Experimental Study of Flexible Pavement Using Polyethylene Terephthalate Plastic

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Abstract- *The contemporary asphalt roads were first developed in the early 20th century. These bituminous roads are still successfull all over the world.Though the roads are successfull they also have some flaws.In india the roads are famous for their bumps and pot holes.On the other hand ,The day -Today increase in plastic waste in the environment leads to a serious crisis to the environment. A solution to solve both the problem is combining both i.e.,constructing the roads using plastic waste .The use of various materials in the road construction has been a trend since a while.Referring the code book IRC:SP:053:2010 (guidelines on use of modified bitumen in road construction) the properties of the bitumen is tested for different proportions of bitumen and plastic. Due to increase in population ,quantum of plastic wate in municipal solid waste (MSW) increases,thus the disposal of waste plastic bottles specifically (PET) polyethylene terephthalate are made to mix with bituminous asphalt ,to produce a flexible pavement , this project sheds light on the concept of eco-friendly road construction. Which comprises eco-design , eco-extraction, eco- construction the effect of recycling (PET) plastic bottle waste produced in (railway neer) in flexible pavement construction.*

Keywords- Bitumen , Plastic ,Polyethyleneterephthalate modified bitumen, PET plastic, thermoplastic, testing of bitumen

I. INTRODUCTION

The disposal on plastic waste becomes large quantity because of enormous production on plastic bottles the major plastic production called (PET) **POLYETHYLENETEREPHTHALATE** though maximum population on railway railway based mineral water bottle manufacturing becomes so high and disposal on those plastics seen every part of street and society which causes environment an major con. by adding (PET)plastic as an mixture improve the properties of bitumen, has been performed for many years. In spite of that, recently there is interest in the replace of commercial virgin material by recycled polymers In view of plastic materials versatility, relatively low cost and their small duration of life the consumption of plastic materials has been growing steadily, although the disposal of waste plastics constitutes a severe environmental problem, due mainly to their chemical inertness.

The Feature of waste plastic modified mixes is :

- Stiffen binders and mix at high temperatures to minimize rutting.
- Minimizing non-load associated thermal cracking.
- Improve fatigue resistance, where higher strains are imposed on bituminous mixes.
- Improve aggregate-bitumen bond and reduce stripping.
- Improve bituminous pavement durability.
- Reduce cost of maintenance.
- Clean environment.

Some aromatic polyesters are biodegradable but Polyethylene Terephthalate (PET) waste is not biodegradable, and PET become very popular during the last decade because it is known as safe, durable and good material for packaging thus, it will create environmental hazards if disposed in landfills. Therefore, the only way of addressing the problem of disposal of post industrial and post consumer PET waste is through recycling. Methods for recycling waste polymer have been developed and new recycling approaches are being investigated. Recycling waste polymer in road construction as a bitumen modifier is a new method

II. LITERATURE REVIEW

Shivraj Sarojero Patil (2015) has observed that disposing of plastic waste has developed a serious issue and disposing it by burning creates air pollution. Consumption of waste plastic in flexible pavement has proved that it improves the performance of the road. Clean plastics of size 1-2 mm was cut using shredding machine so that it can pass through 1-2 mm sieve size. The aggregates are heated and plastic is added in it and it is forms a uniformly layer of plastic over the aggregates. This technique will not only strengthen the roads but also helps to save the environment from pollution. Aim of this analysis was to cut the quantity of bitumen and replace it with rubber. The study was performed to observe the effects of rubber as a partial replacement in bitumen. Percentage of bitumen replaced with rubber was 0%, 2%, 4%, 6%, 8% and 10% of

the total amount of bitumen. It was observed that the adding rubber in the bitumen can give the desired properties.

