# Bitumen Modification with Waste Plastic and Crumb Rubber

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***Abstract: -*** **Worldwide, sustainability is an important need of the hour in the construction industry and towards this end use of waste material in road construction is being increasingly encouraged so as to reduce environmental impact. In the highway infrastructure, a large number of originate materials and technologies have been invented to determine their suitability for the design, construction and maintenance of the pavements. Plastics and rubbers are one of them. . The plastic waste quantity in municipal solid waste is increasing due to increase in population and changes in life style. . Similarly most tires, especially those fitted to motor vehicles, are manufactured from synthetic rubber. Disposal of both is a serious problem. At the same time, continuous increase in number of vehicles emphasizes on need of roads with better quality and engineering design. This waste plastic and rubber can be used to partially replace the conventional material to improve desired mechanical characteristics for particular road mix. . In the present study, a comparison is carried out between use of different waste plastics like carry bags, PET bottles crumb rubber and all three (3%,4.5%,6%,7.5%,9%by weight of bitumen) in bitumen concrete mixes to analyze which has better ability to modify bitumen so as to use it for road construction.**

***Keywords: Polyethylene, PET, Crumb rubber, Bitumen, Marshall Stability test***

## I. INTRODUCTION

In general, pavements are of two types, flexible and rigid pavement. A flexible pavement is the one which has a bitumen coating on top and rigid pavements which are stiffer than flexible ones have PCC on top. The flexible pavements are built in layers and it is ensured that under application of load none of the layers are overstressed. The maximum intensity of stress occurs at top layer, hence they are made from superior material mainly bitumen.

The mix design should aim at an economical blend with proper gradation of aggregates and adequate proportion of bitumen so as to fulfil the desired properties of mix which are stability, durability, flexibility, skid resistance and workability In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. Bitumen is a sticky, black and highly viscous liquid or semi-solid, found in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. The desirable properties of bitumen for pavement are:

1. Good cohesive and adhesive binding property.
2. Water repellent property.
3. It is its thermoplastic nature, (stiff when cold liquid when hot), that makes bitumen so useful.

A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with organic synthetic polymers like rubber and plastics. They can return to the earth as beneficial additives in bitumen roads.

The global problem with land disposal of automobile tires and plastic substances can only be solved by this feasible option left. It is found that plastics. Designers while constructing pavements consider various failure modes that may occur due to distress like rutting, moisture damage, thermal cracking, and thermal distress during freeze thaw cycle in early spring etc. These may affect asphalt's quality and performance in pavement. Thus in pavement construction just the asphalt cannot meet optimum performance requirements. It is thought that the application of automobile tires and plastics will not only solve the environmental problem of this industrial solid waste, but also act as very promising modifiers for the improvement of some materials engineering characteristics such as asphalt pavement Material. Besides, it is thought that the application of automobile tires and plastics will not only solve the environmental problem of this industrial solid waste, but also act as very promising modifiers for the improvement of some materials engineering characteristics such as asphalt pavement Material. Polyethylene would be more economical and effective in asphalt paving than other polymeric materials. But under certain conditions, PE has some difficulties as an asphalt modifier which can be met by Crumb Rubber for modification. The incorporation of CRT into the asphalt binder would cause the asphalt to possess ductility and crack resistant characteristics, resistance to rutting due to high viscosity, high softening point and better resilience, reduction of temperature susceptibility, the resistance to permanent deformation, fatigue failure, and thermal cracking.

### *1.1. Background and Related Work*

***Abhayakumar et al,(2013),***studied the use of polymer and rubber as modifier in aggregate bitumen mix by preparing samples from 3.5 to 5% each with an increment of 0.5%.It was observed that when 8% rubber and polymer were added ,Marshall stability, flow, AV,VMA,VFB goes on increasing.

***Apurva, (2013),***carried out test by preparing samples using 8% and 10% shredded plastic carry bags in 60/70 grade bitumen mixed with aggregates. It was found all the basic properties of aggregates showed increase due to coating of plastic over aggregates.

***Mohamed et al***, carried out study in which CRT and LDPE were used to modify virgin asphalt which was added in 3%, 5%, 10%, 15% by weight. Best results of Marshall test were obtained below 10% most at 5%.

***Prasad et al,(2013),***investigated the use of PET waste by mixing 2%,4%,6%,8%,10% with 80/100 grade bitumen and found that MSV, FV, bulk density increases with increase in PET content whereas VFB decreases.OBC was obtained as 5.4% and optimum content of PET was 8%.

