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Properties Study of Crumb Rubber Modified Bitumen

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Abstract

The properties of Crumb Rubber Modified Bitumen (CRMB) is presented. It is derived from by mixing crushed rubber with the base bitumen. The crumb rubber modifies the various properties of bitumen mix such as elasticity, durability, service life and voids. The present study aims in investigating the experimental performance of bitumen modified with various percentages (6%-14%) by weight of crumb rubber using the wet process. Marshall Test is used for the mix design and common laboratory tests such as softening point, penetration and ductility test are used to investigate properties of modified bitumen.

Key Words: *CRMB, Marshall Test, Wet process, Crumb Rubber*

Introduction

Waste tyres pose a great threat to the environment. Most of the tyres from truck, cars etc are dumped into the landfill and they are nonbio-degradible. Crumb rubber is identified as a modifier because its presence affects the properties of bitumen. The tyre rubber is composed of natural rubber, synthetic rubber, and carbon black. Natural rubber provides the elastic properties, while the synthetic rubber improves the thermal stability properties of the compound and carbon black improves the binder's durability[1,2]. The nature of the mechanism by which the interaction between bitumen and crumb rubber takes place is not still fully characterized. However, the reaction is found to be made up of two simultaneous processes: first the partial digestion of rubber into bitumen, and secondly the adsorption of aromatic oils available in this latter within the polymeric chains that are the main components of rubber. The rubber particles are swollen by the absorption of the bitumen oily phase only at high temperatures (160-220 °C). It is therefore very import to heat the mixture of bitumen and crumb rubber and then stir the mixture from 30-60 minutes to obtain a uniform mixture of CRMB. The interaction between rubber and rubber materials is dependent on following basic factors[2]; Processing variables: temperature, time and device, base binder properties: bitumen source and use of additives, RTR properties: source, processing methods, particle size and content.

Penetration point, softening point and ductility are three parameters which are used to determine the physical properties of bitumen, whereas Marshall Stability test symbolizes the strength parameter of a bituminous mix. Extensive researches carried out in rubberized bitumen shows that with the increase in rubber percentages, the softening point increases whereas the ductility and penetration value decreases[3-9]. The Marshall Stability, which provides the strength parameter in the flexible pavement, is found to

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increase with the addition of crumb rubber[3-9]. The rutting potential of CRMB is low as compared with conventional bitumen pavements and are more durable[10-14.] In this era, a rapid growth of road network is required in developing country like Nepal. Using the upgraded bitumen which improves the performance and service life is critical in our country with budget constraints.

Experimental Methods

Preparation of CRMB

At first 80/100 Penetration Grade bitumen was heated to fluid condition keeping temperature of 160^0C for blending purpose. Crumb Rubber of size 30 µm was also heated to about 160-170 ^{o}C. About 100 gm of 80/100 penetration grade hot bitumen and then crumb rubber according to varying rubber contents (6%-14%) were added to make the CRMB samples[3-9]. The mixture of bitumen and crumb rubber modifier were manually stirred for 3-4 minutes and then kept at hot air oven at 160-170 ^{o}C for 30 minutes.

Tests on Crumb Rubber Modified Bitumen (CRMB)

After the preparation of CRMB, various tests like penetration, softening and ductility tests were performed. The changes in parameters like penetration, softening and ductility with variation in crumb rubber content are shown in the results section.

Marshall Test with varying % of Crumb Rubber in OBC of conventional bitumen

The Optimum Binder Content (OBC) of 80/100 penetration grade bitumen was first fixed at 6%. Then crumb rubber was prepared in varying percentages by weight of OBC. The details of the test are given as follows:

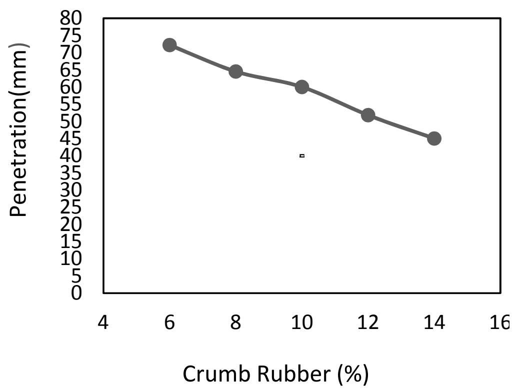
- Preparation of aggregate: Aggregates were dried to temperature of 175-190 ^{o} C. About 1200 gm of aggregate and filler was used. Gradation was done according to specifications[15,16].
- The optimum bitumen content was fixed at 6% i.e 72gm. The CRMB with varying percentages were then prepared. The CRMB and aggregates were mixed at temperature of 160-170 ^{o} C and the sample was transferred to the preheated mould and compacted by hammer (4.5 kg hammer 45.7cm freefall 50 no. of blows).
- The sample was kept at water bath at 60 ^{o} C for 35+-5 mins.
- Marshall Stability and flow test was then performed.
- Voids in total mixture, Voids in mineral aggregate and unit weight was calculated and plotted.
- Optimum binder content was found out by the average of binder content for maximum stability, maximum unit weight and voids in the total mix.
- The change in Marshall Stability and Flow value at various Crumb rubber percentages e then calculated. The results are displayed in the results section.

