

## **Bituminous Modification with Waste Plastic and Crumb Rubber**

Athira R Prasad<sup>1</sup>, Dr Sowmya N J<sup>2</sup>

<sup>1</sup> PG Student, Dept of Civil Engineering, KVGCE, Sullia, Karnataka, India

<sup>2</sup> Associate Professor, Dept of Civil Engineering, KVGCE, Sullia, Karnataka, India

---

**Abstract:** *The use of waste materials like plastics and rubber in road construction is being increasingly encouraged so as to reduce environmental impact. 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 which is bitumen to improve desired mechanical characteristics for particular road mix. . In the present study, a comparison is carried out between use of waste plastic like PET bottles and crumb rubber (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:** *PET, Crumb rubber, Bitumen, Marshall Stability test*

---

### **I. Introduction**

Road network is the mode of transportation which serves as the feeder system as it is the nearest to the people. So the roads are to be maintained in good condition. The quality of roads depends on materials used for construction. Pavements are generally 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 or RCC 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 fulfill the desired properties of mix which are stability, durability, flexibility, skid resistance and workability. Mix design methods should aim at determining the properties of aggregates and bituminous material which would give a mix with these properties. The design of asphalt paving mixtures is a multi-step process of selecting binders and aggregate materials and proportioning them to provide an appropriate compromise among several variables that affect mixture behaviour, considering external factors such as traffic loading and climate conditions.

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. But its resistance towards water is poor. Anti-stripping agents are being used. Bitumen is a sticky, black and highly viscous liquid or semi-solid which can be found in some natural deposits or obtained as by-product of fractional distillation of crude petroleum. It is the heaviest fraction of crude oil, the one with highest boiling point (525°C) .Various Grades of Bitumen used for pavement purpose:30/40, 60/70 and 80/100.

The desirable properties of bitumen for pavement are:

- Excellent binding property with aggregates, both cohesive and adhesive in nature.
- Repellant to water.
- Thermoplastic in nature (stiff when cold ,liquid when hot)

A common method to improve the quality of bitumen is by modifying the Engineering 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.

#### **1.1.1 Plastics**

A plastic is a type of synthetic or man-made polymer; similar in many ways to natural resins found in trees and other plants. India's consumption of Plastics will grow 15 million tonnes by 2015 and is set to be the third largest consumer of plastics in the world. Various activities like packing consume almost 50-60% of the total plastics manufactured .Plastic offer advantages lightness, resilience, resistance to corrosion, colour, fastness, transparency, ease of processing etc.The plastic constitutes two major category of plastics based on physical properties; (i) Thermoplastics and (ii) Thermo set plastics. The thermoplastics, constitutes 80% and

thermo set constitutes approximately 20% of total postconsumer plastics waste generated .In a thermoplastic material the very long chain – like molecules are held together by relatively weak Van der Waals forces. In thermosetting types of plastics the molecular are held together by strong chemical bonds making it quite rigid materials and their mechanical properties are not heat sensitive.

**Table 1.1 Types of plastics**

Thermoplastic	Thermosetting
Polyethylene Terephthalate (PET)	Bakelite
Polypropylene (PP)	Epoxy
Polyvinyl Acetate (PVA)	Melamine
Polyvinyl Chloride (PVC)	Polyester
Polystyrene (PS)	Polyurethane
Low Density Polyethylene (LDPE)	Urea – Formaldehyde
High Density Polyethylene (HDPE)	Alkyd

**Table 1.2 Waste plastic and its sources**

LDPE	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
HDPE	Carry bags, bottle caps, house hold articles etc.
PET	Drinking water bottles etc.,
PP	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.,
PS	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc
PVC	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc

Plastics may be classified also according to their chemical sources. The twenty or more known basic types fall into four general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers and Fibers.

### 1.1.2 Crumb rubber

Crumb rubber is actually small pieces of waste tyre scrapped from light motor vehicles and whose disposal is a serious menace. The annual available capacity for procured tyres retreading is 4.8 million for bus and truck tyres and 4.5 million for car and jeep tyres .The crumb rubber is made by shredding scrap tire, which is a particular material free of fiber and steel. The rubber particle is graded and found in many sizes and shapes. The crumb rubber is described or measured by the mesh screen or sieve size through which it passes during the production process. To produce crumb rubber, generally, it is important to reduce the size of the tires.