Akhilesh Yadav, Ruchi Chandrakar (2017) had investigated the problem with disposal of plastic waste and how to utilize waste in construction of plastic roads. Waste plastic is made powder and mixed with bitumen at various percentages. Plastic was melted and mixed at particular ratio (0- 1%) with bitumen extracted at certain interval. Increase in percentage of waste plastic minimizes the bitumen by 10-12% and also increases strength. They also coated the aggregates with plastic waste at different percentages (0-10%) and observed that better performance of polymer modified bitumen which also gives the better binding properties of bitumen and prevents the moisture absorption and oxidation. It has lowered rutting, raveling and formation of pothole.

Raghvendra Bajpai et al. (2017) have conducted various tests on aggregates having size between 2.36-4.75mm. A reduction of 10% and 22% in aggregate impact value for 8% and 10% of plastic by weight of bitumen mix has been observed. Crushing value is decreased by 30% for PP8 sample and 48% for PP10 sample. The reduction in crushing value shows stronger aggregates also addition of plastic has increased specific gravity of aggregates from 2.45 to 2.85 due to plastic coating. The abrasion value increased by 19.97% for PP8 and 29.88% for PP10. This indicates the hardness of the aggregates.

Ahmed Trimbakwala (2017) has conducted a test to utilize the plastic waste in the road construction. The aggregate size used for the experiment ranges from 0.075mm to 2.36mm. Aggregates were heated to 1650C and different percentages of waste plastic were added to heated aggregates. This test was done by keeping the percentage of plastic as 8% by weight of bitumen. Tests were carried using 60/70 and 80/100 grade of bitumen consisting 0-12% of plastic. It comes out that penetration & 9ductility of the altered bitumen has decreased with increase in plastic content up to 12% and softening point has increased with the addition up to 8% by weight. Results have concluded that 8% of plastic by weight gives the optimum value.

Anuradha Deshmukh et al. (2017) have conducted an experiment on utilization of plastic waste in road construction. Plastic waste was shredded in to size varying from 2.36-4.75mm with the help of shredding machine. In this 8% waste plastic was replaced with bitumen. After that the aggregates were heated to 1650C and also bitumen at 1600C to have good binding. The plastic shreds were put over the hot aggregates then mixed in the chamber and after that aggregates were uniformly coated with plastic. The coated aggregates were added in bitumen and was used in road construction. The plastic coated aggregates increased the resistance and durability of road.

Huda Shafiq and Anzar Hamid (2016) have replaced bitumen by 0%, 2%, 4%, 6%, 8% & 10% of plastic by weight of bitumen and they have performed softening point test, penetration test & ductility test. Similarly, they have coated 0%, 2%, 4%, 6%, 8% & 10% of plastic by weight of aggregates and they have performed Impact test and Los Angeles abrasion test on aggregates. From the above observations it was observed that the coating of plastic over the aggregates give less impact and abrasion values which are beneficial for road construction as they are exposed to wear and tear on the road surface due to traffic. Similarly, softening point, ductility and penetration values are superior by swapping the bitumen with the wastes plastic at 0%, 2%, 4%, 6%, 8% & 10% there by making plastic waste an easy and economic use in bituminous pavement construction.

R. **Manju et al. (2017)** have performed various tests like Aggregate crushing test, Los Angeles abrasion test, Impact test on normal aggregates & plastic coated aggregates and Viscosity test, Marshall Stability test, Penetration and Softening point test on bitumen and modified bitumen (10% of bitumen was replaced with waste plastic). It was observed that the crushing value and impact value of plastic coated aggregates reduced by 40% and 9% respectively. The abrasion value plastic coated aggregates were 21% less than the normal aggregates. The penetration value of bitumen is higher than the bitumen mixed with the plastic. The bitumen softens 100C less than the modified bitumen. The stability of modified bitumen was higher than the normal bitumen.

