Utilization of Waste Plastic in Bitumen

[1.] Mrs. M. Mahalakshmi, [2.] S. Priyankaprakash, [3.] T. Shalini, [4.] R. Rajamanickam, [5.] K. Ramasamy
[1.] Assitant Professor, Adhiyamaan College of Engineering Hosur
[2,3,4,5.] Student,Adhiyamaan college of engineering,Hosur

***Abstract*— This project is a comparative study of normal bitumen and waste plastic added bitumen. This study helps in increasing the strength of bitumen by addition of non-degradable plastic waste which provides reduction in the percentage of bitumen. The waste plastics like polythene bags, milk covers from various sources are collected, cleaned and dried for further processing. The waste plastic is then processed in shredding machine and the shredded plastic is then mixed with the hot bitumen. The normal bitumen and waste plastic added bitumen is tested as per specifications in IRC : SP:53:2010 ,IS 3370.Bitumen can be modified with waste plastic pieces and which can be used as a top layer coat of flexible pavement. This waste plastic modifiedbitumen show 20% better in stability, density and more resistant to water.**

I. INTRODUCTION

GENERAL

Bitumen is a useful binder for road construction. Different grades of bitumen like 30/40,60/70 and 80/ 100 are available on the basis of their penetration values. The steady increase in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature demand improved road characteristics.

Today the availability of the waste plastics is enormous, as the plastic materials have become part and parcel of daily life. They either get mixed with Municipal Solid Waste and/or thrown over land area. If not recycled, their present disposal is either by landfilling or by incineration.

Both the processes have certain impact on the environment. Under this circumstance, an alternate use for the waste plastics is also needed. Thinner polythene carry bags are most abundantly disposed wastes, which do not attract the attending rag pickers for collection for onward recycling, for lesser value. Again, these polythene bags are easily compatible with Bitumen at specified conditions. The waste polymer bitumen blend can be prepared and a study of the properties can throw more light on their use for road laying.

WASTE PLASTICS - AS MODIFIED BINDER:

Waste plastics (polythene carry bags, milk covers) on heating soften at around 130°C. thermogravimetric analysis has shown that there is no gas evolution in the temperature range of 130-180°C.

Moreover the softened plastics have a binding property. Hence, the molten plastics materials can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction.

NEED FOR THE STUDY

1) Disposal of waste plastic is a major problem.
2) It is non-biodegradable.
3) Burning of these waste plastic bags causes environmental pollution.
4) Dump yard and waste pits mainly consists of low-density polyethylene.
5) To find its utility in bituminous mixes for road construction.
6) Properties of bituminous mix provides the solution for disposal in an useful way.

Dry process

For the flexible pavement, hot stone aggregate (170^0C) is mixed with hot bitumen (160^0C) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetrationvalue and viscoelastic property.

The plastic is added to the heated aggregate and it improves its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with

< 2% porosity only allowed by the specification.

OBJECTIVES

- To utilize non- degradable plastic in bitumen.
- To compare the strength characters of normal bitumen and waste plastic added bitumen

II. METHODOLOGY

The waste plastics are collected from the dump yards and are segregated according to microns sizes. The segregated plastics are cleaned and dried. Then the plastics are divided into high density polyethylene and low density polyethylene. Thereafter the plastics are shredded by using the shredding machine into 2mm-4mm sizes each separately. On the other side bitumen is heated upto 160˚c. The shredded plastics are added to the hot bitumen and mixed. Addition of the shredded plastics to the bitumen are at different percentages(5%,7%,9%).Test results are compared and finally the optimum percentage of adding waste plastic to the bitumen is found.

III. LITERATURE REVIEW

1.Mrs. Vidula Swami from KIT'S college of engineering , Kolhapur, Maharashtra has presented paper on the topic **"Use of waste plastic in construction of bituminous roads"** and it was published in **"International Journal of Engineering Science and Technology (IJEST)** in the year 2012. The

author states that "The addition of plastic increases the hardness of the bitumen. The penetration value of the bitumen changes depending on the plastic added and the type of plastic added. The waste plastic to be used is between 5% to 10%. The problems like bleeding are reduced in the hot temperature region by the plastic –bitumen blend. Plastic has a property of absorbing sound which helps in reducing the sound pollution of heavy traffic. Load carrying capacity is increased and can resist water."

