An Experimental Investigation on Plastic Blended Bituminous Concrete Mix Roads With Polythene

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doi: 10.48047/ecb/2023.12.si4.1164

Abstract

In this new era there are lot of changes are observed.But new materials and practices are not coming out that much. Some of the people uses some partial replacement of bitumen and tar which gives some satisfactory results. But later investigations prove that all those materials are not exhibits required properties in all aspects. In that time investigators turn their eye on the recycling materials like rubber and plastic. They noticed that both materials gives the satisfactory results. On the other hand the usage of plastic (polyethylene bags, pet bottles, polystyrene and other plastic products) products increases day by day, that leads to lot of pollution due to plastic waste. This plastic material takes hundreds of years to decompose in the soil. Hence they become complicated to environment. This plastic waste stops the percolations of rain water in to the soil and affects the drainage property of soil. It also damages the soil fertility.A new technology introduced to usages of plastic waste in bitumen to strengthen the bituminous concrete mix and increase the load bearing strength. It will help to reduce the waste plastic content and also make the pavement more durable and strong, economical also. To keep up with the continuous infrastructure development, new roads are being constructed.The ever increasing population has further raised the vehicular density due to increased passenger traffic and freight transport over the last few decades. India and many other countries have more than 90 percent of roads which are constructed with flexible pavements or bituminous courses. So, to achieve the requirements, properties of asphalt binder and bituminous mixes are to be improved by using various additives. For a pavement section different types of additives are used such as Polythene, and other waste materials like waste plastic, discarded tyre tubes etc which increases the life of the pavement depending upon the degree of modification and type of additives used.

Keywords*—polyethylene , marshall stability, Bitumen, plastic , pavement*

1. Introduction

A Highway pavement is a structure consisting of superimposed layers of proceed materials above the natural soil sub-grade, whose primary function is to distribute the applied loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality , adequate skid resistance, favourable light reflecting characteristics , and low noise pollution. The ultimate aim is to be ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade.[1]

Bituminous concrete, commonly known as asphalt concrete, is a widely used construction material for roadways, airport runways, and other heavy-duty applications due to its excellent durability and resistance to wear and tear. [2] However, conventional bituminous concrete often suffers from issues such as cracking, rutting, and premature ageing. To improve the performance of bituminous concrete, various polymers and additives can be used [3] ,[4] .Bituminous concrete, also known as asphalt concrete, is a type of pavement material that is commonly used for roads, parking lots, and other surfaces. It is made up of aggregates (such as stone or sand) and a binder (typically asphalt cement).Polymers and different types of additives can be added to bituminous concrete to improve its properties and performance [5] . For example, polymers can improve the elasticity and durability of the pavement, while additives such as fibers or fillers can enhance its strength and resistance to cracking.Some common polymers used in bituminous concrete include, plastic and polyethylene (PE). These polymers can be added in the form of pellets or powders to the asphalt mix, and they are typically blended with the asphalt cement at high temperatures to ensure proper dispersion.Other additives that can be used in bituminous concrete include fibers (such as glass or synthetic fibers), mineral fillers (such as limestone or granite dust), and anti-stripping agents (such as hydrated lime or liquid anti-stripping additives) [6]. These additives can help improve the strength, durability, and performance of the pavement, as well as prevent moisture damage and reduce the risk of rutting and cracking.[7]

For developing countries like India an efficient road network is prerequisite for national integration, country's development and for socio-economic development. From last few years, the use of vehicles has increased, which has further increased the vehicular density on roads. Due to increase in vehicular traffic, there is a huge demand for improved pavement sections which can resist the increasing vehicular loads [8] . A highway pavement is a structure consisting of different layers of prepared materials above the natural soil subgrade. The primary function of these layers is to disperse the applied vehicle load to the subgrade. The pavement surface should provide the acceptable riding quality, competent skid resistance i.e. adequately smooth. The main aim is to ensure that stresses conveyed due to wheel loads are adequately reduced, so that they will not go beyond the bearing capacity of the soil subgrade [9] . There

are mostly two types of pavements which are primarily recognized as Flexible pavements and Rigid pavements.India boasts of the third largest road network in the world [10]. To keep up with the continuous infrastructure development, new roads are being constructed. The ever increasing population has further raised the vehicular density due to increased passenger traffic and freight transport over the last few decades. India and many other countries have more than 90 percent of roads which are constructed with flexible pavements or bituminous courses [11]. So, to achieve the requirements, properties of asphalt binder and bituminous mixes are to be improved by using various additives. For a pavement section different types of additives are used such as Plastic , polythene and other waste materials like waste discarded tyre tubes etc which increases the life of the pavement depending upon the degree of modification and type of additives used [12] .

2. Literature review

- **Dr.R Vasudevan**, dean and professor of chemistry thiagarajar college of engineering, he made detailed research on plastic usage in bitumen as a substitute. He did that research for a time period of 5 years and finally he achieved a patent.
- **Srivatsava** from IIT Kanpur, he did his PhD on plastic blended roads and behavior of plastic waste in pavements. Based on his paperIrc recommended some more specifications.
- **Vamsi Jaya dev** who did a lot of research in plastic waste and he analyzes the type of plastic and how they recycle the different types of plastics.while working in bangalore he started the plastic waste recycling plant Then he started his research in plastic waste recycling. He received the award from Karnataka state for his work.
- **Mohammed Bhasha,** who did his phd on partial replacement of bitumen by plastic wastage and rubber wastage.He is trying to make a new way to make eco-friendly bitumen. He published many papers on his research. In the future , plastic usage value increases at a high rate, which leads to a lot of disposal problems. It can be faced by this method of plastic waste recycling. Plastic is a major environmental problem. It can be used for green environment development by this type of usage methods.

- Several studies have investigated the effect of polymer modifiers on the properties of bituminous concrete. One such study conducted by **Li et al. (2019**) explored the use of styrene-butadiene-styrene (SBS) and styrene-ethylene/butylene-styrene (SEBS) polymers as modifiers for bituminous concrete. The researchers found that the addition of SBS and SEBS improved the rutting resistance and fatigue life of the concrete.

- Another study by **Yang et al. (2018)** investigated the use of waste polyethylene terephthalate (PET) fibers as a modifier for bituminous concrete. The study found that the addition of PET fibers improved the tensile strength, ductility, and fatigue resistance of the concrete.

- In addition to polymers, researchers have also investigated the use of various additives to enhance the performance of bituminous concrete. One such study by **Basha et al. (2015)** explored the use of waste plastic and crumb rubber as additives for bituminous concrete. The study found that the addition of waste plastic and crumb rubber improved the mechanical properties and durability of the concrete.