Results and Discussion

The penetration and ductility values go on decreasing with increase in crumb rubber content whereas the softening point increases.

Table 1: *Change in various properties with rubber content*

S.N.	Rubber (%)	Bitumen(%)	Ductility(cm)	Softening point(^oC)	Penetration(mm)
1	0	6	109	45	82
2	w6	6	80	44.85	72.2
3	8	6	56	45.4	64.5
4	10	6	42	46.4	60
5	12	6	30	48.2	51.8
6	14	6	25	50.5	45



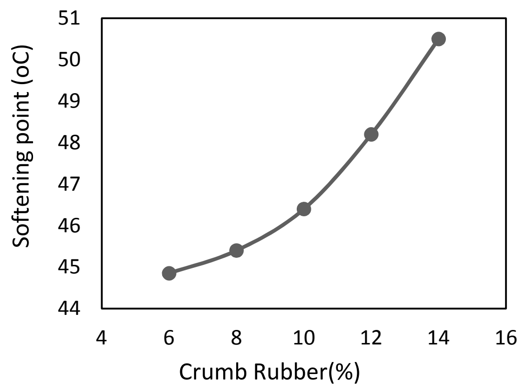


Figure 1: *Penetration vs Crumb Rubber content* ***Figure 2:*** *Softening Point vs Crumb Rubber content*

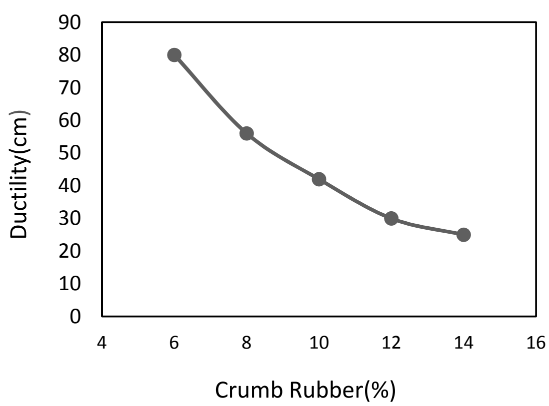


Figure 3: *Ductility vs Crumb Rubber Content*

Softening point is the indicative of the tendency of material to flow at elevated temperatures encountered in the service. With increase in crumb rubber content, the softening point is found to increase. Hence, high percentages of crumb rubber should be used in areas with higher average temperature.

Ductility is the material's ability to deform under tensile stress. As the crumb rubber percentage increases, the CRMB becomes more brittle and prone to failure at low tensile stresses. However, due to low ductility CRMB becomes favorable to be used in the areas with high temperature susceptibility.

The penetration is a measure of hardness or softness of bitumen binder and was used for grading of materials and assessing the suitability of bitumen in various climatic conditions. The penetration shows lower values as crumb rubber content increases which signifies that the binder becomes more stiff and viscous by the use of crumb rubber.

Marshall Test

Various percentages of crumb rubber by the weight of bitumen is added to form CRMB at various percentages and then three samples were prepared for the Marshall test. The details of the test results are given below:

Table 2: *Change in Marshall Parameters with Crumb Rubber Content*

S.N.	Rubber Content(%)	Flow(mm)	Stability(kg)
1	6	2.95	1310.015
2	8	2.75	1391.955
3	10	2.6333	1505.550
4	12	2.5	1397.461
5	14	2.425	1336.044

