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EXPERIMENTAL STUDIES ON THE PROPERTIES OF MODIFIED BITUMINOUS MIXES USING CRUMB-RUBBER

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Abstract - *The abundance and increase of waste tire disposal is a serious problem that leads to environmental pollution. Crumb rubber obtained from shredding of those scrap tires has been proven to enhance the properties of plain bitumen since 1840. It can be used as a cheap and environmentally friendly modification process to minimize the damage of pavement due to increase in traffic density, axle loading and low maintenance services which has deteriorated and subjected road structures to failure more rapidly. The use of crumb rubber leads to excellent pavement life, driving comfort and low maintenance. The rheology of CRMB depends on internal factors such as crumb rubber quantity, type, particle size. The present study aims in investigating effect of crumb rubber on bitumen as a modifier in various proportions. Common laboratory test will be performed on the modified bitumen in various proportion of Bitumen and thus analyzed. Marshall method is adopted for mix design. Finally a comparative study is made among the plain Bitumen and modified Bitumen by varying the proportions of crumb rubber.*

Key Words: Crumbrubber, Modifier, Modified Bitumen, Marshall test

1.INTRODUCTION

In India flexible pavement type of construction is preferred over the rigid pavement type of construction due to various advantages such as low initial cost. Bitumen is used as binder and water proofing material for construction of road, pavement and air field surfacing for several years. The demand of bitumen has increased tremendously because of rapid urbanization in recent years. The objective can be achieved by enhancing the durability of existing road surfacing which will result in reducing maintenance and resurfacing operations.

Hence the modification of Bitumen to meet the required performance standards of the pavement appears to be logical and economical approach .Bituminous pavement fails to give the expected life under adverse climate, environmental and traffic conditions. By adding certain additives called as Bitumen modifiers which can improve properties of bitumen and bitumen mixes. For many years, researchers and development chemists have experimented with modified bitumen mainly for industrial uses, adding asbestos, special filler, mineral fibers and rubber. In the last thirty years many researchers have looked at a wide spectrum of modifying materials for bitumen's used in road construction.

In the present study, Crumb-rubber is used as a modifier. Crumb-rubber modified bitumen (CRMB) is a hydrocarbon blinder obtained through physical and chemical interaction of Crumb-rubber with bitumen and some additives. The use of Crumb-rubber in bitumen modification helps in achieving better performance of wearing courses and also helps to reduce environmental pollution. The aim of the study is to investigate the effect of Crumb rubber as modifier in various proportions in bitumen and also compare the Marshall Test properties of plain and modified bitumen at various proportions of crumb rubber as a modifier.

2. EXPERIMENTAL METHODOLOGY

2.1 Materials used

2.1.1 Bitumen

Bitumen is a common binder used in road construction. It is principally obtained as a residual product in petroleum refineries after higher fractions like gas, petrol, kerosene and diesel, etc are removed. Bitumen of VG-30 grade was used in the study.

Table -1: Basic properties of Bitumen

Properties	Value
Softening Point	46.5˚C
Ductility test	74 cm
Loss on heating test	0.4%
Specific gravity	1.01
Marshall stability	1262.7kg
Flow value	7.4 mm

2.1.2 Aggregate

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stress occurring to the wheel loads on the pavement and on the surface course they also have to resist wear due to abrasive action of traffic. Therefore the properties of the aggregates are of considerable significance to the highway engineers. In our present study we use aggregates of size less than 25 mm. The required aggregates sizes are chosen according to fulfill the gradation

Table -2: Basic properties of Aggregate

Properties	Value
Crushing test	30.54 %
Impact test	18.37 %
Specific gravity of fine aggregate	2.52
Specific gravity of coarse aggregate	2.73
Flakiness index	14.63 %
Elongation index	23.03 %

2.1.3 Crumb-Rubber (Modifier)

Crumb-rubber is recycled powder from automotive and truck scrap tires. During the recycling process, steel and tire cord (fluff) are removed, leaving tire rubber with a granular consistency. Continued processing with a granulator or cracker mill, possibly with the aid of cryogenics or by mechanical means, reduces the size of the particles further.