2.AmitGawandeand **G.S. zamre**from**College of engineering and technology akola , Akola Maharashtra** ,has presented a paper on the topic "**Utilization of waste plastic in asphalting on roads**" and it was published by **"scientific research and chemical communication"**. The authors states that "use of modified bitumen with addition of processed waste plastic of 4%-8% by weight of bitumen helps in substantially improvement of marshall stability and reduces the fatigue life. This results in the longevity of the roads and pavement performance with reduction in the marginal usage of bitumen. The process is environmental friendly and gives better infrastructure. Adding of plastic in bitumen doubles the binding property of bitumen .Flexible films of all types of plastic can be used.

3.Afro Sultana .S.K and **K.B.S Prasad** from **"GMR Institution of technology ,Rajam ,Andhra Pradesh "** has presented a paper on the topic **"Utilization of waste plastic as a strength modifier in surface course of flexible and rigid pavement "** was published in the **"International journal of engineering research and applications"** in July-august 2010 issue 4 . The authors concluded that "By adding plastic to the modified bitumen, the flow characteristics have been improved. There is an increase in the softening point and decrease in the penetration and ductility value. The stability values of poly propylene and LDPE are 6% and 8% respectively. The LDPE plastics show better performance value than polypropylene. By using the plastic waste for road construction we can reduce disposal of waste plastic which is harmful to the environment".

4.Remadeviand**Lenistphen**from the **"MA college of engineering , Kothamangalam , Kerala"** has presented a paper on the topic **"Reduction of optimum bitumen content in bituminous mixes using plastic coated aggregates"** and it was published in the **"International journal of innovative research of innovative research in science "** in the year 2013- march. The authors of this paper concluded that "The properties of aggregates which mainly cause rutting action are reduced using plastic coated aggregates. There is considerable increase in Marshall Stability value. The use of bitumen content is reduced. All the waste plastic which is a pollution menace can find its use in road construction and thereby solving the problem of pollution to a certain extent".

MATERIALS :

The materials used are

1) Plastics
- Waste milk cover (HDPE)
- Carry bags (LDPE)

2) Bitumen(60/70)

3) Aggregate

COLLECTION OF SAMPLES

MILK COVERS

CARRY BAGS

SHREDDED PLASTICS

SHREDDEDMILK COVERS (2 mm -4mm)

SHREDDED CARRY BAGS(2 mm – 4 mm)

PROPERTIES OF BITUMEN

Bitumen is a black, highly viscous non crystalline material derived either naturally as an organic by product of decomposed organic materials or by refinery process as an end product from distillation of crude oil or petroleum. It solidifies on exposure to air and has an adhesive property in its viscous state. Bitumen is also termed as Asphalt or Asphalt Cement in USA.

Bitumen is very important component for paving roads . The quality of bitumen varies in accordance to its source and hence it is necessary to test the properties of bitumen before its use. There are many tests which are conducted to check the quality of bitumen.The bitumen is brought to sufficient fluidity or viscosity before use in pavement construction by any one of the following three methods:

-By heating, in the form of hot bitumen binder.

-By dissolving in light oils, in the form of Cutback Bitumen.

-By dispersing bitumen in water, in the form of Bituminous Emulsion.

the paving bitumen available in India is classified into two categories:

- Paving bitumen from Assam petroleum, denoted as A-Type and designated as A 35 grade, A 90 grade, etc
- Paving bitumen from other source denoted as S-Type and designated as S 35 grade, S 90 grade, etc.

MARSHALL MIX DESIGN

The mix design (wet mix) determines the optimum bitumen content. This is preceded by the dry mix design. There are many methods available for mix design which vary in the size of the test specimen, compaction, and other test specifications. Marshall method of mix design is the most popular one and is discussed below.