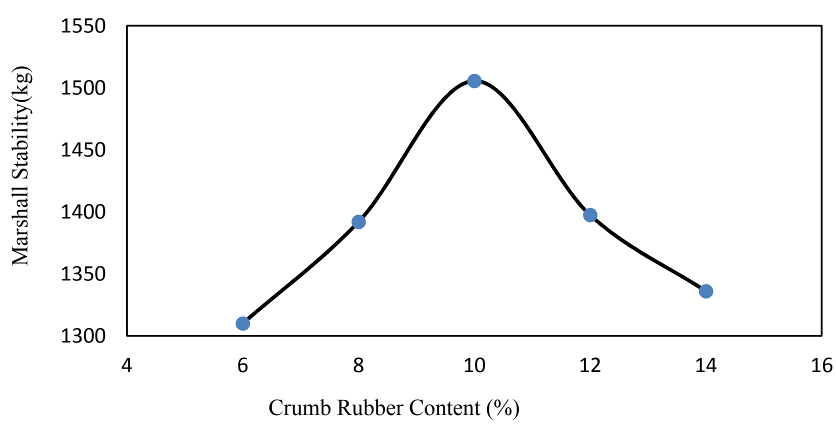


Figure 4: *Variation of Marshall Stability with Crumb Rubber Content*

The Marshall Stability at 6% OBC was found to be 1285.629 kg. With addition of rubber, the Marshall Stability value increases by 2-17%. The Marshall Flow value decreases which exemplifies the low ductile nature of crumb rubber.

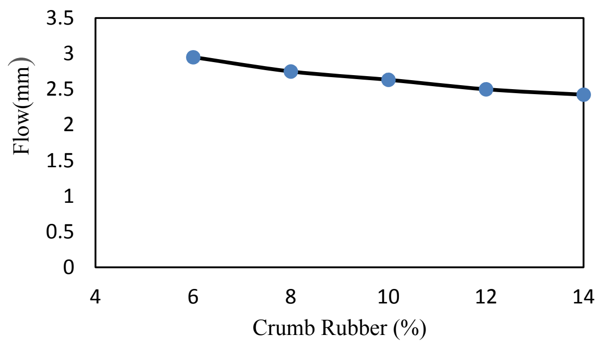


Figure 5: *Variation in Marshall Flow with Crumb Rubber Content*

The Marshall Stability, which is the strength parameter of the mix changes after the addition of rubber in following way.

Table 3: *Change in Marshall Stability with various percentages of rubber content*

S.N.	Rubber Content(% by wt. of bitumen)	Increase in Marshall Stability (%)
1	6	1.8
2	8	8.2
3	10	17.0
4	12	8.6
5	14	3.9

Table 4: *Variation of Marshall Parameters with different rubber content*

S.N.	Rubber Content	Bulk Unit Weight	Maximum unit weight	%VTM	%V.M.A	%VFB
1	6	2.301	2.414	4.691	17.340	77.055
2	8	2.3391	2.423	3.469	16.281	78.818
3	10	2.337	2.421	3.474	16.285	78.670
4	12	2.342	2.423	3.332	16.162	79.382
5	14	2.351	2.438	3.571	16.369	78.208