- Similarly, a study by **Huang et al. (2017)** investigated the use of nanoclay as an additive for bituminous concrete. The researchers found that the addition of nanoclay improved the stability and durability of the concrete.

3. Methodology

Testing Materials

In this study, the materials used are:

1.Bitumen

2.Aggregates (fine and coarse)

3. Plastic waste and polythene

- Bitumen

Different grades and types are avliable in bitumen.various physical tests are specified to judge the stability of binders.

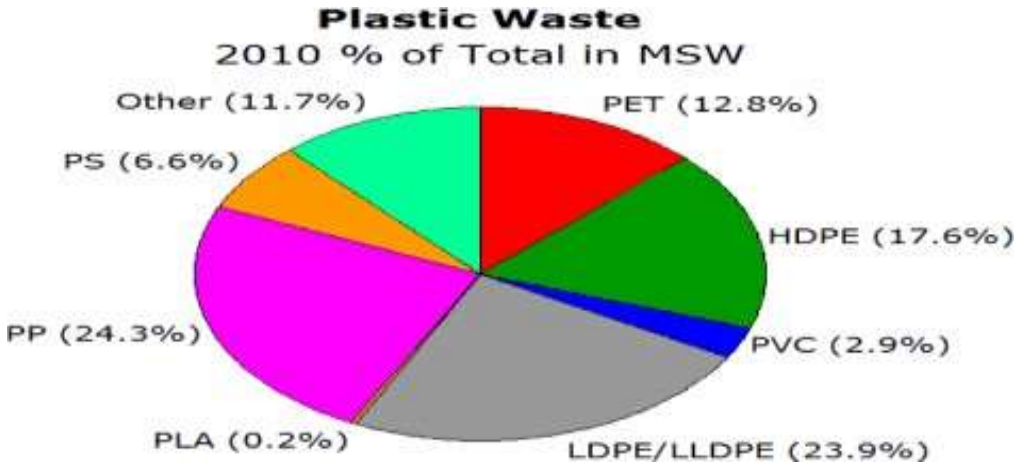
Penetration test ,ductility test, softening point test, viscosity tests are used for classifying bitumen and to study bituminous performance.

- Aggregates

An aggregate should be selected in such a way that which can attains enough strength. Crushed aggregates produce higher stability. Basic physical parameters of aggregates are

- Plastic Waste & polythene
  - Poly ethylene
  - Poly propylene
  - Poly styrene
  - PET (polyethylene terephthalate)
  - HDPE
  - LDPE
  - PVC

2.	Abrasion test	25.8%
3.	Impact value	20.8%
4	Specific Gravity	2.64



Structure of the project

The utilization of plastic waste in flexible pavements to increase strength and durability is our main moto in this project the plastic is introduced in to the bituminous concrete mix in two processes.

Wet process. Dry process

- The selected bitumen is heated to 170+-20 0c
- The aggregate heating temperature is not higher than 28oc above the binder temperature
- The shredded plastic is introduced into the hot bitumen, then that bitumen is heated to 5 more minutes at that temperature.
- Then the plastic is fully melted into that bitumen and forms a emulsion and easily blended.
- Then that plastic added bitumen is mixed with aggregate to form a plastic blended concrete mix.
- Now a day's mini hot mix plants are also using for preparing these concrete mix.

- Then the prepared material is sent to road site within 4 hours to get best results
    - Cleaning of plastic and polythene
    - Shredding of plastic and polythene
    - Collection of plastic and polythene
    - Mixing of waste into bitumen
- The cleaning of plastic is most important why because any impurities in plastic cause decrease in strength of concrete mix.

Mixing of aggregates with bitumen

Laboratory Investigation

The laboratory testing program was undertaken to achieve the objectives of the study. Laboratory tests were

conducted on on road aggregates and Bitumen with plastic waste. Abrasion test, Impact test, Soundness test, Shape test, Specific gravity and water absorption test

Tests done for bituminous material are: Penetration test, Ductility test, Viscosity tests, Float test, Specific gravity tes,t Softening point test, Flash and Fire point test,Solubility test , Spot test, Marshall stability test, Loss on heating test, Water content test.

4.Results and Discussion

The experiments results are presented and discussed Here in this section. It is observed that the addition of plastic waste to bitumen gave good results as well as economically benefitted.The observed results are tabulated below

Table. 1: Test on Road aggregates

Table. 2: Test on Bitumen

S.no	Name of the test	Value
1	Penetration test	69%
2	Ductility test	76.4mm
3	Specific Gravity	1.03
4	Softening point	46.5%

Marshall Stabilty Test

The mix design (wet mix) determines the optimum bitumen content. This is introduced by dry mix design. Various methods are available for mix design which can differentiate in size of specimen, compaction properties and other specifications. Marshall method of mix design is adopted for this project.

Marshall mix design

Marshall mis design method helps to provide the performance of marshall stability and flow test. Maximum load is measured by the stability portion, and the loading rate of specimen is 50mm/min.after that load is applied on the specimen til it achieves its failure and the peak load is called as stability. In this process the plastic deformation of the specimen is reported by dial gauge. At the same time the flow value is recorded in 0.25mm(0.01 inch) in an increasing manner.. The important steps involved in marshal mix design are summarized next.

Specimen preparation

At a temperature of 175 ^{0}C to 190 0C a filler is heated and arounf 1200gm of aggregates are taken. At a temperature 121^{0}C- 125^{0}C bitumen is heated. Both the aggregates and bitumen are mixed throughlty at a temperature of 154- 160 ^{0}C. Later the mould is preheated and the mix is placed. Then the mix is compacted by a rammer by giving 50 blows at a temperature of 138 ^{0}C- 149^{0}C. 63+ or – 3mm thickness the result required. The procedure is repeated by different bitumen content in gterms of percentages , as shown in figyre prepared mould is loaded.

Marshal test procedure

1. Take 1200 grams of aggregate which is passed through 12 mm sieve and retained on 10mm sieve
2. Then take it into the tray and allowed to dry them in oven at 105 ^{o}C to110 ^{o}C for 20 minutes
3. Bitumen of required percentage is is weighed and heated to 165 ^{o}C to 180 ^{o}C, mix the bitumen and aggregate in rotary mixer in hot mix plant(in lab the mixing is carried by using a cylindrical apparatus which rotates by means of electrical motor).
4. During mixing of constituents the temperature of those materials are maintained at recommended values.