Marshall mix design

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) as a result of the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next.

Specimen preparation

Approximately 1200gm of aggregates and filler is heated to a temperature of 175^{0}C to 190^{0}C. Bitumen is heated to a temperature of 121^{0}C- 125^{0}C with the first trial percentage of bitumen (say 3.5 or 4% by weight of the material aggregates) to the heated aggregates and thoroughly mixed at temperature of 154^{0}C to 160^{0}C

The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of 138^{0}C to 149^{0}C. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0:5% and repeat the above procedure.

Determine the properties of the mix

The properties that are of interest include the theoretical specific gravity Gt, the bulk specific gravity of the mix Gm, percent air voids Vv, percent volume of bitumen Vb, percent void in mixed aggregate VMA and percent voids filled with bitumen VFB.

Theoretical specific gravity of the mix Gt

Theoretical specific gravity Gt is the specific gravity without considering air voids, and is given by:

$$Gm = \frac{\mathrm{W1 + W2 + W3 + Wb}}{\frac{W1}{G1} + \frac{W2}{G2} + \frac{W3}{G3} + \frac{Wb}{Gb}}$$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of fine aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, G1 is the apparent specific gravity of coarse aggregate, G2 is the apparent specific gravity of fine aggregate, G3 is the apparent specific gravity of filler and Gb is the apparent specific gravity of bitumen.

Bulk specific gravity of mix (Gm)

The bulk specific gravity or the actual specific gravity of the mix Gm is the specific gravity considering air voids and is found out by:

$$Gm = \frac{\mathrm{Wm}}{Wm - Ww}$$

where, Wm is the weight of mix in air, Ww is the weight of mix in water.

Air voids percent (Vv)

Air voids Vv is the percent of air voids by volume in the specimen and is given by

$$Vv = \frac{(\mathrm{Gt - Gm)\ X\ 100}}{\mathrm{Gt}}$$

Percent volume of bitumen Vb

The volume of bitumen Vb is the percent of volume of bitumen to the total volume and given by:

$$\gamma = \frac{\mathrm{(wb/Gb)}}{\mathrm{(W1 + W2 + W3 + Wb)/GM}}$$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of fine aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, Gb is the apparent specific gravity of bitumen, and Gm is the bulk specific gravity of mix.

TEST PROCEDURES FOR NORMAL BITUMEN

SOFTENING POINT

- 60/70grade of bitumen is heated to 160^{0}C-170^{0}C
- The rings are placed on the glass plate to which the heated bitumen is poured(dextrin powder is applied on the surface of glass plate to avoid sticking of bitumen)
- The rings with the heated bitumen is kept until it cools to room temperature
- The rings are placed in the stand and then kept in the beaker
- The beaker is filled with ice and kept at 5^{0}C for 15 minutes
- The thermometer is fixed in the stand for checking the accuracy of temperature
- After 15 minutes the apparatus is kept on the flames with a mesh under it
- The ball is placed in the centre of the ring and thermometer is placed in the beaker
- When the ball comes down along with the bitumen ;the temperature is noted and that is the softening point of the plastic added bitumen

DUCTILITY

- Bitumen is heated to 160^{0}C-170^{0}C
- Heated bitumen is poured into the ductility mould
- The mould is kept until it cools to room temperature
- The mould is placed in ice and kept at 27^{0}C for 1 hour
- The mould is placed in ductility machine
- The readings are noted when the bitumen breaks into threads

MARSHALL STABILITY

- The bitumen is heated to 160^0-170^0
- The aggregates (19mm, 13mm, 6.7mm & dust) are weighed to all total of 1200gm & than heated to 140^0C.
- The heated aggregate & bitumen is added and mixed then transferred to the compaction mould.
- The mould is given 75 blows on the topside of the specimen mix with standard hammer (45cm, 4.86Kg). reverse the specimen & 75 blows is given on the other side.The mould is kept undisturbed for 24hrs.
- The specimens from the mould is gently removed .
- A series of specimens are prepared by a similar method with varying quantities of bitumen content.
- The dry specimen is weighed & noted as W1.
- The specimen is immersed in water and is weighed & noted as W2.
- The specimen immersed in water is removed and weighed W3.
- The specimen is immersed in hot water bath at 60^0 for 30min .
- The specimen is tested for its stability & flow.

