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Research Paper

# AN EXPERIMENTAL STUDY ON EFFECT OF WASTE TYRE RUBBER ON 60/70 GRADE BITUMEN

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Bitumen is an important binder used in flexible pavement construction. About 80% of the produced bitumen is used for pavement construction. The quality of the binders can be improved by their modification with polymers and rubber obtained from waste tyre. At the same time, utilization of waste rubber would solve a serious environmental problem. In the present study effects of Crumb Rubber (CR) obtained from waste tyre on physical and strength properties of 60/70 penetration grade bitumen are evaluated. The crumb rubber modified bitumen is prepared in the laboratory, taking CR content 2%, 4%, 6%, 8% and 10% by weight of bitumen. It is found that the physical and strength properties of the binder are improved due to the modification by waste tyre rubber.

***Keywords:*** Waste tyre, Modified bitumen, Crumb rubber

## INTRODUCTION

Factors such as durability, strength and economic need to be consider in design and construction of road pavement. To a large extend these factors are depends on the properties of binder. Bitumen is recognized as good adhesives and load resistant materials suitable for paving applications. The strength and durability of the bitumen can be increased by adding small quantity of polymer in it. Polymer, such as styrene–butadiene–styrene (SBS), has been shown to be very effective modifier for bitumen due to its thermoplastic elastomeric properties. Uses of SBS copolymers as bitumen additives are limited due to their high cost in comparison to bitumen. Therefore the use of crumb tyre rubber (CR) is an interesting alternative from both economical and environmental point of view. In the present study effect of CR on physical and Marshall Properties of bitumen have been studied.

## EARLIER STUDIES

Many studies have been carried out on the use of crumb rubber for modification of bitumen. Hak-Seo Kim (2010) claimed that the use of crumb rubber as a modifier have positive

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effects on rheological properties of the bitumen, including improved penetration resistance and less potential to permanent deformation. The creep compliance value for crumb rubber modified bitumen is considerably lower than neat binder. Addition of rubber to the virgin binder increases the complex modulus at higher temperatures, and lowered the phase angle at lower temperatures. Baha Vural Kök *et al.* (2011) concluded that both SBS and CR modified bitumen exhibited reduced temperature susceptibility with increasing additive contents. However, this trend was more pronounced for the SBS modified bitumen. Abdelkadar *et al*. (1996) based on laboratory investigation on modification bitumen by pyrolytic carbon black concluded that addition of pyrolytic carbon black in 5 to 30% of weight of the binder changes the rheological properties of the binder. The temperature susceptibility of the bitumen is reduced and the loss modulus and the storage modulus increase significantly at 30% pyrolytic carbon black. Also softening point, temperature susceptibility of penetration and viscosity are also improved by the addition of pyrolytic carbon black.

Praveen Kumar (2009) based on his laboratory study on rheological properties of crumb rubber modified bitumen found that the physical properties like penetration, ductility and softening point are improved due to addition of crumb rubber. It is also found that complex modulus increases with increase in modifier content but the phase angle decreases with increase in modifier. The increase in complex modulus and decrease in phase angle is an indication of higher resistance to deformation as compared to unmodified bitumen. Airey *et al*. (2002) reported that modified bitumen using crumb rubber showed an improvement in the performance of pavements over the base binders as a result of the interaction of crumb rubber with base binders. Due to this interaction, the viscosity, physical and rheological properties of the modified bitumen are improved.

## MATERIALS AND METHODS

For present study 60/70 penetration grade bitumen, obtained from Shell Corporation India is used as base material. The physical and strength characteristics of the base bitumen are as shown in Table 1.

The rubber used was a sample of reclaimed car tyres shredded into fine fibers. Apart from use as a bitumen modifier, this rubber is also used for playground surfaces and athletic tracks, carpet backing, brake pads, roofing and cattle mats. The sample used was derived from ambient grind of waste tyres. Table 2 contains typical constituent of crumb rubber as indication of content only.

**Table 1: Properties of Base Bitumen**

| Properties | Penetration Value | Softening Point | Ductility | Stability | Flow |
|---|---|---|---|---|---|
| Values | 67 (dmm) | 40 (ºC) | >120 (cm) | 16.38kN | 3.05mm |

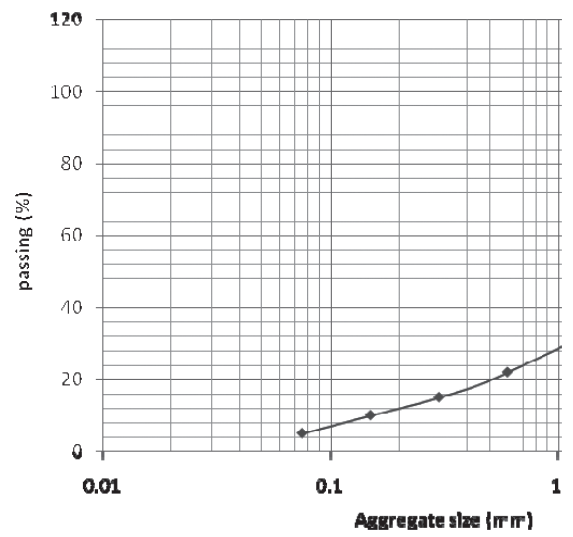
**Table 2: Typical Constituents of Crumb Rubber**

| Material | Content (%) |
|---|---|
| Natural rubber | 25-50 |
| SBR/Butadiene content | 5-30 |
| Carbon black | 25-30 |
| Processing agents | 20-25 |
| Acetone extraction | 3.5-9 |
| Ash content | 10 |
| Benzene Extraction | 4-6 |