5. The analysis and calculations are carried as shown below Weight of aggregate taken =1200 gms

   Temperature of aggregate =110^{o}C Temperature of bitumen =170 ^{o}C Specific gravity of aggregate =2.65

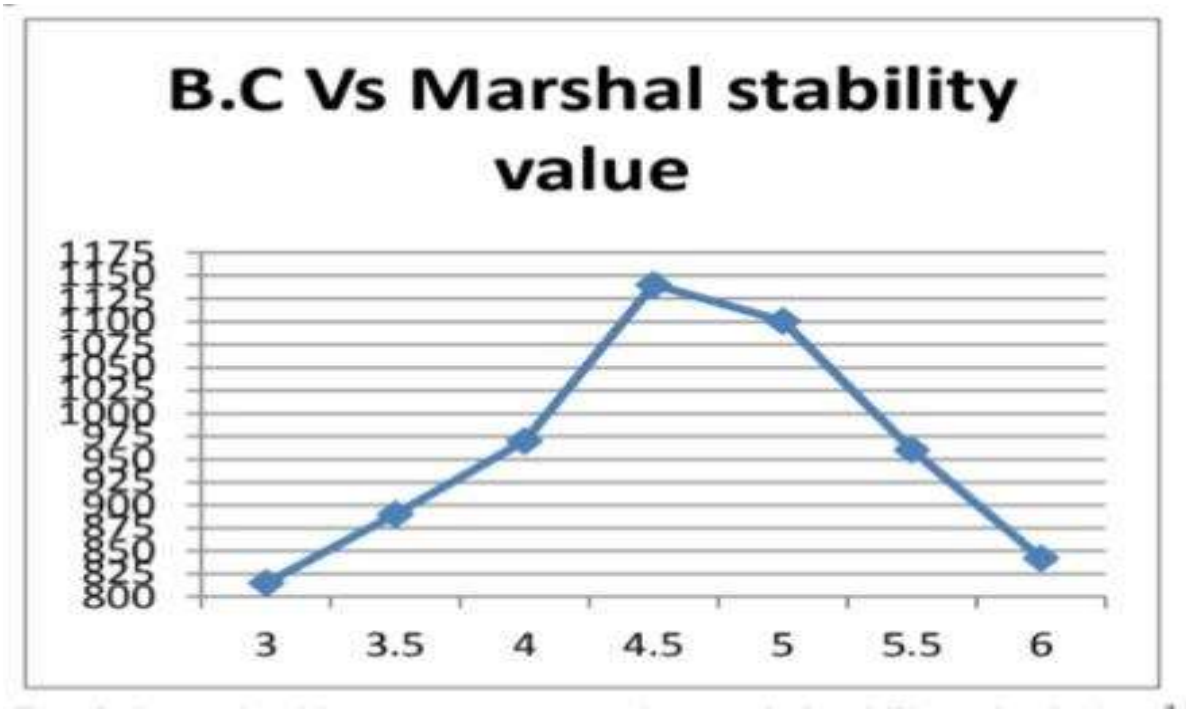
   Specific gravity of bitumen of 60/70 grade =1.021 Specific gravity of bitumen of 80/100 grade =1.01

Sl.No	**Name of the test**	**Recorded value**
1.	Aggregate crushing value test	18%

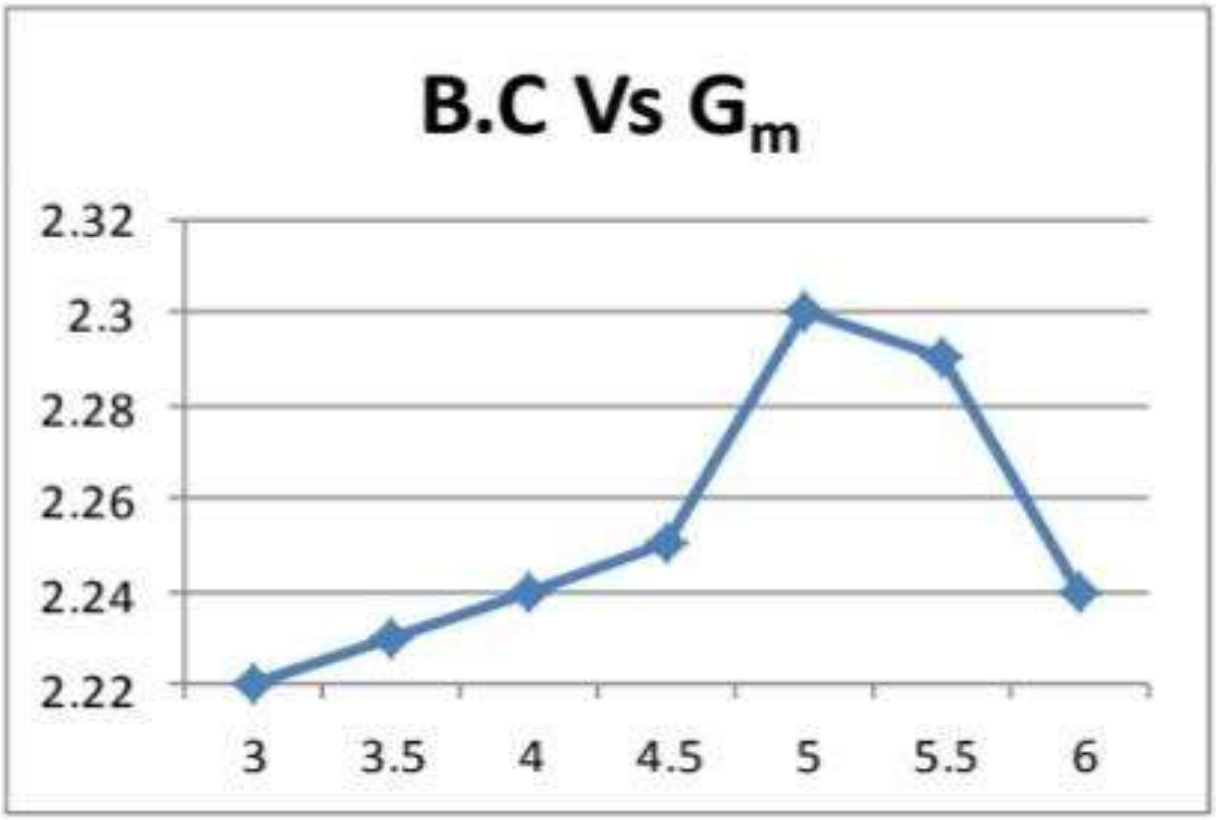
Table 3: The marshal test values for bitumen are tabulated below:

Bitumen	Marshal Strength	flow	Wb	Gt	Gm	Vv	Vb	Vfb	Vfb
3%	815	2.76	36	2.53	2.222	12.17	6.33	18.56	34.10
4%	970	2.78	48	2.496	2.24	10.25	8.43	18.69	45.108
4.5%	1140.5	3.1	54	2.48	2.25	9.274	9.48	18.76	56.521
5%	1100.6	3.26	60	2.46	2.3	6.50	10.8	17.3	63
5.5%	960.3	3.3	66	2.44	2.29	6.14	11.69	17.83	65.50
6%	842	3.34	72	2.43	2.24	7.818	12.41	20.228	61.3