FLASH POINT TEST

The flash point of a material is the lowest temperature at which the application of test flame causes the vapours from the material to momentarily catch fire in the form of a flash under specified conditions of the test.

The apparatus required for this test is
i) Pensky-Martens apparatus
ii) Thermometer- Low Range : -7 to 110^{o}C, Graduation 0.5^{o}C
High Range : 90 to 370^{o}C, Graduation 2^{o}C.
The sample should be just sufficient to fill the cup upto the mark given on it.

PROCEDURE

1) Soften the bitumen between 75 and 100^{o}C. Stir it thoroughly to remove air bubbles and water.

ii) Fill the cup with the material to be tested upto the filling mark. Place it on the bath. Fix the open clip. Insert the thermometer of high or low range as per requirement and also the stirrer, to stir it.

iii) Light the test flame, adjust it. Supply heat at such a rate that the temperature increase, recorded by the thermometer is neither less than 5^{o}C nor more than 6^{o}C per minute.

iv) Open flash point is taken as that temperature when a flash first appears at any point on the surface of the material in the cup. Take care that the bluish halo that sometimes surrounds the test flame is not confused with the true flash. Discontinue the stirring during the application of the test flame.

v) Flash point should be taken as the temperature read on the thermometer at the time the flash occurs.

The fire point is the lowest temperature at which the application of test flame causes the material to ignite and burn at least for 5 seconds under specified conditions of the test.

FIRE POINT TEST

The apparatus required for this test is
i) Pensky-Martens apparatus
ii) Thermometer- Low Range : -7 to 110^{o}C, Graduation 0.5^{o}C
High Range : 90 to 370^{o}C, Graduation 2^{o}C
The sample should be just sufficient to fill the cup upto the mark given on it.

PROCEDURE

i) After flash point, heating should be continued at such a rate that the increase in temperature recorded by the thermometer is neither less than 5^{o}C nor more than 6^{o}C per minute.

ii) The test flame should be lighted and adjusted so that it is of the size of a bead 4mm in dia.

MODIFIED BITUMEN

MARSHALL STABILITY INSTRUMENT

PROCEDURE

- The bitumen is heated to 160^0C - 170^0C.
- The shredded plastic (plastic covers, milk covers) is added to the bitumen.
- The aggregate (19mm,13mm,6.75mm& dust) are weighed to all total of 1200 gm and then heated to 140^0C.
- The heated aggregate & the plastic added bitumen is mixed & transferred to the compaction mould.
- The specimen is given 75 blows on the topside of the specimen mix with std hammer(45cm,4.86kg).reverse the specimen & 75 blows is given on the other side.
- The mould is kept undisturbed for 24hours.
- The specimen from the mould is gently removed.
- A series of specimens are prepared by a similar method with varying quantities of bitumen content with plastics.
- The dry mould is weighed & noted as W1.
- The mould is immersed in water & is weighed & noted as W2.
- The mould is immersed in water is removed & weighed asW3.
- The mould is immersed in hot water bath at 60^0c for 30min.
- The mould is tested for its stability & flow.