## Experimentation

The crumb rubber modified bitumen is prepared in the laboratory by heating bitumen up to 200°C and shredded waste tyres are mixed and stirred for 1 h. The waste rubber is melted and blended in the bitumen. The waste tyre modified bitumen is prepared for 2%, 4%, 6%, 8% and 10% of waste tyre by weight of bitumen. The various physical and mechanical properties like penetration, softening point and ductility of these modified bitumen are determined and compared with neat bitumen. The penetration test is carried out by standard bitumen penetration test apparatus, measured in terms of 1/10$^{th}$ of mm under weight of 100 g for 5 s at 25°C. The softening point is determined by ring and ball method. The ductility is determined in terms of centimeter at 27°C. Also the Marshall Stability and flow of neat and modified bitumen is determined. The aggregate grading taken for the Marshall Stability test is as shown in the Table 3 and gradation curve is as shown in Figure 1.

**Figure 1: Gradation Curve of an Aggregate Blend for Marshall Test**




## RESULTS AND DISCUSSION

The penetration test results are as shown in Figure 2. It is observed that penetration value is reducing with increase in concentration of CR. This is an indication of increase in stiffness and shear strength of binder. The penetration value of neat bitumen reduces from 67 dmm to 46 dmm at 10% of CR content. Absorption of maltene phase by CR increases the asphaltene part of bitumen. Furthermore, the stiffness of CR particles is more than bitumen. Hence, increasing the CR content leads to increased stiffness.

The effect of crumb rubber on softening point of bitumen is shown in the Figure 2. The

**Table 3: Aggregate Grading for Marshall Test**

| Size (mm) | 10.0 | 4.75 | 2.36 | 0.6 | 0.3 | 0.15 | 0.075 | Bitumen |
|---|---|---|---|---|---|---|---|---|
| Cumulative Percentage | 80-100 | 55-75 | 35-50 | 18-29 | 13-23 | 8-16 | 4-10 | 5% |

**Figure 2: Effect of CR Concentration on Penetration of Bitumen**

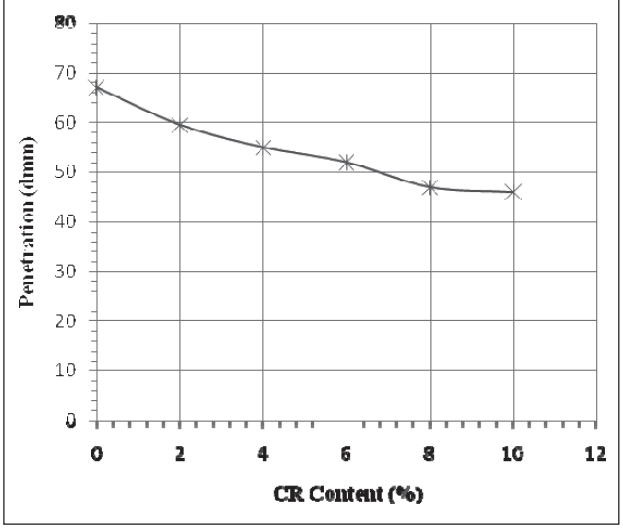
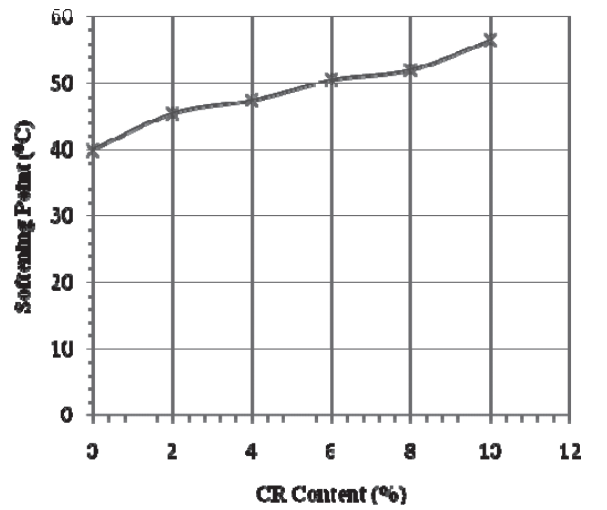