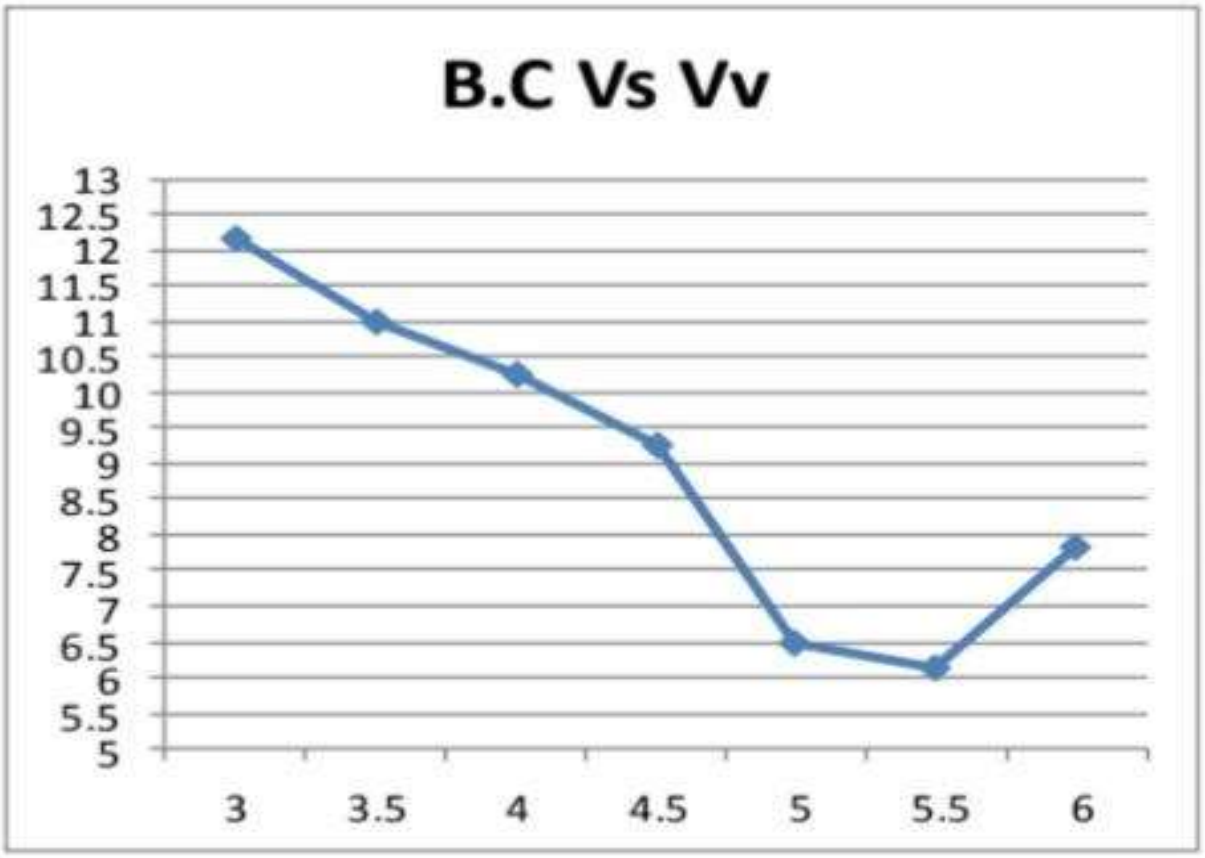
The graphs for above values are drawn in excel sheets
and pasted below



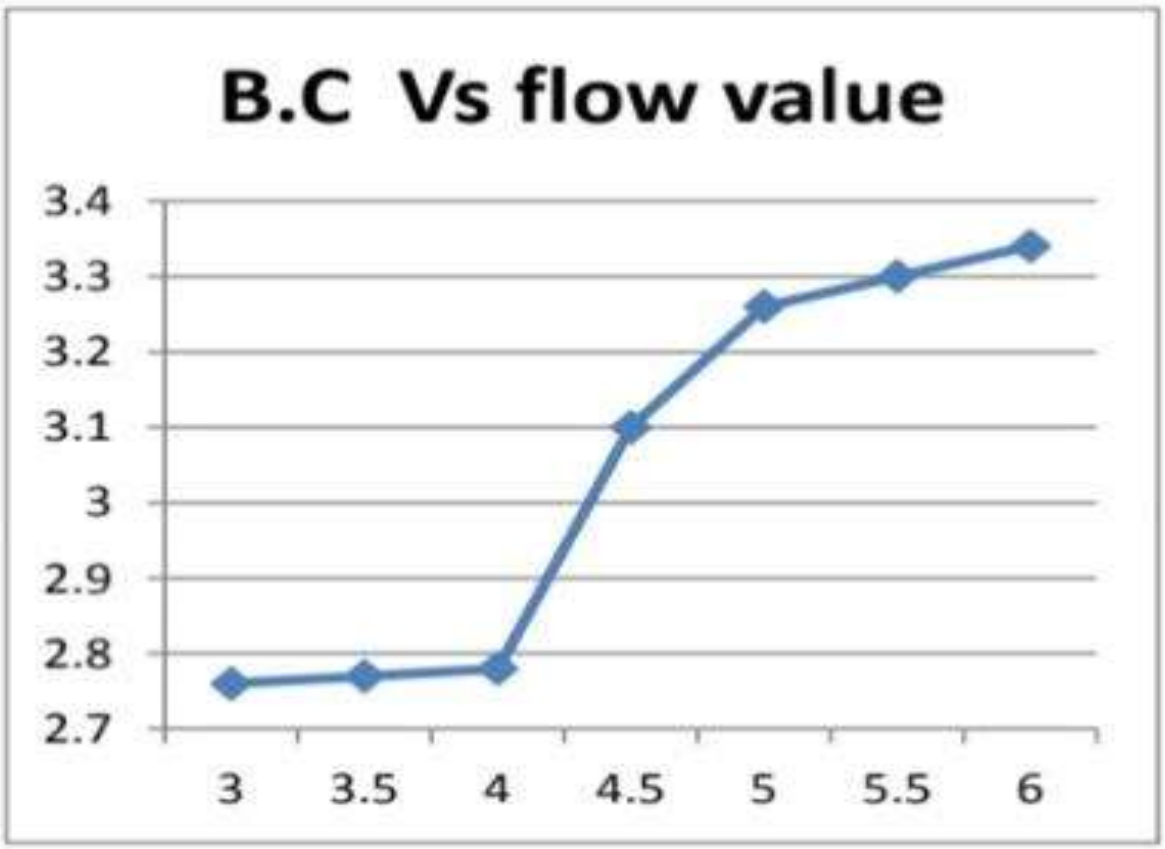
Graph 1: x-axis= bitumen content, y-axis=marshal stability value kg/mm2



