Modified Paving Block- a Solution for Waste Plastic into Value added Applications for Mathura-Vrindavan City

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Abstract

This investigation is focused on the conversion of waste plastic into modified pavement interlock block (Bitumen: quarry dust: coarse aggregate: rice straw ash: waste plastic:: 5% by weight of aggregate mix : 1:2:2% by weight of aggregate mix : 8% by weight of Bitumen) for Mathura Vrindavan city. The aim of this work is to reduce the rapid accumulation of waste plastic at religious places/ tourist spot by throwing the PET bottles in Mathura Vrindavan city. With the application of these experimental results, can make economical and environment friendly paving block. For each 6.7 no. of paving block, 1 PET bottle (38gm) of 1lit volume consumed hence in $10m^2$ areas 55.37no. bottles can be utilized. From Marshall Stability- Flow value test, 8% of PET plastic is optimum value which can use in manufacturing of modified paving block with 80/100 grade of bitumen. The average compressive strength of these blocks at 3 and 7 days is15.94MPa and 24.2MPa and the water absorption value is approximately 0.27%. In the presence of sodium sulphate (250gm in 1lit water) loss of weight is around 7.7%. It was estimated that the manufacturing cost of designed paving block is 12Rs. whereas concrete paving block of same size is Rs. 17. Hence its cost quite low as compared to conventional block.

Keywords- Mathurav vrindavan city, waste plastic, Bitumen

1. Introduction

Waste plastic is one type national and global concern. The waste management for plastic continues to be major thereat for developing country. Socioeconomic growth and consumption status are the after-effects of intense enhancement in the utilisation of plastic in India. Plastic consumption has explored from 5 million tons to 100 million tons in between 1950s -2000s.The single-use waste plastic management is a accrescent issue of Nagar Nigam Mathura Vrindavan (NNMV). It may because of NNMV have experienced population growth during recent decades and the high rate of migration from the rural area due to 51 villages is added to Nagar Nigam Boundary(in 2011) and also a lot of tourist comes to visit Mathura as a holy place.

2. Material

2.1 Bitumen

Bitumen is an essential material in bituminous mix because it acts as a binding material which makes mix adhesive. Now a day's bitumen mainly classified according to viscosity grading (VG). For road construction Bitumen Grade 60/70 is standard grade of bitumen. The specific temperature-viscosity relation is crucial for finding Bitumen's rheological property in the presence of plastic.

For the present research work Bitumen Penetration Grade 80/100 is used for partial replacement of bitumen with waste plastic. And all the properties of each type plastic content binder are compared with bitumen grade 60/70

2.2 Rice Straw Ash

The rice straw ash (RSA) is silica-based finest fillers which are produced of particles with roughly texture. It is composed from the uncontrollable combustion of rice straw. 1000Kg of rice straw produces 150Kg of ash after burning. RSA influence the characteristics of bitumen mix. German Filler value revealed that filler value of RAS is 30g/Kg. Bitumen mix with RSA filler has higher Voids mineral aggregate (VMA) and air voids due to which higher amount of binding material consume. RSA played a crucial role for superior resistance against moisture as well as adhesion

Figure-1 Rice straw ash[iii] and Quarry Dust

2.3 Aggregates

In plastic modified bituminous paving block, aggregates are used in major proportion. It includes coarse aggregates and fine aggregates. The aggregates are inert material which helps to give proper appearance to paving block also decrease shrinkage. Volume of paving block contains about 70% to 80% of aggregates. In

paving block, 40mm size to 20mm coarse aggregate are used for providing high strength.

In plastic modified bituminous paving block, quarry dust with specific gravity 1.95 is used as fine aggregate shows in fig no.1. Samples of quarry dust were dried in oven for 24 hr at 105 ^{o}C before measuring to get the adequate proportions for test

Aggregate's physical properties are directly influence the Marshall Stability value. Higher Marshal Stability value is obtained by using higher quality of aggregate.