Santosh Sharma et al. (2018) have conducted tests to analyze performance of aggregates coated with waste plastic. Analysison numerous amount of thermoplastics have shown that there is no release of gases in the temperature varies from 1300C – 1800C and beyond 1800C there is release of gases and thermal degradation can also take place. Various satisfactory tests are done on the aggregates and bitumen for the flexible pavements. In dry process, heated aggregates at 1700C are mixed with heated bitumen (1600C) and this mix is then usedfor construction of road. In wet process 6-8% plastic is mixed with bitumen. Plastic content enhances melting point of bitumen and helps in retaining the flexibility of road during cold weather, hence results in its prolonged life. The coating of aggregates was done in different proportions i.e. 1%, 1.3%, 1.5%, 1.8% & 2% by weight. The size of shredded plastic varied from 4.75-10mm, which was different from the previous studies. It was observed that aggregate impact value reduced to 12.54% for 1% coating, 11.43% for 1.3% coating,

10.44% for 1.5% coating, 8.95% for 1.8% and 7.55% at 2% coating. The average impact 11value significantly reduced as there is increase in percentage of coating. Los Angles abrasion value reduced from 15.58% for coated sample to 12.02%, 11.21%, 11.0%, 10.12% & 9.05% at 1%, 1.3%, 1.5%, 1.8% & 2% respectively

III. METHODOLOGY

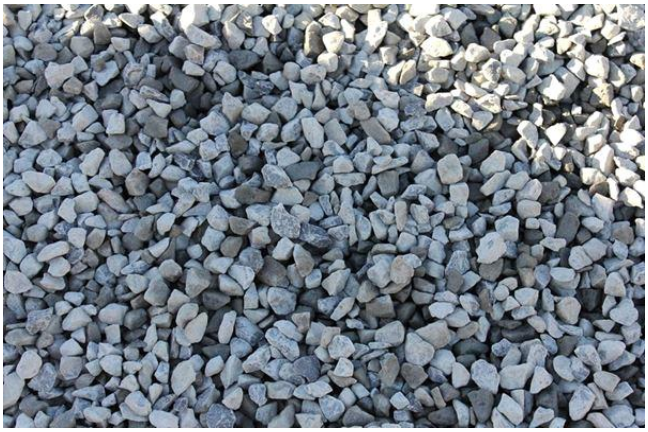
IV. MATERIALS

BITUMEN

Bitumen is the basic material used in the construction of road. The basic type of bitumen used is asphalt which is commonly known as tar in local market. The bitumen is of various grades based of the location of the use of the bitumen.such as grade 40 is used in cold areas. 60 in tropical. 80 in high temperature areas.

BALLAST

Ballast is the granular material usually broken stone or brick, shingle or kankar, gravel or sand. It provides a suitable foundation for the sleepers. It also holds the sleepers in their correct level and position. The lateral stability of a track depends on it. In DBMS layer the size of ballast used is about 9mm.



PLASTIC(PET)

The plastic is the most important material of our project. In our project the polyethylene terephthalate plastic which can molded in various forms is used. The plastic is cleaned, shredded and melted, the melted plastic is then mixed with the bitumen.

V. TESTING

MATERIAL TESTING

PENETRATION TEST :

Penetration test of Bitumen determines the hardness or softness of bitumen by measuring the depth in millimeter to which a standard loaded needle will penetrate vertically in five

seconds while the temperature of the bitumen sample is maintained at 25 C.Also, the Penetration test of bitumen is used to measure the consistency of bitumen. This test is applied almost exclusively to bitumen. For Tars, cutbacks and emulsions other consistency tests are used

Penetration test on bitumen is carried to determine:

i. Consistency of bituminous material
ii. Suitability of bitumen for use under different climatic conditions and various types of construction

VISCOSITY TEST :