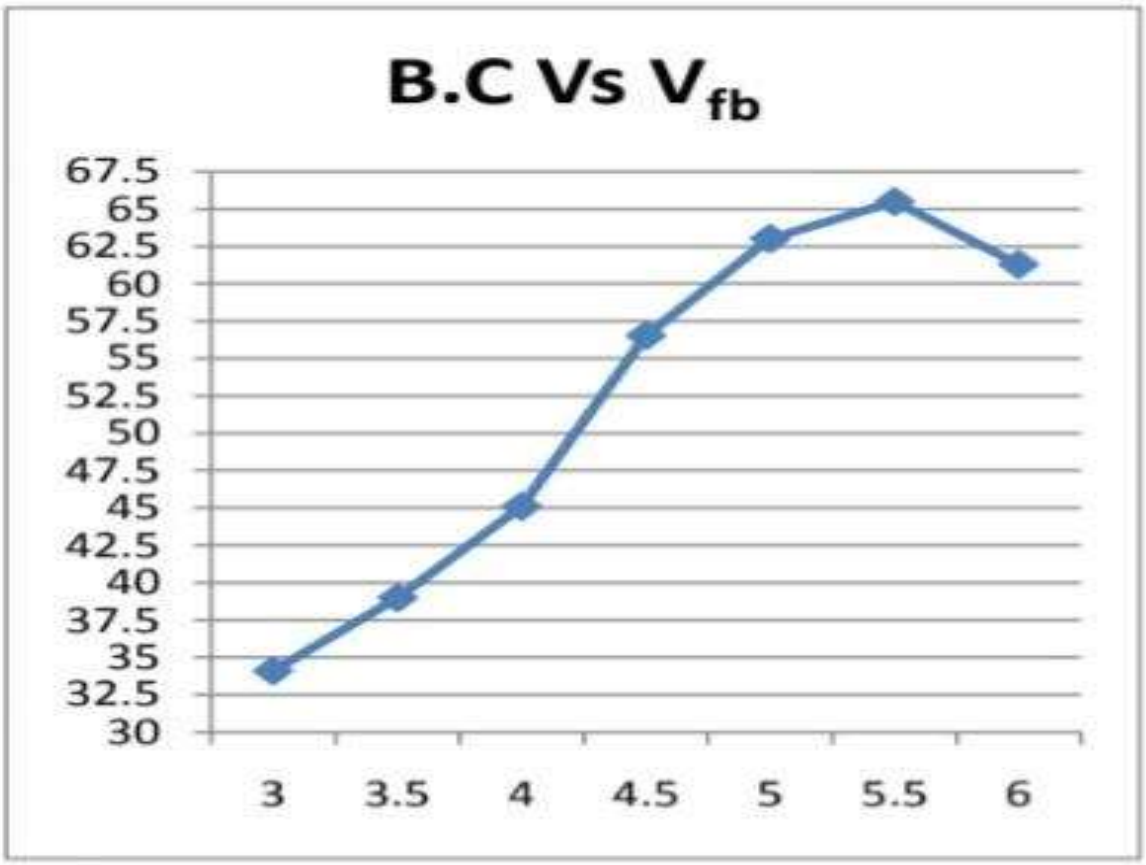
Graph-2: x-axis= bitumen content, y-axis= bulk specific gravity (Gm)



Graph-3: x-axis= bitumen content, y-axis=percentage of air voids (Vv)



Graph-4: B.C Vs flow value



Graph-5:x-axis bitumen content, y-axis=voids filled With bitumen (Vfb)

By analysis of above graphs the optimum bitumen content is taken as follows: The optimum bitumen value is taken by taking the average of higher values of marshal stability, Vv, Gm graphs.

(4.5+3+5)/3 =12.5/3 =4.5

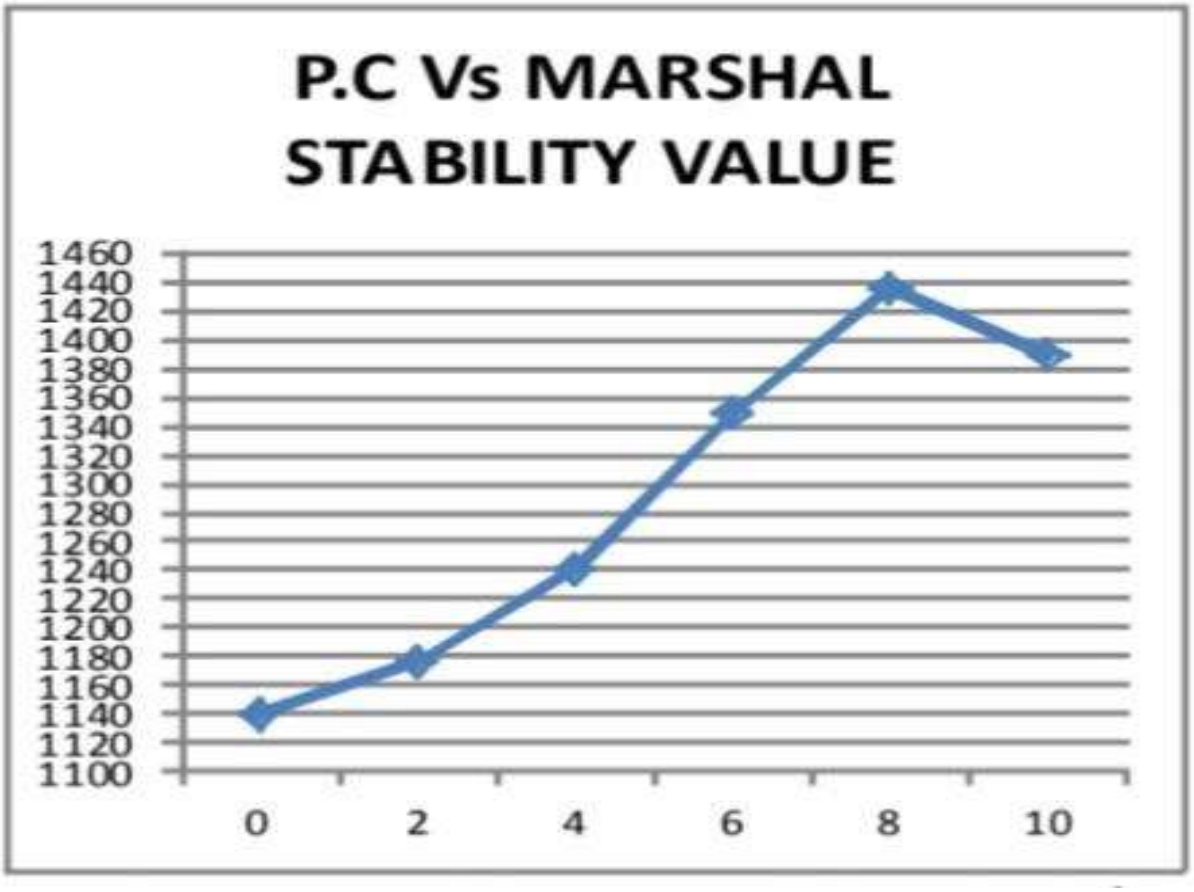
Hence 4.5% of bitumen content is taken as optimum bitumen content. Therefore 4.5% bitumen content is used to prepare mix.