2.4 Waste Plastic

Plastic waste can use on a very large scale in construction sector which seems to be more efficient solution of this problem where this plastic waste can be removed for a long time period. Plastic codes are classified into different categories as per Central Pollution Control Board (2015)

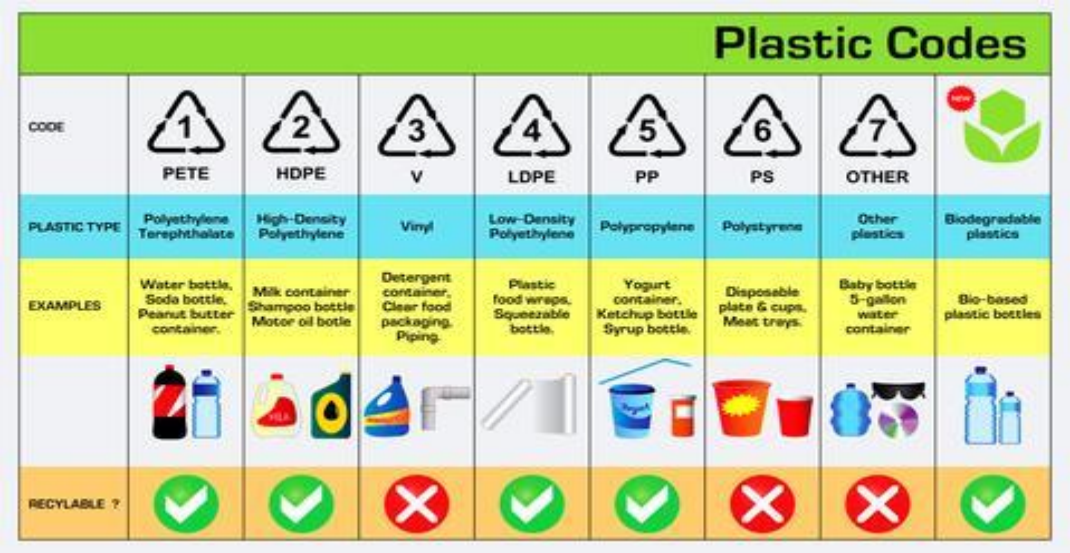

Fig: 2 Plastic codes of *Central Pollution Control Board (2105)*[vi]

In our research work, type of plastic we use is polyethylene terephthalate (PET) because much of research work has been carried out on low and high density polyetheleane (LDPE and HDPE) plastic with bitumen.

The discarded and thrown waste PET plastic bottle used for manufacturing of paving block and were collected from surrounding waste collecting point near religious places shows in fig no 3 which is mainly use for carrying water, cold drink and fruit juice etc. After collection these PET bottles were washed to remove any impurity after that dried in open area until absolutely no moisture was present. After that PET bottle are shredded into particle size 650mm mechanically by using grinding machine. These waste plastic is used for the partial replacement of bitumen to manufacture paving block to reduce the cost.

Physical and mechanical properties of PET Fibbers

Properties	Value
Density (gm/cm^3)	1.38
Tensile strength at break (MPa)	79.3
Tensile modulus	2758
Elongation at break (%)	70
Flexural strength (MPa)	103.42
Flexural modulus (MPa)	2758
Water absorption , 24 hr (%)	0.10
Melting point ºC	260

Fig : 3 collected Pet bottles from religious places

Fig : 4 PET waste plastic Fibers[iv]

3. METHODOLGY

3.1Laboratory testing program for rheological property of bitumen with plastic

Here we prepared a binder mixes namely **A** i.e. Bitumen (B) and Plastic (P) with varying proportion of plastic in bitumen. The rheological properties of this mix having varying percentages of plastic are compared with conventional binder Bitumen namely **B.** The methodology is used in experimental program for determine the changes in rheological property of bitumen with plastic has been illustrated with flow chart in fig: 5