### 1.1 Background and Related Work

**Niraj (2013)** carried out study in which waste tyres were cut in the form of aggregates of sizes ranging from 22.4mm to 6 mm in the tyre cutting machine. These rubber aggregate were added in bituminous mix, 10 to 20 % by weight of stone aggregate. The addition of rubber aggregate in bituminous mix decreases the quantity of stone aggregate and increases the flexibility and flexural strength of carpet layer of highways.

**Nabin (2014)** investigated the modification of bitumen with 15% by weight of crumb rubber with varying sizes. It was observed from the study that stability increases first and then decreases.OBC was determined at 5.3%.It was concluded that best size was finer size.

**Zahra et al (2010)** conducted a study using powdered PET in 2%,4%,6%,8%,10% with 80/100 penetration grade. It was found that viscosity increases by 5% by every 2% increase of PET. It was observed that penetration shows considerable decrease with increase in PET content.

**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%.

**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 basic properties of aggregates, bitumen, plastic wastes used and Crumb rubber.
- To select the optimum percentage of plastic waste (PET) 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 PET bottles and crumb rubber so as to determine how they affect the properties of mixes and to compare it with each other and with the conventional mix.

## II. Materials

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

### 2.6. 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	Specific gravity Results
PET bottles	1.38
Crumb rubber	1.15

### III. 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	FA:57%	108
0.6	26-38	32	68	9		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°C 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 homogeneously. 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  $60^\circ\text{C} \pm 1^\circ\text{C}$  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 rod 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.

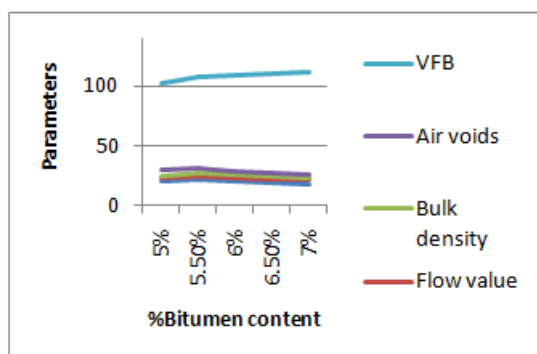
- (a) Determine the theoretical density ( $G_t$ ) by ASTM D 2014 method for at least 2 bitumen contents nearer to the optimum binder content.
- (b)  $V_v$ , VMA and VFB are then computed using the standard equations

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 <sub>b</sub>	G <sub>t</sub>	V <sub>v</sub>	VMA	VFB
5%	2.33	2.4	4.4	16.05	72.61
5.5%	2.33	2.4	3.9	16.69	76.65
6%	2.33	2.38	3.24	17.20	81.18
6.5%	2.31	2.37	3.15	18.20	82.68
7%	2.31	2.35	2.74	18.90	85.53



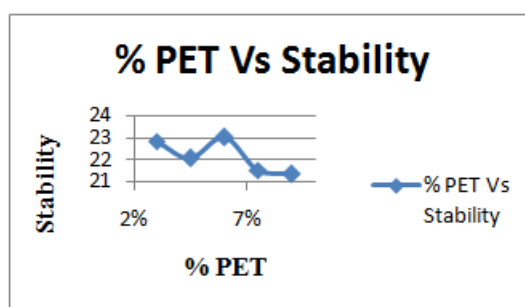
**Fig 4:** % Bitumen content Vs various parameters for control mix

**Table 9:** Marshall stability and flow values for PET modified BC mix

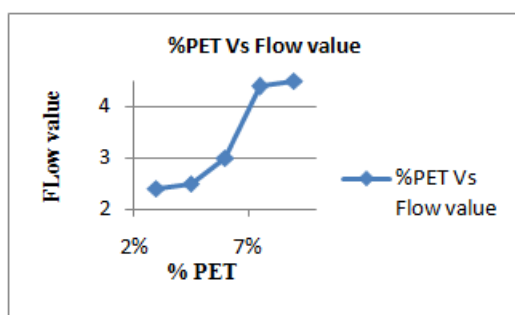
Bitumen %	Flow value mm	Stability KN
3%	2.4	22.82
4.5%	2.5	22.07
6%	3	23.00
7.5%	4.4	21.53
9%	4.5	21.33