***Rema et al,(2013),***carried out Marshall test using 60/70 grade bitumen and shredded plastic in which OBC WAS 4.658% for control mix and it decreased to 4.583% by adding plastic. Marshall Stability was found to increase upto 4.5% polymer and then decreases.

***Raol et al,(2014),*** carried out test using crumb rubber blended with bitumen in 5%,10%,15% and 20% and found an increase in Marshall stability upto 15% and then reduction on further addition.

### *1.2. Objectives*

The main objectives of the study are

- To determine the relevant index and engineering properties of plastic waste, rubber tyres and compare them with conventional bitumen.
- To study the effect of polythene carry bags, PET bottles, crumb rubber on strength of BC mix with quarry dust as filler.
- To select the optimum percentage of plastic waste and rubber to be blended with commonly used bitumen to produce maximum compressive strength
- To study the Marshall properties of the bitumen concrete mixes with polyethylene carry bags, PET bottles and crumb rubber to determine how they affect the properties of mixes.

## 2 MATERIAL

### *2.1 Bitumen*

60/70 bitumen was used in this investigation to prepare the samples. Table 1 shows the test results of basic properties of bitumen

Table 1: Basic Properties of Bitumen

| Properties | Results |
|---|---|
| Specific gravity | 1.01 |
| Penetration | 67 mm |
| Softening point | 42°C |
| Flash point | 330°C |
| Fire point | 350°C |
| Ductility | 63.4 mm |

### *2.2. Fine Aggregate*

Aggregates of size below 4.75mm as per MORTH Specification were used as fine aggregate. Table 2 shows the test results of basic properties of fine aggregates.

**Table 2:** Basic Properties of Fine Aggregates

| **Properties** | **Results** |
|---|---|
| Specific gravity | 2.6 |
| Water absorption | 1.45% |

### *2.3. Coarse Aggregate*

Aggregates of 13mm down size were used as coarse aggregate. Table 3 shows the test results of basic properties of coarse aggregates.

**Table 3:** Basic Properties of Coarse Aggregates

| **Properties** | **Results** |
|---|---|
| Specific gravity | 2.6 |
| Water absorption | 0.39% |

### *2.4. Quarry dust*

Quarry dust was used in this study .Table 4 shows the test results of basic properties of Quarry dust.

Table 4: Basic Properties of Quarry dust

| Properties | Quarry dust |
|---|---|
| Specific gravity | 2.44 |

### *2.5. Polyethylene carry bags*

Polythene carry bags were collected and shredded in shredding machine to uniform size of 2-3mm.

### *2.6. PET bottles*

In this investigation, PET bottles shredded in shredding machine were used.

### *2.7. Crumb rubber*

Rubber shredded into pieces of uniform size was used in the study. Table 5 shows the basic properties of modifiers used.

Table 5: Basic Properties of modifiers

| Modifier used | ecific gravity Results |
|---|---|
| olythene carry bags | 0.905 |
| PET bottles | 1.38 |
| Crumb rubber | 1.15 |

## 3 EXPERIMENTAL METHODS

### *3.1. Marshall Stability test*

The experimental work carried out in this present investigation is the Marshall Stability test. The original Marshall method is applicable only to hot asphalt paving mixes, with a maximum aggregates with maximum size of 25mm. Marshall Stability test is empirical in nature. Hence no modifications can be affected to the standards procedure, such as reheating of mix for preparing specimens, conducting Marshall Test on field compacted sample etc.

The Marshall test uses standard test specimens of 64mm (2.5 inches) height and 102 mm (4 inches) mm diameter. They are prepared using a specific procedure for proportioning materials heating, mixing and compacting the aggregate – bitumen mixture. It involves mainly 2 processes:

- Preparation of Marshall samples
- Marshall Test on samples

### *3.2. Preparation of Marshall samples*

For BC mixes the coarse aggregates, fine aggregates and filler were mixed with bitumen and modifier used according to the adopted gradation as given in Table 6, such that each aggregates are weighed as per Table 7.This will be about 1200gm. First a comparative study was done on BC mixes by using carry bags, PET bottles and crumb rubber. At least three specimens are required for each aggregate grading and asphalt content.