MARSHALL MOULD TESTING APPARATUS

PROPERTIES	NORMAL BITUMEN	5% PLASTIC ADDED BITUMEN	7% PLASTIC ADDED BITUMEN	9% PLASTIC ADDED BITUMEN
STABILITY(KN)	17.77	7.7	8.24	6.42
AIR VOIDS(%)	3.27	2.46	2.28	2.66
FLOW(%)	4.16	6.41	5.04	6.26
VFB(%)	74.93	65.19	71.6	66.23
SPECIFIC GRAVITY	1.02	0.99	0.97	0.93

MODIFIED BITUMEN
MARSHALL STABILITY TEST
VALUES FOR HDPE

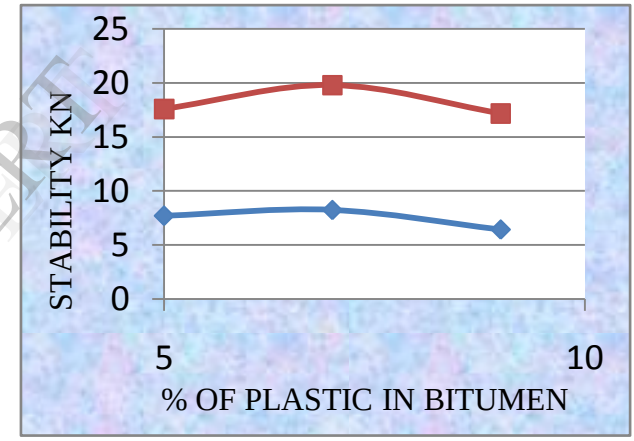
PROPERTIES	NORMAL BITUMEN	5% PLASTIC ADDED BITUMEN	7% PLASTIC ADDED BITUMEN	9% PLASTIC ADDED BITUMEN
STABILITY(KN)	17.77	15.20	18.58	18.70
AIR VOIDS(%)	3.27	3.08	3.76	3.22
FLOW(%)	4.16	3.72	3.71	4.26
VFB(%)	74.93	77.48	77.54	74.89
SPECIFIC GRAVITY	1.02	1.04	1.05	1.03

VALUES FOR LDPE

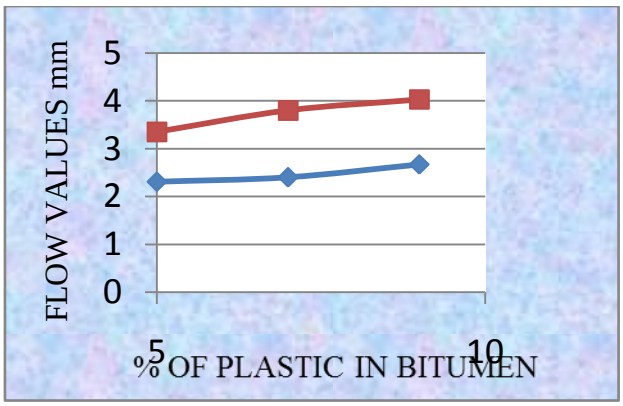
Test	NORMAL BITUMEN	5% PLASTIC ADDED BITUMEN	7% PLASTIC ADDED BITUMEN	9% PLASTIC ADDED BITUMEN	Range
Ductility(kn)	71	52	47	42	MIN 75
Softening point(˚C)	47	53	54	55	47-80
Flash point(˚C)	180	173	175	177	180-185
Firepoint (˚C)	186	180	183	184	185-190

Test	NORMAL BITUMEN	5% PLASTIC ADDED BITUMEN	7% PLASTIC ADDED BITUMEN	9% PLASTIC ADDED BITUMEN	Range
Ductility(kn)	71	52	47	42	MIN 75
Softening point(˚C)	47	53	54	55	47-80
Flash point(˚C)	180	173	175	177	180-185
Firepoint (˚C)	186	180	183	184	185-190

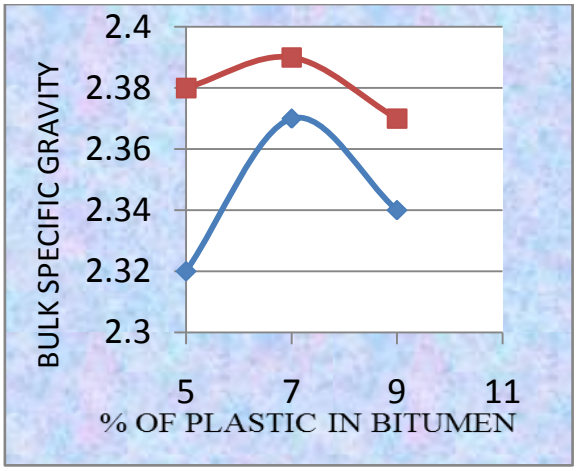
GRAPHS FOR HDPE AND LDPE
BITUMEN % Vs STABILITY:



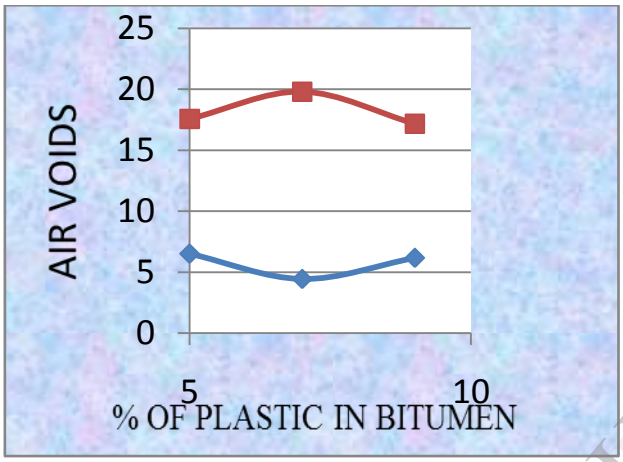
BITUMEN % Vs FLOW VALUES:



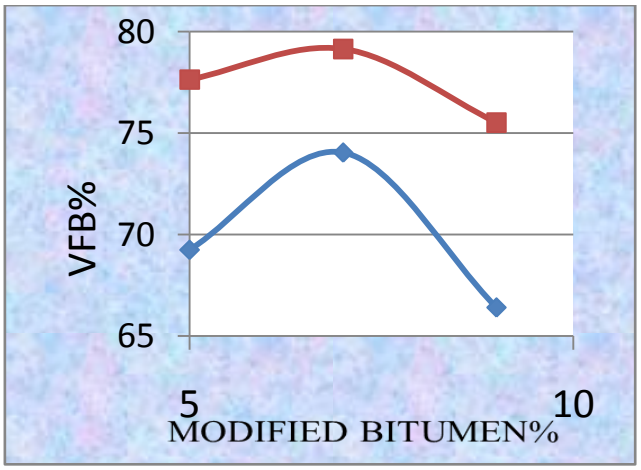
BITUMEN % Vs BULK SPECIFIC GRAVITY(Kg/m3):



BITUMEN % Vs AIR VOIDS:



BITUMEN % Vs VFB:



SPECIMENS AFTER TESTING:

LDPE HDPE

DUCTILITY TEST INSTRUMENT

DUCTILITY TESTING MACHINE

PREPARATION OF SAMPLE

i) The sample should be just sufficient to fill the ring. The excess sample should be cut off by a knife.

ii) Heat the material between 75 and 100^{o}C. Stir it to remove air bubbles and water, and filter it through IS Sieve 30, if necessary.

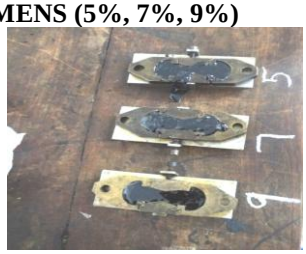
iii) Heat the rings and apply glycerin. Fill the material in it and cool it for 30 minutes.

iv) Remove excess material with the help of a warmed, sharp knife.

PROCEDURE

- Bitumen is heated to 160^{0}C - 170^{0}C
- The shredded milk cover is added to the hot bitumen is poured into the ductility mould
- The ductility mould is kept it cools to room temperature
- The mould is placed in ice and kept at 27^{0}C for 1 hour
- The mould is placed in ductility machine
- The readings are noted when the bitumen breaks into threads

SPECIMENS (5%, 7%, 9%)



SPECIMENS OF DUCTILITY

SOFTENING POINT TEST

SOFTENING POINT

PREPARATION OF SAMPLE

i) The sample should be just sufficient to fill the ring. The excess sample should be cut off by a knife.

ii) Heat the material between 75 and 100^{o}C. Stir it to remove air bubbles and water, and filter it through IS Sieve 30, if necessary.

iii) Heat the rings and apply glycerin. Fill the material in it and cool it for 30 minutes.

iv) Remove excess material with the help of a warmed, sharp knife.