Table 4: The marshal test values for plastic blended bitumen are tabulated

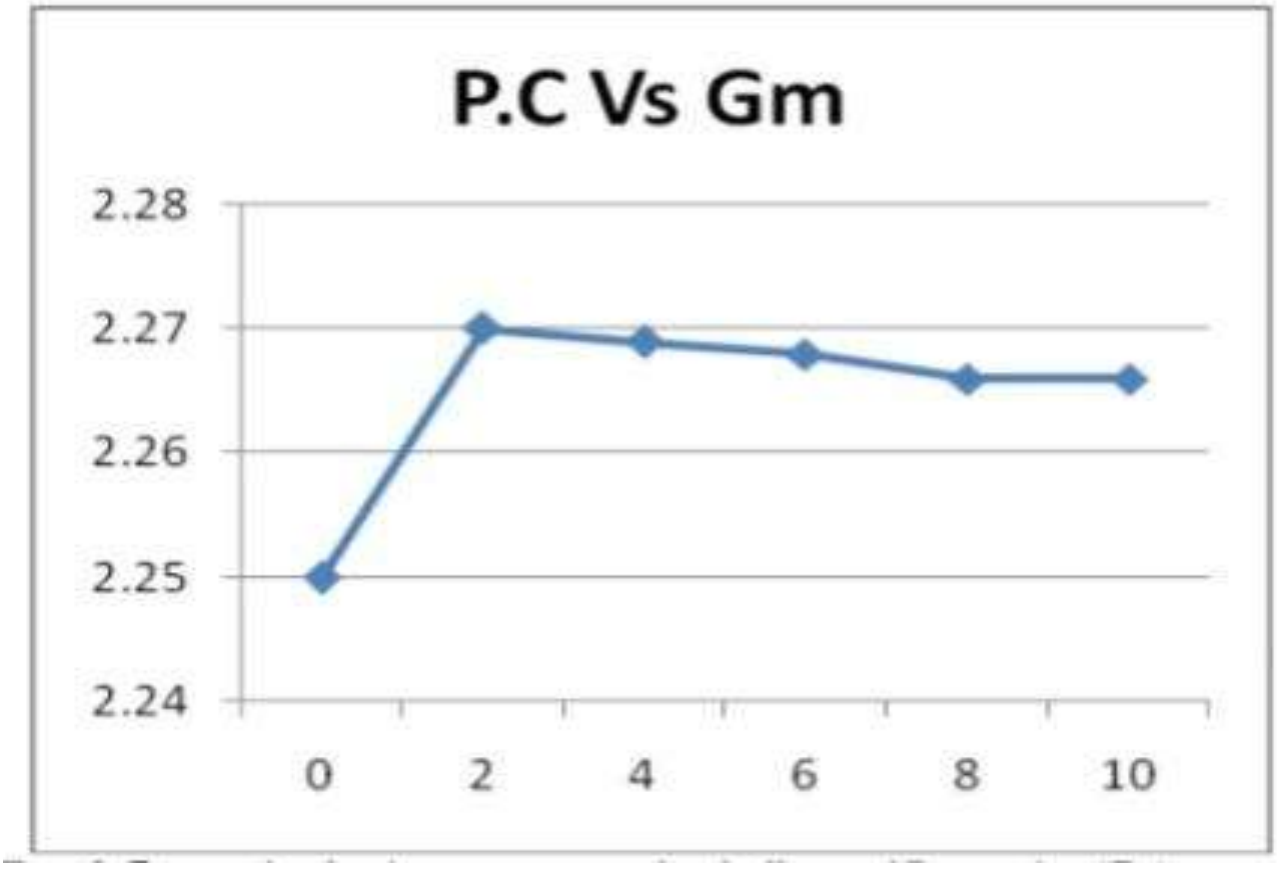
Plastic added	**Marshal strength**	**Flow**	**Wb**	**Gt**	**Gm**	**Vv**	**Vb**	**Vma**	**Vfb**
0%	1140.5	3.11	54	2.48	2.25	9.274	9.48	18.76	56.52
2%	1176	3.025	54	2.48	2.27	8.46	9.38	17.84	52.57
4%	1240	2.916	54	2.48	2.269	8.47	9.186	17.656	52.027
6%	1350	2.818	54	2.48	2.268	8.511	8.99	17.5	51.371
8%	1435	2.794	54	2.48	2.266	8.59	8.792	17.38	50.581
10%	1390	2.876	54	2.48	2.266	8.59	8.576	17.166	49.59