Table 6: Gradation of aggregates

| Sieve mm | % passing | | Cumulative retain % | Individual retain % | % of C.A, F.A, Filler | Individual weight of 1200gm |
|---|---|---|---|---|---|---|
| | Specification | Blend | | | | |
| 19 | 100 | 100 | 0 | 0 | C.A:38 % | 0 |
| 13.2 | 79-100 | 89.5 | 10.5 | 10.5 | | 126 |
| 9.5 | 70-88 | 79 | 21 | 10.5 | | 126 |
| 4.75 | 53-71 | 62 | 38 | 17 | | 204 |
| 2.36 | 42-58 | 50 | 50 | 12 | | 144 |
| 1.18 | 34-48 | 41 | 59 | 9 | | 108 |
| 0.6 | 26-38 | 32 | 68 | 9 | FA:57 % | 108 |
| 0.3 | 18-28 | 23 | 77 | 9 | | 108 |
| 0.15 | 12-20 | 16 | 84 | 7 | | 96 |
| 0.075 | 4-10 | 7 | 93 | 9 | | 120 |
| | | | | | Filler:5 % | 60 |
| Total weight of aggregates for a sample | | | | | | 1200 gm |

Fig 1: Gradation of aggregates

### *3.3. Mixing and sample preparation*

The mixing of ingredients was done as per the following procedure;

- Required quantities of coarse aggregate , fine aggregate & mineral fillers were taken in a pan and kept in an oven at temperature 160℃ for 2 hours. Preheating is required because the aggregates and bitumen are to be mixed in heated state.
- The required amount of shredded modifier was weighed and kept in a separate container.
- The aggregates in the pan were heated on a controlled gas stove for a few minutes maintaining the above temperature. Then the polyethylene was added to the aggregate and was mixed for 2 minutes.
- Now bitumen was added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for few minutes till they were properly mixed

which was evident from the uniform colour throughout the mix.

- Then the mix was again placed in oven for about an hour for proper conditioning of the mix.
- Then the mix was transferred to a casting mould. 75 no. of blows were given per each side of the sample so subtotal of 150 no. of blows was given per sample. Then each sample was marked and kept separately.

*3.4. Marshall test on samples*

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm/min. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. In India, it is a very popular method of characterization of bituminous mixes due to its simplicity and low cost. In the present study the Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and then compare mixes to check addition of which of the additive mentioned gives more stability.

Fig 3: Marshall stability apparatus

In the Marshall method of mix design, each compacted test specimen is subjected to the following tests and analysis.

a. Bulk specific gravity ($G_b$) determination
b. Stability and Flow test
c. Density and Void analysis

*Bulk specific gravity ($G_b$) determination*

Bulk specific gravities of saturated surface dry specimens are determined.

*Stability and flow tests*

After determining the bulk specific gravity of the test specimens, the stability and flow tests are performed. Immerse specimen in water bath kept at 60˚C ±1˚C for 30 to 40 minutes before testing. When the testing apparatus is ready, remove the specimen from water bath and carefully dry the surface. Place it centrally on the lower testing head and fit upper head carefully. Fix the flow meter with zero as initial reading. The load is applied at a constant rate of deformation of 51 mm (2 inches) per minute. The total load at failure is recorded as its Marshall Stability Value. The reading of flow meter in units of 0.25 mm gives the Marshall Flow value of the specimen.

The entire testing process starting with the removal of specimen from bath up to measurement of flow and stability shall not take more 30 seconds. While the stability test is in progress, hold the flow meter firmly over the guide road and record.

*Density and voids analysis*

After completion of the stability and flow test, a density and voids analysis is done for each set of specimens. The calculations are given in section 3.6 .Average the bulk density determinations, for each asphalt content. Values obviously in error need not be considered. This average value of $G_b$ is used for further computations in void analysis.

(a) Determine the theoretical density ($G_t$) by ASTM D 2014 method for at least 2 bitumen contents nearer to the optimum binder content.
(b) $V_v$, VMA and VFB are then computed using the standard equations

Table 7: Marshall stability and flow values for control mix

| Bitumen % | Flow value mm | Stability KN |
|---|---|---|
| 5% | 2.6 | 20.03 |
| 5.5% | 2.8 | 21.84 |
| 6% | 3.1 | 19.82 |
| 6.5% | 3.4 | 18.79 |
| 7% | 3.8 | 17.61 |

Table 8: Density and void analysis for control mix

| Bitumen% | $G_b$ | $G_t$ | $V_v$ | $V_b$ | VMA | VFB |
|---|---|---|---|---|---|---|
| 5% | 2.33 | 2.4 | 4.2 | 11.5 | 15.04 | 76.6 |
| 5.5% | 2.32 | 2.4 | 3 | 12.7 | 15.66 | 80.8 |
| 6% | 2.31 | 2.38 | 2.89 | 13.7 | 16.61 | 82.6 |
| 6.5% | 2.31 | 2.37 | 2.24 | 14.9 | 17.13 | 86.9 |
| 7% | 2.31 | 2.35 | 1.75 | 16 | 17.75 | 90.2 |