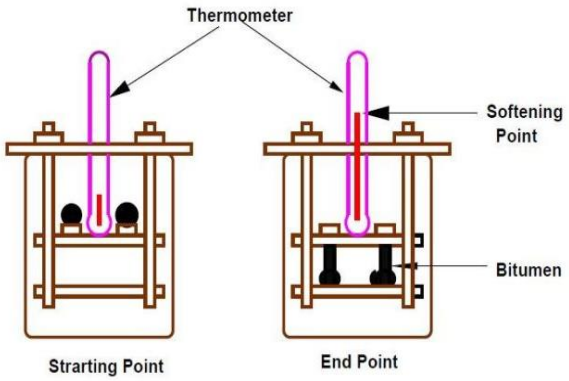
The viscosity test is conducted to determine viscosity of a fluid which is the property by which it offers resistance to flow. Higher the viscosity, the slower will be the movement of liquid. The viscosity affects the ability of binder to spread, move into and fill up the voids between aggregates. It plays an important role in coating of aggregates. Binder which are highly viscous may not fill up the voids completely thereby resulting in poor density of the mix.At lower viscosity the binder does not hold the aggregates together but just acts as a lubricant. The viscosity of bituminous binders falls down very rapidly as the temperature rises. Since binders exhibit viscosity over wide ranges, it is necessary to use different methods. For binders in liquid state (road tars, cutback bituminous), the viscosity is determined as the time in seconds by 50 c.c of material to flow from a cup through a specified orifice under standard conditions of temperature.

SOFTENING POINT TEST :

The softening point of bitumen or tar is the temperature at which the substance attains particular degree of softening. As per IS: 334-1982, ASTM E28-67 or ASTM D36 or ASTM D6493 – 11, it is the temperature in ºC at which a standard ball passes through a sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerine at specified conditions of test. The binder should have sufficient fluidity before its applications in road uses.The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by ring and ball apparatus

Apparatus for Softening Point Test

1. The ring and ball apparatus consisting of:
2. Steel balls-two numbers each of 9.5 mm diameter weighing 3.5 ± 0.05 g.
3. Brass rings-two numbers each having depth of 6.4 mm. The inside diameter at bottom and top is 15.9mm and 17.5 mm respectively.
4. Ball guides to guide the movement of steel balls centrally.
5. Support -that can hold rings in position and also allows for suspension of a thermometer. The distance between the bottom of the rings and the top surface of the bottom plate of the support is 25mm.
6. Thermometer that can read up to 100° C with an accuracy of 0.2° C.
7. Bath–heat resistant glass beaker not less than 85 mm in diameter &1220mm deep.
8. Stirrer



FLASH AND FIRE POINT TEST:

Flash and Fire point test is conducted on bitumen to know the safe mixing and application temperature values of particular bitumen grade

At higher temperatures bituminous materials leave out volatiles. These volatile vapors contains hydro carbons. So, they can catch the fire easily and will cause flash at one point and if it is further prone to heat the material may ignite and burn.

Catching fire is very dangerous during mixing of bitumen especially during its application. So, it is necessary to recognize the safe temperature values of bitumen grades for mixing as well as for applying. The limited values of temperature can be determined by conducting Flash point and Fire point test on bitumen

The Flash point of a material is the lowest temperature at which vapor of substance quickly catches fire in the form of flash under definite conditions of the test. So, at this point fire will not last longer, just a flash will appear for a fraction of second

The fire point of a material is the lowest temperature at which material catches fire and burns under definite conditions of test.The presence of combustible materials in a bituminous material can be indicated by the Fire point

Apparatus

- Pensky-Martens closed tester
- Thermometer

Pensky-Martens closed cup tester contains testing cup, lid, stirrer device, shutter, and flame exposure device. Thermometer of specified range generally 0oC to 350oC with sensitivity of 0.1oC should be used.

DUCTILITY TEST :

Ductility of bitumen is its property to elongate under traffic load without getting cracked in road construction works. Ductility test on bitumen measures the distance in centimeters to which it elongates before breaking.

Apparatus required, theory, procedure, precautions, observations, reporting and recommended values of bitumen ductility is discussed in this article

The ductility test on bitumen will be used to determine following:

1. To measure the ductility of a given sample of bitumen
2. To determine the suitability of bitumen for its use in road construction.