The graphs for above values are drawn in excel sheets

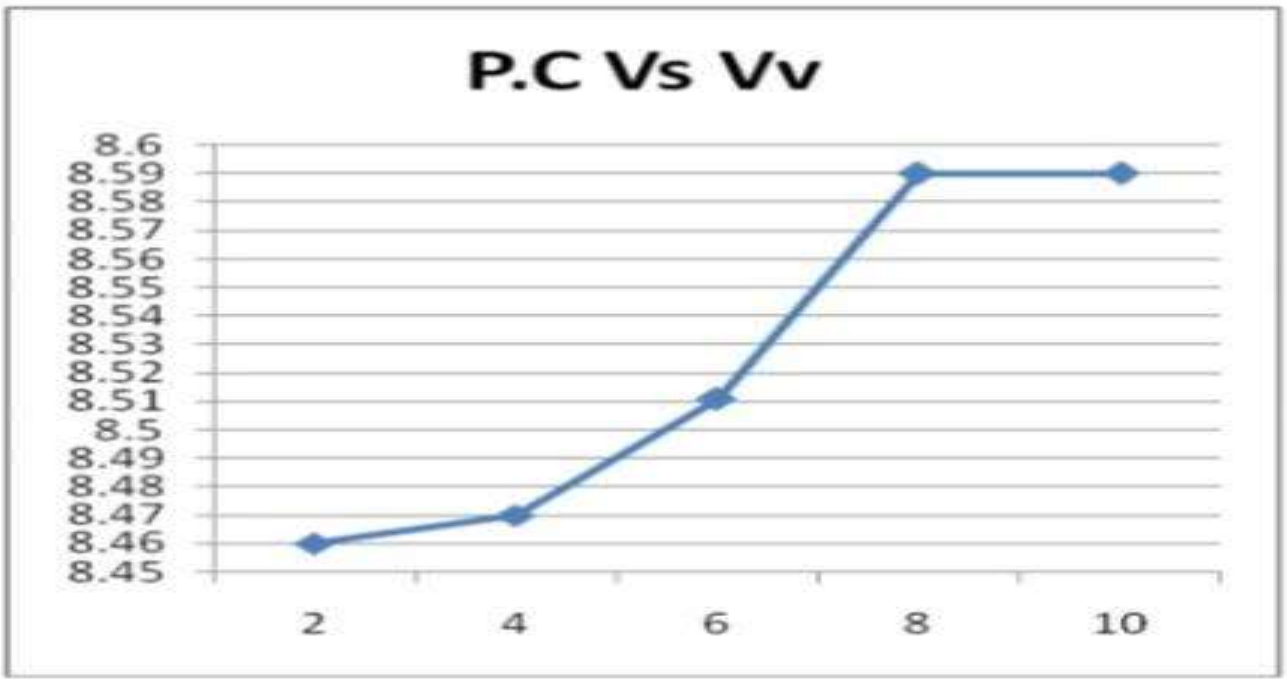
and pasted below



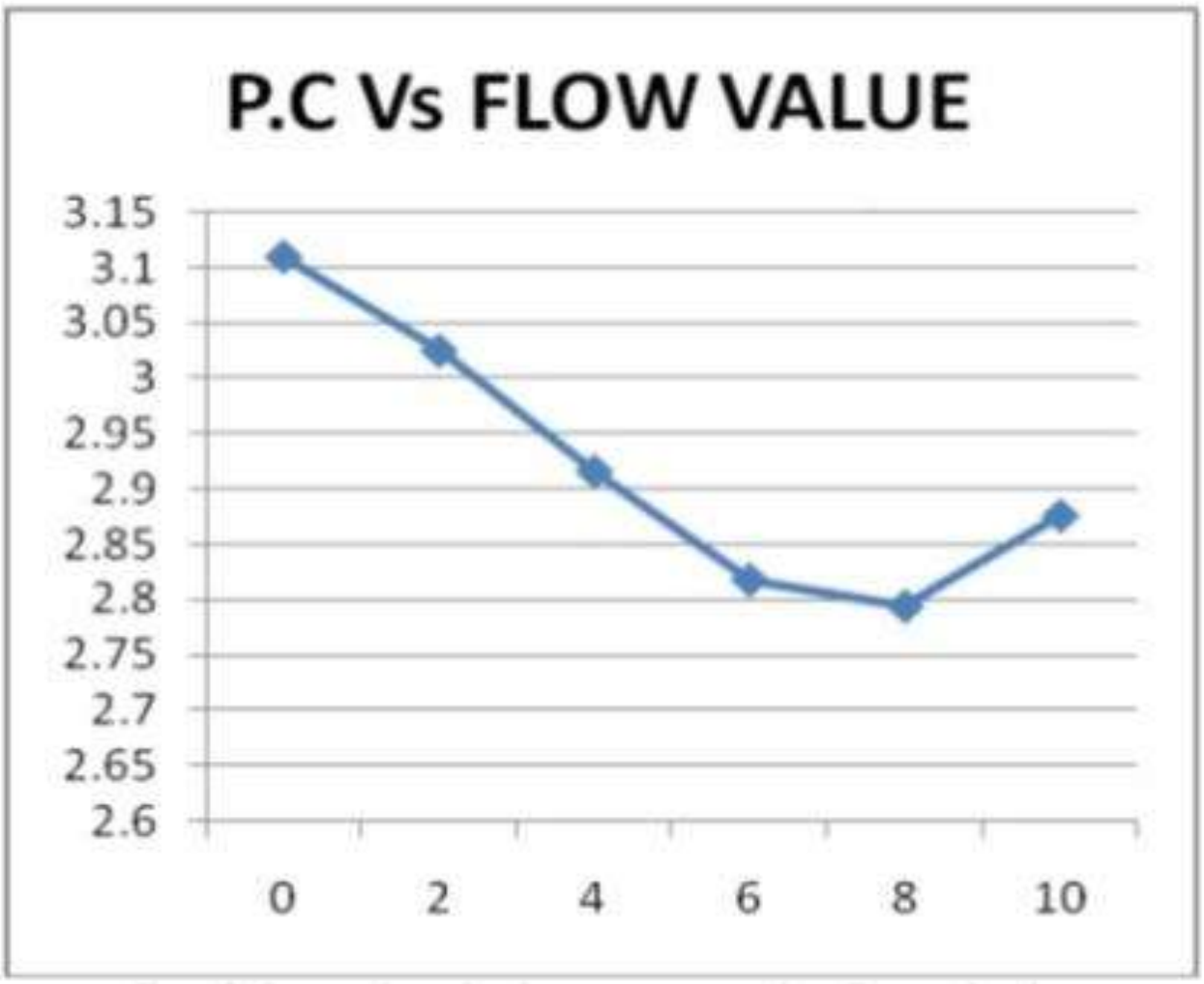
Graph 6: x-axis= plastic content, y-axis=marshal stability value kg/mm2