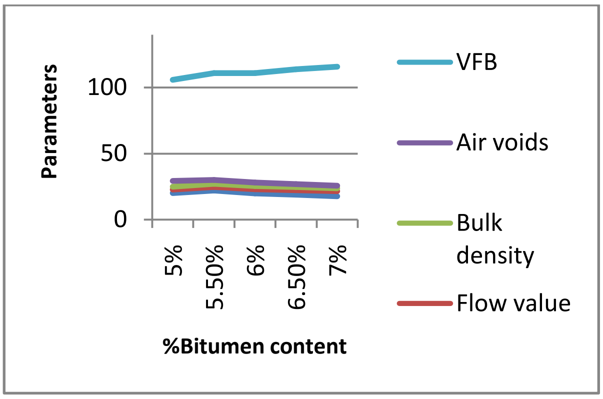


**Fig 4:**% Bitumen content Vs various parameters for control mix

**Table 9:**Marshall stabilityand flow values for polythene modified BC mix

| Polythene % | Flow value mm | Stability KN |
|---|---|---|
| 3% | 2.2 | 20.60 |
| 4.5% | 2.4 | 22.73 |
| 6% | 2.63 | 22.94 |
| 7.5% | 3.8 | 20.74 |
| 9% | 4.23 | 19.94 |

**Table 10:**Marshall stabilityand flow values for PET modified BC mix

| Bitumen % | Flow value mm | Stability KN |
|---|---|---|
| 3% | 2.4 | 22.82 |
| 4.5% | 2.5 | 22.07 |
| 6% | 3 | 23.00 |
| 7.5% | 4.4 | 21.53 |
| 9% | 4.5 | 21.33 |

**Table 11:**Marshall stabilityand flow values for rubber modified BC mix

| Bitumen % | Flow value mm | Stability KN |
|---|---|---|
| 3% | 2.23 | 20.14 |
| 4.5% | 2.5 | 21.57 |
| 6% | 3.0 | 22.64 |
| 7.5% | 4.8 | 21.47 |
| 9% | 4.17 | 18.00 |