Apparatus Required for Ductility Test on Bitumen:

The apparatus as per IS: 1208-1978 consists of:

(i) Briquette mould: It is made of brass. Circular holes are provided at ends called clips to grip the fixed and movable ends of the testing machine. The mould when properly assembled form a briquette specimen of following dimensions:

- Total length 75.0 ± 0.5 mm
- Distance between clips 30.0 ± 0.3mm
- Width at mount of slip 20.0 ± 0.2mm
- Width at minimum cross-section (half way between clips) 10.0 ± 0.1mm
- Thickness throughout 10.0 ± 0.1mm

(ii) Water bath: A bath maintained within 27.0° ±0.1 °C of the specified test temperature containing not less than 10 litres

of water, the specimen being submerged to a depth of not less than 10 cms and supported on a perforated shell and less than 5 cms from the bottom of the bath.

(iii) Testing machine: For pulling the briquette of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously submerged in water while the two clips are being pulled apart horizontally at a uniform speed of 50 ± 2.5 mm per minute.

(iv) Thermometer: Range 0-44°C and readable up to 0.2°C

STRENGTH TESTING :

The strength test are marshall stability test for bitumen , california bearing ratio,benkelmen beam test

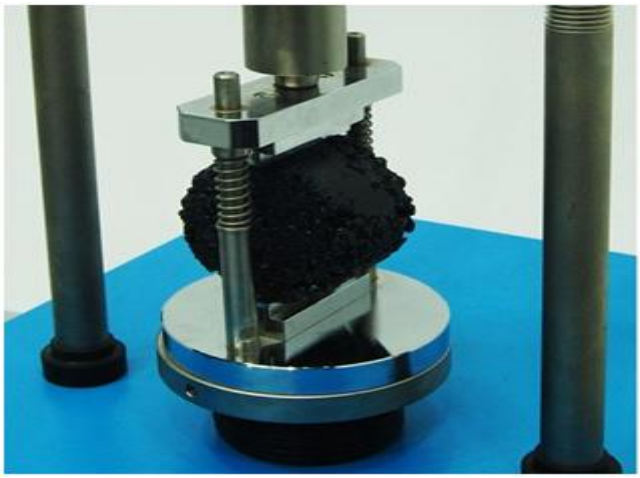
MARSHALL STABILITY TEST :

Marshall stability test – flow test on bitumen and is applicable to hot mix design of bitumen and aggregates of maximum size 2.5 cm.

Bituminous concrete mix is commonly designed by Marshall Method. This test is extensively used in routine test programmes for the paving jobs.

The stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature of 600C. The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test (flow value may also be measured by deformation units of 0.1 mm).

This test attempts to get the optimum binder content for the aggregate mix type and traffic intensity. This is the test which helps us to draw Marshall Stability vs. % bitumen.



VI. RESULT & DISCUSSIONS

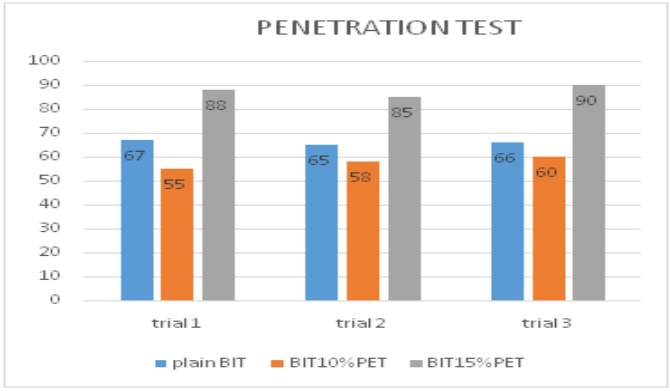
PENETRATION TEST :

TRIAL	PLAIN BITUMIN	BITUMIN WITH 10% PLASTIC(PET)	BITUMIN WITH 15% PLASTIC(PET)
1	67	55	88
2	65	58	85
3	66	60	90

PENETRATION TEST RESULTS (TABLE)

1. The penetration value of normal bitumen is 66mm.
2. The penetration value of bitumen with 10% plastic is 60mm.
3. The penetration value of bitumen with 15% plastic is 87mm.

