 0.65%, 2.85%, 2.07%, 0.59% and 0.12%. Similarly by using 3% limestone filler the marshall stability value is increased upto 15% and flow value also shows the same result.
6. Since now days as the crumb rubberwaste materials are increasing day by day there efficient disposal has become difficult. The recycle of the crumb rubber(CR) material in the road construction has given us a new ray of hope and getting new innovative method so we can go towards the sustainable development of the city and thus by dropping man made dangerous impacts on the environment.

The following result concluded that for the optimum performance of the surface course of flexible pavement and to give us improved properties of bitumen material we can use crumb rubber(CR) of 15% to 20% with respect to weight of bitumen to give the desired results.

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