**Table 10:** Marshall stability and 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:** % PET Vs Stability



**Fig 6:** % PET Vs Flow value

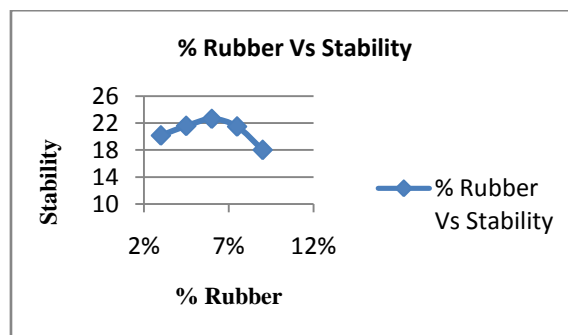


Fig 7: % Rubber Vs Stability

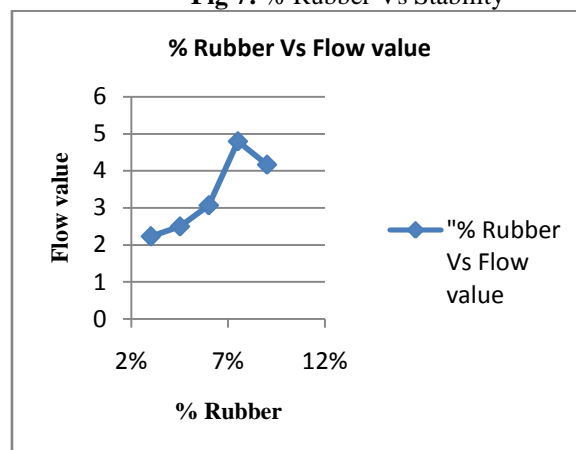


Fig 10: % Rubber Vs Flow Value

#### IV. 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% from% bitumen v/s stability graph (Fig.4).Bitumen content corresponding to maximum density is 5% from Fig.4.The bitumen content corresponding to 4% air voids was obtained from Fig.4 as 5.4%. Hence the Optimum Binder Content was calculated as 5.1%.Voids filled with bitumen should between 75-85.At 5.1% bitumen by weight aggregate, VFB was 76.58 which is satisfactory. Flow value corresponding to 5.1% 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 both 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.

#### V. 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 5.1%.
- Addition of PET and 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, they can be regarded as the best modifier among two.
- Thus, it can be concluded from the study that the modifiers when used in 6% by weight of bitumen can improve the stability of pavements, best among them being PET bottles.
- The use of rubber and PET in roads can solve the problem of environmental damage which can be caused by their disposal.

**References**

- [1]. Zahra N.K., Abdelaziz M, Mohamed.R.K, (2010) "Properties of Bituminous Binder Modified with Waste Polyethylene Terephthalate ", Proceeding of Malaysian Universities Transportation Research Forum And Conferences, Universiti Tenaga Nasional.
- [2]. Nabin Rana Magar,(2014),"A Study on the performance of Crumb rubber Modified Bitumen by varying the sizes of Crumb rubber",Vol.14,Num.2,PP.51-56
- [3]. Niraj D Baraiya,(2013),"Use of Waste Rubber Tyres in construction of Bituminous Road-An Overview",Vol.2,Issue 7,PP.108-110
- [4]. Prasad K.V.R, Mahendra.S.P, Kumar.N.S, (2013)"Study on Utilization of Pet PolyethyleneTeraphthalate) Waste in Bituminous Mixes",IJECT ,Vol. 4, Issue Spl – 1.
- [5]. Harpalsinh Raol,Abhijitsinh Parmar,Jitendra Jayswal,Dhaval Patel,(2014),"Effect of the use of Crumb rubber in conventional bitumen on the Marshall Stability value",IJRET,Vol 3,Issue 1.
- [6]. MORTH Specification (2009), Section 500