The penetration value results clarify that the bitumen with 10% plastic is optimum**.**



GRAPH FOR PENETRATION TEST

4.2 VISCOSITY TEST :

Viscosity of cutback bitumen = 360seconds
Viscosity of cutback bitumen 10% plastic = 890seconds
Viscosity of cutback bitumen 15% plastic = 1000seconds
Based on the results of the viscosity test the bitumen with 15% plastic is optimum

4.3 DUCTILITY TEST :

Result of ductility test on Bitumen

Ductility value of normal bitumen = 83cm
Ductility value of bitumen with 10% plastic = 52cm
Ductility value of bitumen with 15% plastic = 100cm

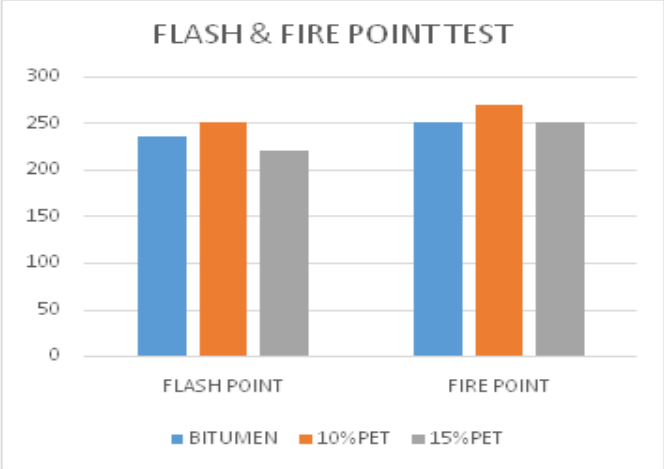
SOFTENING POINT TEST :

Softening point of bitumen / tar = 53°C
Softening point of bitumen 10% of plastic = 64°C
Softening point of bitumen 15% of plastic = 40°C

FLASH & FIRE POINT TEST:

TEST	PLAIN BITUMEN	BITUMEN & 10% PLASTIC	BITUMEN & 15%PLASTIC
FLASH POINT	235°C	250°C	220°C
FIRE POINT	251°C	270°C	250°C

FLASH & FIRE POINT TEST(TABLE)



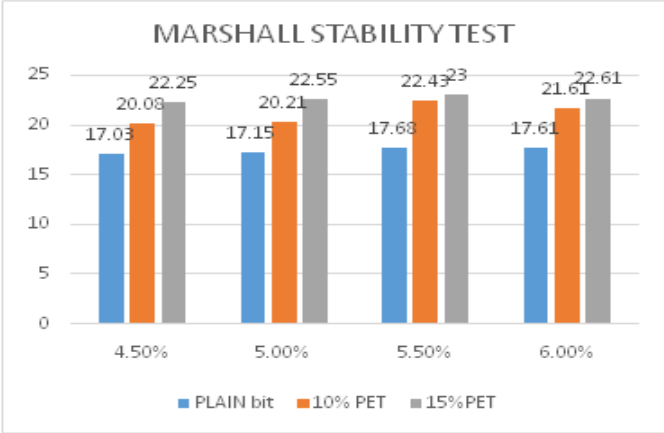
GRAPH FOR FLASH & FIRE POINT TEST

MARSHALL STABILITY TEST :

BITUMEN CONTENT	STABILITY OF PLAIN BITUMEN	STABILITY OF BITUMEN WITH 10% PLASTIC	STABILITY OF BITUMEN WITH 15% PLASTIC
4.5%	17.03	20.08	22.25
5.0%	17.15	20.21	22.55
5.5%	17.68	22.43	23
6.0%	17.61	21.61	22.61

MARSHALL STABILITY TEST(TABLE)

Based on the result obtained from the marshall stability test of the normal bitumen and modified bitumen containing various concentrations of plastics a graph is drawn and according to the graph the maximun values gives the strength of the materials.Based on the table above the maximum strength is attained at 5.5% of the bitumen content.