Fig 1: Crumb-rubber

The particles are sized and classified based on various criteria including color (black only or black and white). Crumb-rubber is sized by the screen or mesh through which it passes in the production process. Crumb-rubber of size 30 mesh is used as the modifier in the present study. The finer the screen/mesh the more openings it will have per linear inch, i.e. 30 mesh means there are 30 holes or openings per linear inch.

2.2 Test on modified bitumen

2.2.1 Softening point

Softening point test on bitumen was conducted as per IS: 1205 usually conducted by using Ring and Ball apparatus.

Specimen was prepared by placing the rings on a metal plate by applying grease to inside of the ring plate. Bitumen sample was heated to a pouring consistency and then pour into the ring up to the specified mark. The sample was allowed to cool in air for about 30 minutes. Excess sample was cut off with hot knife. The balls were kept centrally over the sample. And the rings were kept on the ring plate of the metallic support and the assembly was immersed in beaker containing distilled water. A Thermometer was inserted in water. Water was heated gradually. At certain temperature, the sample becomes soft. Note down the temperature on the thermometer at which ball sinks down and touch the bottom plate. This temperature was recorded as the softening point of the sample.

The experimental result on bitumen is modified by the addition of crumb rubber at 5,10,15,20 and 25% of the weight of the bitumen .

2.2.2 Ductility test

The ductility test on bitumen was conducted as per the procedure laid down in IS: 1202 by using Briquette mould.

Sample was prepared by applying grease on the briquette mould. The given bitumen sample was heated to a pouring consistency and carefully pour into the mould and it was allowed to cool in air for about 30-40 minutes. Later the mould with the plate was immersed in a water bath maintained at $27^{\circ}C$ for 30 minutes. Later the mould was taken out and excess of bitumen, if any, was cut off with a sharp hot knife. Later again the mould was replaced back in water for 85 to 90 minutes at 27°C.

The side pieces of the mould were removed and the sample from the plate was separated with the help of a hot knife. The sample was placed carefully in the ductility machine on the plate provided by fixing the ends of the mould to the plate. The temperature of the water should be 27°C. The initial reading on the scale provided on the machine was noted. Machine was started and the sample was stretched and a thread is formed in the middle. The sample stretches at a uniform rate of 50 mm per minute. The thread formed at the middle breaks at a certain distance. The distance up to which the sample stretches before the thread breaks, is recorded as the ductility value expressed in terms of cm. The experimental result on bitumen modified by the

addition of crumb rubber at 5,10,15,20 and 25% of the weight of the bitumen.

Fig 2: Different stages of Ductility test

2.2.3 Marshal test

Bituminous concrete mix is commonly designed by Marshall method. In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at a rate of 5 cm per minute. The test procedure is used in the design and evaluation of bituminous paving mixes. The test is extensively used in routine test programme for the paving jobs. There are mainly two features of the Marshall method of design mixes namely,

i. density-void analysis
ii. stability-flow test

The Marshall stability of the bituminous mix specimen is defined as a maximum load carrying in kg at a standard test temperature of 60˚C when load is applied under specified test conditions.

The Flow value is the total deformation that the Marshall test specimen undergoes at the maximum load, expressed in mm units.

For performing the Marshall test, 1200 g of aggregate consisting of different aggregate fractions is taken as per MoRTH-2001. The aggregate sample is then heated to a temperature 175 to 190˚C and the bitumen to a temperature 121 to 138˚C. The mix was thoroughly mixed at a temperature 154 to 160˚C and was placed in a Marshall mould preheated in an oven. Collar is placed and specimen is compacted by a rammer with 75 blows. The prepared specimen was allowed to cool at room temperature for 20 to 25 minute. By using a mechanical sample extractor the specimen was extracted from the mould and the dimensions of the specimen are measured. From these measurements the volume of the specimen was calculated and also weight of water is determined. The Marshall test was then conducted and the load and the flow values at failure were recorded. The conventional Marshall graphs were plotted and the optimum bitumen content was determined.