SPECIMENS (5%, 7%, 9%):

SPECIMENS OF SOFTENING POINT

IV. PROCEDURE

- 60/70 Grade of bitumen is heated to 160^{o}C - 170^{o}C
- Shredded milk covers (≥ 40 μ) are added to the hot bitumen & mixed homogeneously.
- The rings are placed on the glass plate to weigh the plastic added bitumen is poured (dextrin powder is applied on the surface of glass plate to avoid sticking of bitumen)
- The rings with plastic added bitumen is kept until it cools to room temperature
- The rings are placed in the stand and then kept in the beaker .The beaker is filled with ice and kept at 5^{o}C for 15 mins
- Thermometer is fixed in the stand for checking the accuracy of temperature.
- After 15 min the apparatus is kept on the flame with a mesh under.
- The ball is placed in the centre of the ring & thermometer is placed in the beaker.
- when the ball comes down along with the plastic added bitumen the temperature is noted.That is the softening point of the plastic added bitumen

V. FLASH & FIRE POINT TEST

The flash point of a material is the lowest temperature at which the application of test flame causes the vapours from the material to momentarily catch fire in the form of a flash under specified conditions of the test.The apparatus required for this test is

i) Pensky-Martens apparatus

ii) Thermometer- Low Range : -7 to 110^{o}C, Graduation 0.5^{o}C High Range : 90 to 370^{o}C, Graduation 2^{o}C.The sample should be just sufficient to fill the cup upto the mark given on it.

PROCEDURE

1) Soften the bitumen between 75 and 100^{o}C. Stir it thoroughly to remove air bubbles and water. Fill the cup with the material to be tested upto the filling mark. Place it on the bath. Fix the open clip. Insert the thermometer of high or low range as per requirement and also the stirrer, to stir it.

ii) Light the test flame, adjust it. Supply heat at such a rate that the temperature increase, recorded by the thermometer is neither less than 5^{o}C nor more than 6^{o}C per minute.

iii) Open flash point is taken as that temperature when a flash first appears at any point on the surface of the material in the cup. Take care that the bluish halo that sometimes surrounds the test flame is not confused with the true flash. Discontinue the stirring during the application of the testflame.

iv).The fire point is the lowest temperature at which the application of test flame causes the material to ignite and burn at least for 5 seconds under specified conditions of the test.

VI. RESULT

COMPARISON OF NORMAL BITUMEN AND PLASTIC ADDED BITUMEN

s.no	Test conducted	7% hdpe	7% ldpe	Normal bitumen	Permissible limit
1	Marshalll stability(kn)	8.24	19.81	17.77	≥9
2	Softening point(˚c)	54^{o}C	48^{o}C	47^{o}C	47^{o}C-50^{o}C
3	Ductility(cm)	47	79	77	≥75
4	Flash(˚c)	175^{o}C	182^{o}C	180^{o}C	180^{o}C-185^{o}C
5	Fire(˚c)	183^{o}C	187^{o}C	186^{o}C	186^{o}C-190^{o}C

VII. CONCLUSION

In our project we compared the normal bitumen properties with the waste plastic bitumen at different percentages. We infer from our results that the optimum percentage of plastic to

be added is 7%.The waste plastic bitumen has 20% better results. This project is also a waste plastic management and also helps in the better disposal of waste plastics.

VIII. DISCUSSIONS

- HDPE plastic fails in wet process .
- LDPE plastics yields good results at optimum as 7%
- LDPE added plastic is more stable and durable when compared to the normal bitumen.
- Addition of LDPE plastics have reduced the bitumen content and also better way of waste plastic disposal.

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