Graph 7: x- axis plastic content, y-axis= bulk specific gravity



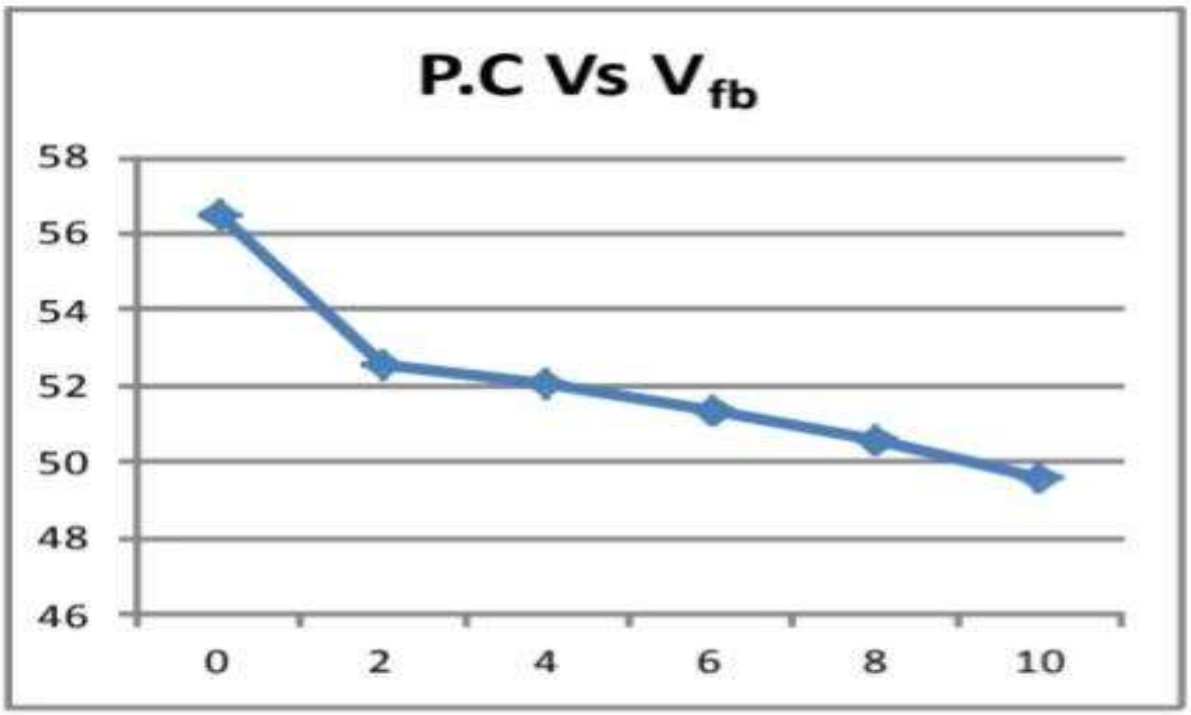
Graph 8: x- axis plastic content, y-axis=percentage of air voids (V**v)**



Graph 9: x-axis= plastic content, y-axis= flow value in mm

Table 5: The marshal test values for plastic %, Specific gravity & flow value

Plasic % added	**Marshal stability Value(kg/ mm^2)**	**Flowvalue (mm)**	**Specific gravity, Gm**
0%	**1140.5 kg/mm^2**	**3.11**	**2.25**
2%	**1176 kg/mm^2**	**3.025**	**2.27**
4%	**1240 kg/mm^2**	**2.916**	**2.269**
6%	**1350 kg/mm^2**	**2.818**	**2.268**
8%	**1435 kg/mm^2**	**2.794**	**2.266**
10%	**1390 kg/mm^2**	**2.876**	**2.266**



Graph 10: x-axis= plastic content, y-axis=voids filled with bitumen (Vfb)

By analysis of above graphs the optimum plastic content is taken as follows:

The optimum plastic percentage value is taken by taking the average of higher values of marshal stability, Vv, Gm graphs.

(8+2+8)/3=18/3 = 6

Hence 6% of plastic content is taken as optimum plastic content. As we observing the graphs of the marshal stability value nearly 8% give better results than 6%, in strength point of view. As graph analysis is observed the values are slightly changing from 6-8%. Hence 8% is also recommended.

5. Discussion on test results

By all the above bitumen test results analysis, it was noted as better values are obtained for plastic added bituminous mix design. The main test results are specific gravity and marshal stability test, flow value are analyzed.

The graph results shown that the 6-8% plastic blended bituminous mix gives better results, as the plastic percentage increases, the above test values are decreased slowly.

By observing all the above value we strongly conclude that the plastic blended bituminous concrete mix give better values.

The marshal stability value is increased from 1140.5 to 1435 kg/mm^2 . that means the marshal stability value increased by 25 percent than the conventional bitumen strength value. It is great achieving in strength point of view. It noted that 8% plastic gives better values.

Then coming to flow value 3.11 is reduced to 2.876. the flow value slightly changed . the change is noted as better results.

All the other values are nearly same and no change is observed.

Economic Point Of View

When coming to economic point of view cost of road construction is slightly decreases. One more point is disposal cost of plastic waste is reduced and problems of incineration, land filling are prevented.

- In market based on the type of bitumen grade and source, cost will vary. We used 60/70 of other source.
- 1 kg bitumen in Andhra Pradesh = 40 Rs/kg
- The better results will obtain with 8% plastic blended mix.
- 1 km road require 8500 kg of bitumen to lay wear coat, if plastic used is 8% then amount of plastic used is=680kgs
- Then cost of bitumen reduced for 1 km road is =680*40

  =27200 Rs/-.
- As compared to cost of road it is small amount, but the plastic disposal problem is over come easily.
- Cost for plastic collection is 4Rs/kg

- Processing of plastic blended plastic involves in addition step, it takes 10Rs/kg
- Then finally it takes 14Rs/kg to collection and processing of waste plastic in bitumen.
- The savage amount is = 40-14 = 26Rs/kg.
- Then savage amount for 680 kgs =680*26 =17680 Rs/- The incineration cost for tone plastic

waste =1500 Rs/-

The plastic used for 1 km road with 8% plastic =680 kg The cost of incineration for 680kgs =0.68*150 =1020 Rs/- Then total profit /1 km road is=17680+1020 =18700Rs/km

Hot mix plant is best way to prepare plastic blended bituminous concrete mix.

Environmental Point Of View

- If we adopt this process we easily escape from the problem of incineration and land filling.
- As per statistics all over india 10,000 km are re-laid on already existing roads.
- It will consume 68 lacks tones of plastic.

The land filling leads to formation of plastic layer over the earth which causes lot of problemsUnable to ground water recharge Reduce in fertility of soil Loss of soil l erosion Takes long time to decompose.

- During the mixing of plastic to bitumen it is observed that emission of chlorine gas.
- During road laying process also chlorine gas is evolved.
- But when compared to open firing of plastic it is very much adoptable.
- The workers must wear face mask while dealing with this material
- The clogging of water in drains are mainly due to non degradable plastic.
- The percentage of plastic enters in to sewers are controlled by this process.
- IRC and municipal authorities are recommended it is the best way of plastic recycle.

As this strong due to carbon bonding, it can easily serve as pavement surface

6. Conclusions

- Finally we conclude that the plastic blended bituminous concrete mix exhibits better performance than the conventional bituminous roads. In case of friction it exhibits same friction co-efficient value.
- It is observed that the stripping of bitumen is reduced due to plastic blend.
- The pot hole formation is also reduced.
- The pot hole formation in roads are highly reduced with

  6% plastic, but Strength point of view 8% gives better results.
- The penetration value is reduced that means the load bearing capacity increases.

  In economic point of view it is economic also. the waste plastic disposal also become easier

process.

- In future plastic usage value increase at high rate, it leads to lot of disposal problem it can be face by this method of plastic waste recycle.
- Plastic is major environmental problem it can be used for green environment development by this type of usage methods.

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