Marshall method is used for Bituminous mix design. Suitable materials must be incorporated while constructing the pavement surface to minimize the pavement deterioration. Since this project aims to propose a new material which is a combination of bitumen along with Crumb-rubber. Specimens were prepared at bitumen content 3.5%, 4%, 4.5%, 5% and 5.5% weight of dry mix modified using Crumb rubber at 5%, 10%, 15%, 20%, 25% weight of bitumen respectively. The Marshall test was then conducted and the optimum modifier content could be determined.

2.2.4 Preparation of dry mix using mid-point gradation

Table 2.3: Composition of Bituminous concrete pavement layers (MORTH-2001)

Grading	1	2
Nominal aggregate size	19 mm	13 mm
Layer thickness	50-65 mm	30-45 mm
IS sieve (mm)	Cumulative % by weight of total aggregate passing	
45	-	-
37.5	-	-
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
.6	15-27	26-38
.3	10-20	18-28
.15	5-13	12-20
.075	2-8	4-10
Bitumen content % by mass of total mix	5.0-6.0	5.0-7.0

Fig 2 : Preparation of specimen

Fig 4: Marshall stability test

3. EXPERIMENTAL RESULTS AND A NALYSIS

3.1 Softening Point Test

The experimental result on bitumen modified by the addition of crumb rubber at 5,10,15,20 and 25% of the weight of the bitumen. It is observed that softening point increases gradually as the rubber-content increases. The softening points of bitumen are almost linear with the addition of crumb-rubber. This shows that the bitumen become less susceptible to temperature changes as content of crumb-rubber waste increased.

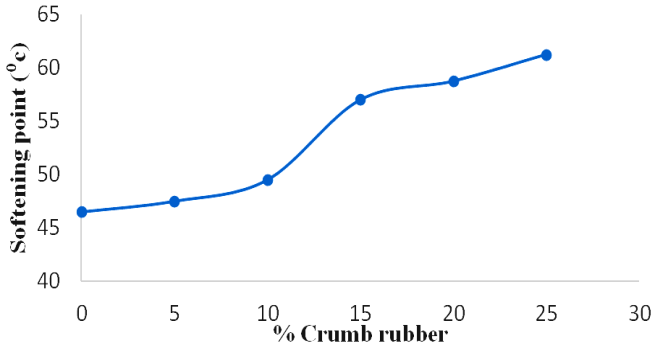

Fig 5: Variation of softening point with Crumb rubber

3.2 Ductility test

The experimental result on bitumen modified by the addition of crumb rubber at 5,10,15,20 and 25% of the weight of the bitumen is shown in figure 6. The ductility value decreases as the rubber content increases.

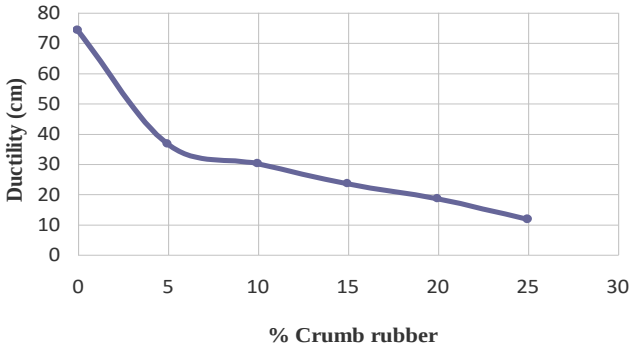

Fig 6: Variation of Ductility with Crumb rubber

3.3 Marshall test properties of modified bituminous concrete mixes

Figure 7 shows the variation of Marshall flow value with bitumen content at various % of crumb-rubber. An increase in trend is followed with increase in bitumen content and also flow value increases as rubber content increases. There is a small variation in the Marshall flow value which may be due to the experimental error