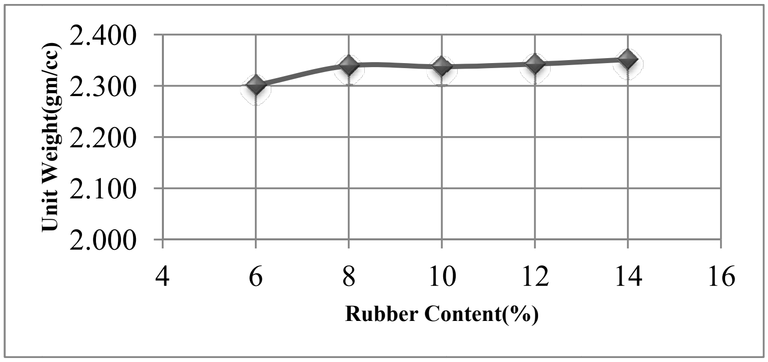


Figure 6: *Density vs Crumb Rubber content (%)*

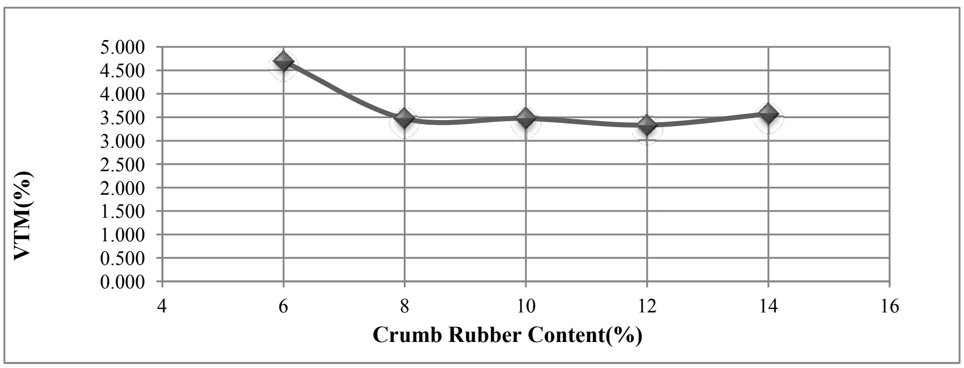


Figure 7: *VTM(%) vs Rubber (%)*

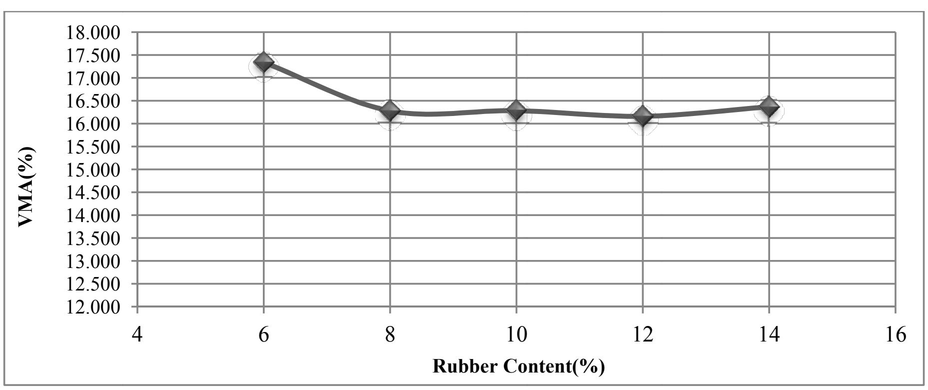


Figure 8: *VMA (%) vs Crumb Rubber Content (%)*

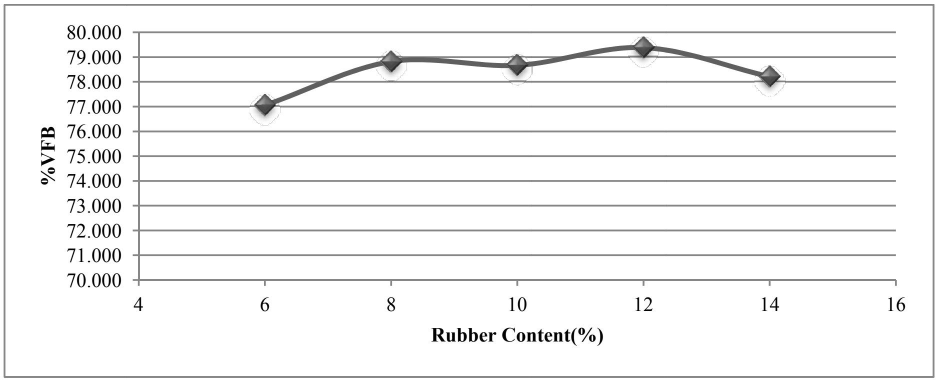


Figure 9: *VFB (%) vs Crumb Rubber Content (%)*

The bulk unit weight goes on increasing with the increase in crumb rubber content whereas the air voids decreases slightly. As we see from the table above, the %VMA and %VFB varies slightly.

The unit weight goes on increasing with higher rubber content and is greater than density of mix prepared with 80/100 penetration grade bitumen. Furthermore, the air voids as well as VMA decreases with respect to the base bitumen. The results indicate that the CRMB will be more durable, less moisture susceptible and can take more axle loads than the conventional bitumen.

Table 5: Requirements of Modified Bitumen Mixes IRC SP 53-2010

S.N.	Parameters	Recommended Value
1	Marshall Stability	Min 12 KN
2	Marshall Flow (mm)	2.5-4
3	Air voids (%)	3-5

The maximum Marshall stability is found at 10% of crumb rubber content, but the obtained ductility is only 42 cm at the particular rubber content. Hence, considering the penetration, softening and ductility tests the recommended optimum rubber content is 8%.

Conclusions

The CRMB shows variable properties with change in crumb rubber content. The percentages of crumb rubber to be added to base bitumen depend upon the field temperature, required ductility and penetration values. However, with small addition of crumb rubber, the Marshall Stability increases which indicates that the rubber-bitumen reaction enhances the strength of a bituminous mix, decreases air voids and provides durable flexible pavements. The value of optimum rubber content is 8% on basis of IRC consideration.

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