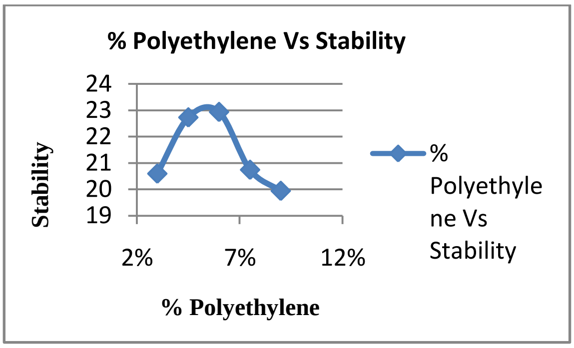


Fig 5:% polythene Vs stability

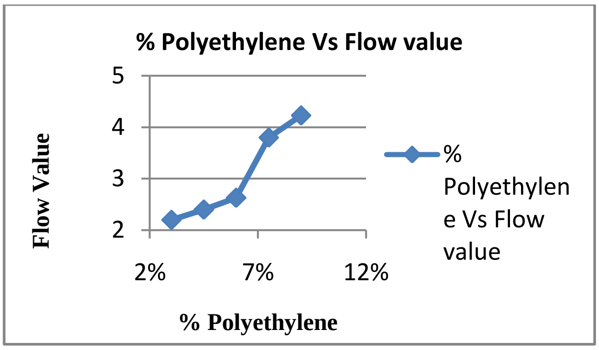


Fig 6: % Polythene Vs Flow value

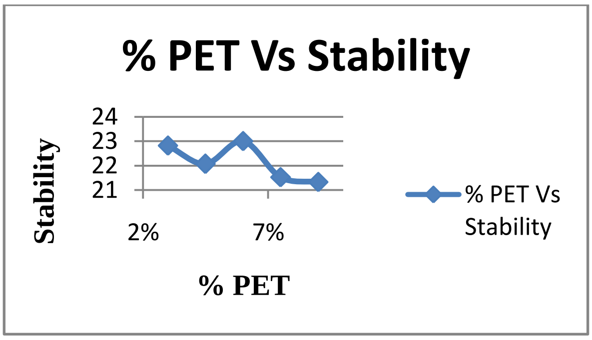


Fig 7: % PET Vs Stability

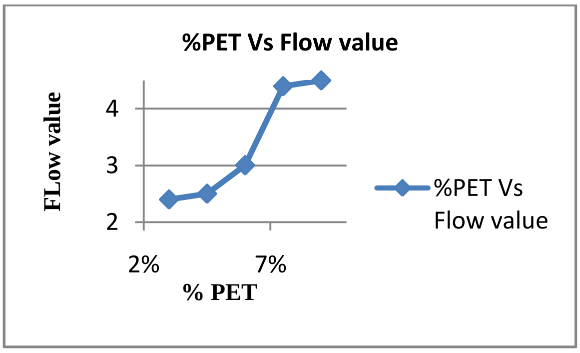


Fig 8: % PET Vs Flow value

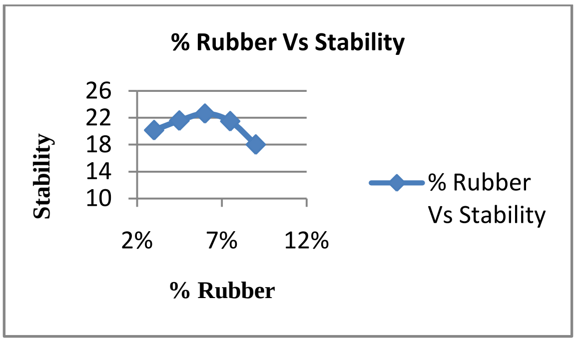


**Fig 9:** % Rubber Vs Stability

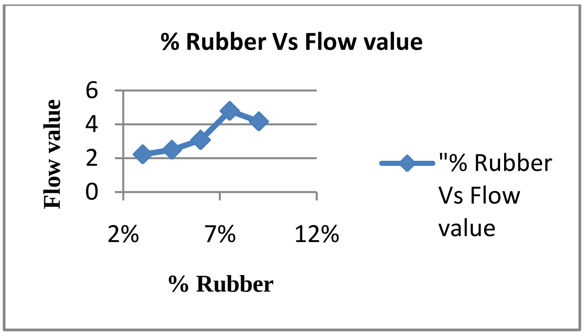


Fig 10: % Rubber Vs Flow Value

## 4 DISCUSSIONS

It is observed from graphs that with increase in bitumen concentration the Marshall stability value increases up to certain bitumen content and there after it decreases. Thus, the maximum stability was obtained at 5.5% from% bitumen v/s stability graph (Fig.4).The bitumen content corresponding to 4% air voids was obtained from Fig.4 as 5.3%. Hence the Optimum Binder Content was calculated as 5.3%.Voids filled with bitumen should between 75-85.At 5.3% bitumen by weight aggregate, VFB was 76.58 which is satisfactory. Flow value corresponding to 5.3% is 3.4 which is also satisfactory as per standards.

From the graphs(Fig.5,9,10), it can be observed that with addition of all the three modifiers stability value also increases up to certain limits and further addition decreases the stability. This may be due to excess amount of modifier which is not able to mix in asphalt properly. Thus at optimum bitumen content, varying contents of modifiers it was found in first three cases maximum stability was obtained at 6%.Thus the optimum modifier content was obtained as 6%. It is observed from graphs(Fig.6,8,10) that with increase in binder content flow value increases but by addition of modifier flow value decreases than that of conventional mixes, again further addition of modifier after OPC the flow value starts to increase.

## 5 CONCLUSIONS

Based on the experimental investigation the following conclusions are drawn:

- By carrying out Marshall Test for control mix samples which was prepared by adding 5%, 5.5%, 6%, 6.5%, 7% bitumen by weight of aggregate to form BC mix, OBC was obtained as 5.3%.
- Addition of polythene, PET, rubber in 3%, 4.5%, 6%, 7.5% and 9% to BC mix samples keeping constant OBC. It was found that in all three cases, the optimum content was obtained as 6%.
- Since the Marshall stability is higher in case of PET bottles compared to rubber and polythene, they can be regarded as the best modifier among three.
- Thus, it can be concluded from the study that all three modifiers when used in 6% by weight of bitumen can improve the stability of pavements, best among them being PET bottles.
- The use of polythene, rubber and PET in roads can solve the problem of environmental damage which can be caused by their disposal.

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