GRAPHFOR MARSHALL STABILITY

SUMMARY OF RESULTS :

The table below compares the result obtained in various test foe bitumen and plastic added bitumen .The result of the normal bitumen and modified bitumen containing various percentage of plastic is compared among each other and based on the code book IRC:SP:053:2010 and the ratio containing a considerable values is chosen and given as a result of analysis. according to the code book IRC:SP:053:2010,The values of the test results are compared with the table.2 Properties of modified bitumen(page no 7).The values havng approximate values as the table is consider to be the best results given in the code book for modified bitumen.

EXPERIMENT	NORMAL BITUMEN	BITUMEN WITH 10% PLASTIC	BITUMEN WITH 15% PLASTIC
Penetration test	68mm	58mm	88cm
Ductility test	83cm	52cm	100cm
Viscosity test	360sec	890sec	1000sec
Flash point	235	250	220
Fire Point	251	270	250
Softening point	53	64	40
Marshall stability test	17.68	22.43	23

COMPARITIVE ANALYSIS TABLE

After the comparison of the results obtained it is observed that when the plastic is added to the bitumen its strength is considerably increased. As per our results we conclude that the bitumen containing 10% plastic is more suitable than the normal bitumen and the bitumen containing 15% plastic.

SIGNIFICANCE OF USING PLASTIC IN ROAD:

The polymer bitumen blend is a better binder compared to plain bitumen. The blend as increased Softening point and decreased penetration value with the suitable ductaility.when used for road construction it can withstand higher temperature. Hence it is suitable for tropical regions. It has decreased penetration values. Hence its load carrying capcity is increased. The bend with aggreagte had no stripping value. Hence it can resist the effect of water. The marshall stability value is high.The bitumen required can be reduced depending upon the pecentage of polymer added. It is a good cost saving too.No toxic gases are produced. Disposal of waste plastic wil no longer be a problem,as the plastic waste can be used in the construction of roads.The binding properties of polymer also improves the strength of mastic flooring.

The use of waste plastic on the road helps to provide better place for burying the plastic waste without causing disposal problem. At the same time, a better road is also constructed. It also helps to avoid the general disposal technique of waste plastic namely Land-filling and the incineration, which have certain burden on ecology

VII. CONCLUSION

Based on the results obtained from the comparative analysis a conclusion can be made for the strength and durability on the bituminous roads. As per the penetration test result values obtained, The value of the bitumen with 10% plastic is more efficient. As per the viscosity test values obtained, The viscosity value of the bitumen sample with 15% plastic is more optimum. As per the ductility test, the value of the bitumen sample with 15% plastic is more efficient. As per the softening point test, The values obtained from the bitumen samples with 10% plastic is more efficient. As per the result from the flash and fire point test, The values indicate that the bitumen sample with 10%plastic is more efficient. As per the marshall stability test results obtained,the values of bitumen with 10%plastic and the bitumen containing 15% plastic only have slight variation at 5.5% of bitumen content.Overall comparison of the results implies that results obtained from the bitumen sample with 10% plastic is more optimum when compared to the results obtained from the bitumen sample containing 15% plastic.Test the penetration value :ranges between 60-70 for normal bitumen,55-60 for bitumen with 10% plastic and 80-100 for bitumen with 15% plastic. Marshall stability :value top for 5.5% bitumen content as a value of 17.68 for normal bitumen,22.3 for bitumen with 10% plastic and 22 for bitumen 15% plastic. Softening point :the value of normal bitumen is 53°C,bitumen with 10% plastic is 60°C and bitumen with 15% plastic is 43°C.Flash and fire point test :the result value ranges between 220°C-250°C .The ductility test: the value of normal bitumen is 83mm,the value of bitumen with 10% plastic is 52mm and the value for bitumen with 15% plastic is 100mm.Viscosity test :the value for normal bitumen is 360seconds,for bitumen with 10% plastic is 890seconds and for bitumen with 15% plastic is 1000seconds. Thus we conclude that adding **polyethylene terephthalate(PET)** plastic to the bitumen increases the strength more than the normal bitumen with only sample,that to the sample containing 10% plastic is more optimum for usage.

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