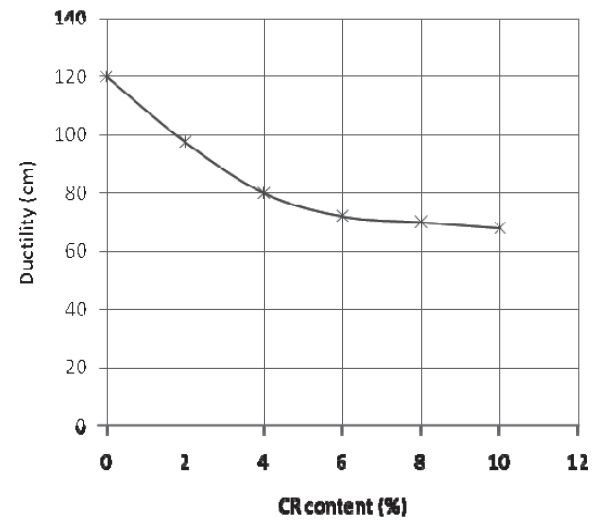

**Figure 3: Effect of CR Concentration on Softening Point of Bitumen**




softening point refers to the temperature at which the bitumen attains a particular degree of softening. The use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as crumb rubber content increases Effect of CR on softening point of bitumen is shown in Figure 3. It is found that the softening point of bitumen is increasing with increase in the CR content. The softening point increases from 40°C to 56.5°C at 10% of CR content. Crumb rubber absorbs the light oily components of bitumen in CR-bitumen matrix, which reduces the content of free radicals. Antioxidant and anti-ozone agent in CR raised the anti-oxidative capacity of Crumb Rubber Modified Bitumen (CRMB). These two reasons contribute directly to the improvement of anti-oxidative capacity of CRMB which leads to higher softening point (Fereidoon *et al.,* 2012).

However, the ductility of the bitumen reduces with increase in the CR percentage in bitumen as represented in Figure 4. The

**Figure 4: Effect of CR Concentration on Ductility of Bitumen**




reduction of oily material in CR-bitumen mix and presence of CR particles in specimen which have no deformation properties results in reduction of ductility (Fereidoon *et al.,* 2012).

The effect of CR modification on the stability and flow value, on the basis of Marshall test are as shown in the Figure 5 and 6 respectively. It is found that the stability value increasing with

**Figure 5: Effect of CR Concentration on Stability of Bitumen Mix**

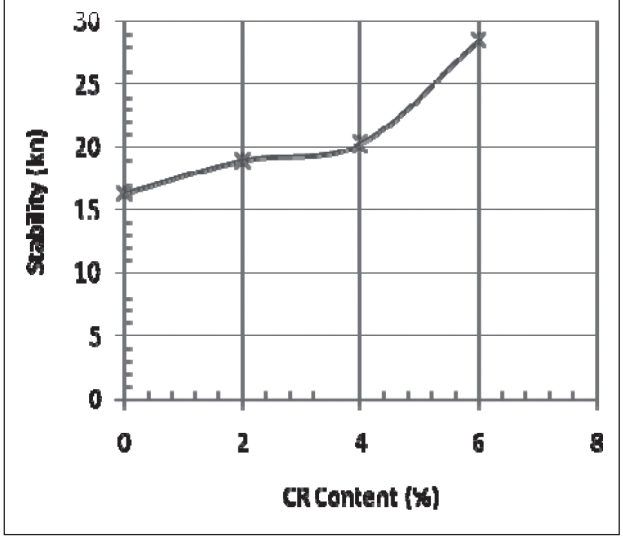
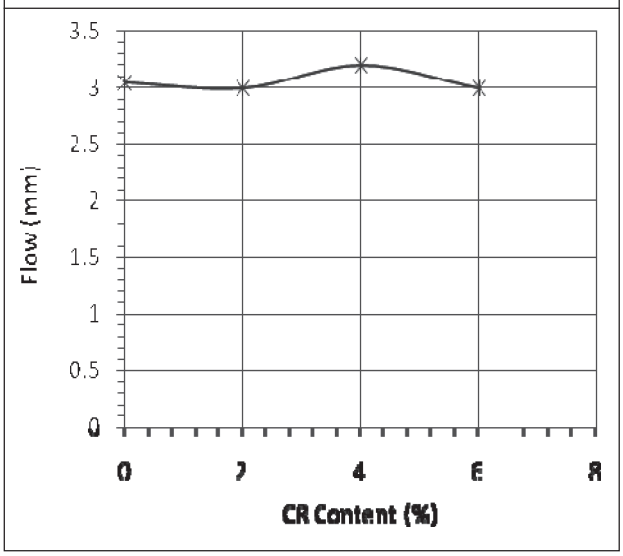



**Figure 6: Effect of CR Concentration on Flow of Bitumen Mix**




increasing in CR content; however the flow remains fairly unchanged. This implies that the stiffness and deformation property of the bituminous concrete is improving with increase in CR content. The stability value of neat bitumen mix increases from 16.38 kN to 28.53 kN for bitumen modified by 10% of CR.

## CONCLUSION

Based on laboratory investigations and obtained results in this study, the following conclusions can be drawn.

1. The use of crumb rubber as a modifier seems to have positive effects on physical and strength properties of the binders, including improved penetration, softening point.
2. There is a significant improvement in the stability value of bituminous concrete. However the ductility of the binder reduces with increase in CR content. It is therefore recommended to use the 5% to 10% of CR to keep the ductility with in permissible limit.
3. The use of crumb rubber as an additive in bitumen modification would reduce pollution problems and protect our environment as well.

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