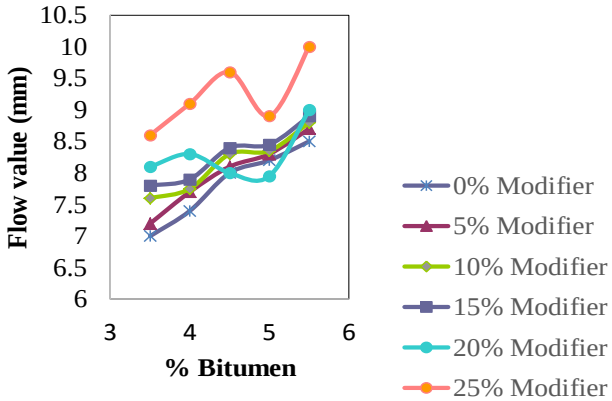

Fig 7: Variation of flow value with bitumen content at various % of crumb-rubber

Figure 8 shows the variation of flow value with bitumen content at various % of crumb-rubber. Here stability value increases with bitumen content initially and then decreases. Maximum stability value at 0% modifier is obtained at 4.5 % bitumen content (OBC). The obtained maximum stability value is 1262.7 kg. The Marshall stability increases as the rubber content increases up to 15% modifier and starts to decrease as rubber content increases. Thus the maximum stability is obtained at 15% modifier which is the optimum modifier content. The maximum stability obtained is 1839.15 kg which is 1.45 times greater than the plain bitumen.

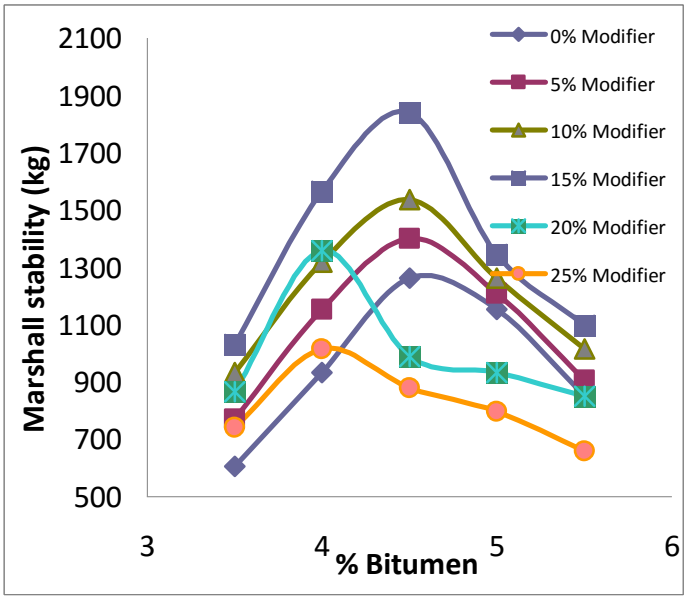

Fig 8: Variation of Marshall stability with bitumen content at various % of crumb-rubber

4. CONCLUSION

The use of crumb rubber as a modifier in bitumen can improve the properties of bitumen. The various studies conducted on the bitumen with different modifiers gives satisfactory results. The properties of softening point and Ductility test has improved gradually by the addition of Crumb rubber. This showed that the bitumen becomes less susceptible to temperature changes as content of crumb-rubber increased. The ductility value decreases as the rubber content increases thus the bitumen become more viscous and harder which would be useful to obtain stiffer bitumen. In bituminous concrete pavement, Crumb-rubber gives the Marshall stability value of 1839.1 kg for 4.5% bitumen by using 15% of crumb rubber with bitumen mix which is 1.45 times greater than the Marshall stability value of conventional bitumen mix.

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