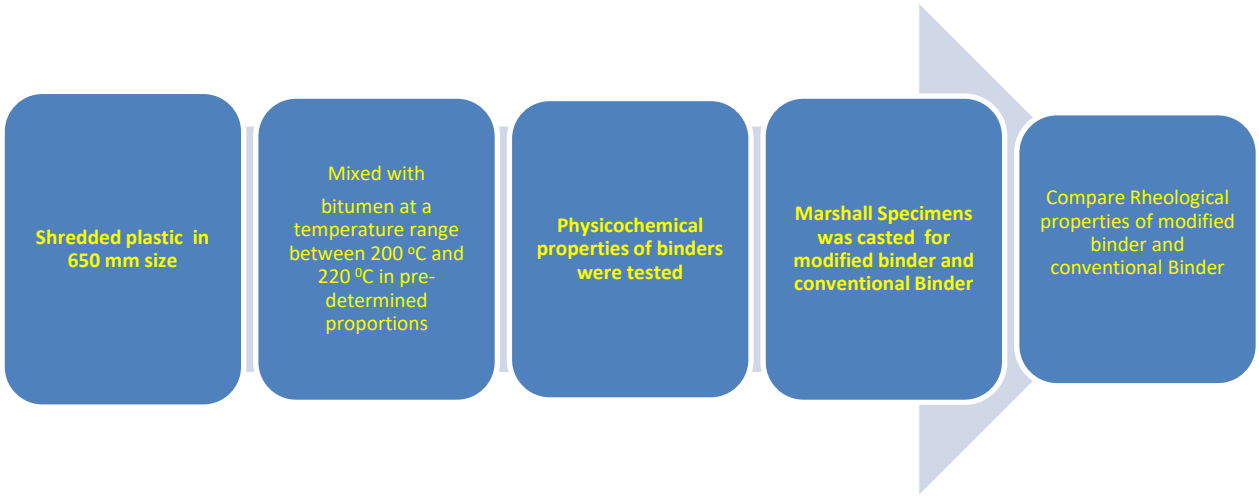

Fig.5. Flow chart depicting overall methodology

3.2. Mix proportion of Binder

Firstly we shredded the PET Bottles into 650mm particle size then these plastic mixes with bitumen at varying proportion at temperature range 180°c to 200 °c. Plastic uses in this modified binder in order of 6%, 8% and 10% by weight of bitumen. The modification effect on plastic modified binder is compared with conventional bitumen binder and can be divided into two modification effect i.e. effect on Physicochemical and rheological properties of binders.

Test results are shown in table no.1 with comparison of conventional binder. It has been found that 8% plastic utilizes by the weight of bitumen for modification gives satisfying physiochemical properties as conventional binder demand in road construction work.

Table:1 Physical properties of binders

Test	Composition				
	100%B (60/70)	**100% B (80/100)**	**94%B+ 6%P**	**92%B+8%P**	**90%B+10%P**
Penetration (25 ^{o}C, 100 g, 5 sec)	**60-70**	80-100	74-94	**71.5-91.5**	69-89
Ductility, cm (25 ^{o}C)	**80**	75	45	**27**	24
Softening Point ^{o}C	**49-56**	42-50	55-57	**60-65**	65-70
Specific Gravity (27 ^{o}C)	**1.06**	1.01	1.06	**1.08**	1.1

3.3. Marshall Specimen preparation with non- modified binder and modifier binder

- First we cast three specimens for each type non-modified binder i.e. grade 60/70 and 80/100 (100% bitumen). Thus total 6 no. of specimen were prepared from non-modified binder on the other hand Three specimen of each type of plastic modified binder content (grade 80/70) for Marshall Test were prepared in which optimum bitumen content is use 5% shown in fig :6. (total 9 specimens were casted)
- Approx. 1275gm of total aggregate mix were taken in which 720gm coarse (40-20mm) aggregate and 360gm of fine aggregate (quarry dust) and 2% filler is present in conventional binder mix
- Aggregate sample were heated in oven at temperature 150-175^{O}C also at the same time both bitumen grades are heated at temperature 150-160^{O}C.
- Both binders (proportion 5%) were mixed with aggregate homogenously at mixing temperature of 165^{O}C for bitumen grade 60/70 and 160^{O}C for bitumen grade 80/100.and For modified binder, 5% Binder by weight of mix (trial proportion 94%B+6%P, 92%+8%P, 90%B+10%P) were mixed with aggregate homogenously at mixing temperature of 160^{O}C for bitumen grade 80/100.
- After complete cover of aggregate with binders this mix were placed in pre heated (at temp.100-140 ^{O} C) cylindrical Mould assembly (in 10 cm dia. and 7.5cm height) with a base plate and collar extension also a filter paper is placed at bottom and top of the sample.
- Now the mould were place on Marshall compaction pedestal where impact load is applied on specimen for compaction purpose

- The mix was placed into three layers in the mould and each layer was compacted by hammer with 50 blows.
- After the compaction the base plate were removed and specimen is extracted by the pushing of extractor.
- Specimen is allowed to cool for few hours.
- Specimen mass in air and when submerged is use to measure the density for the calculation of void properties.

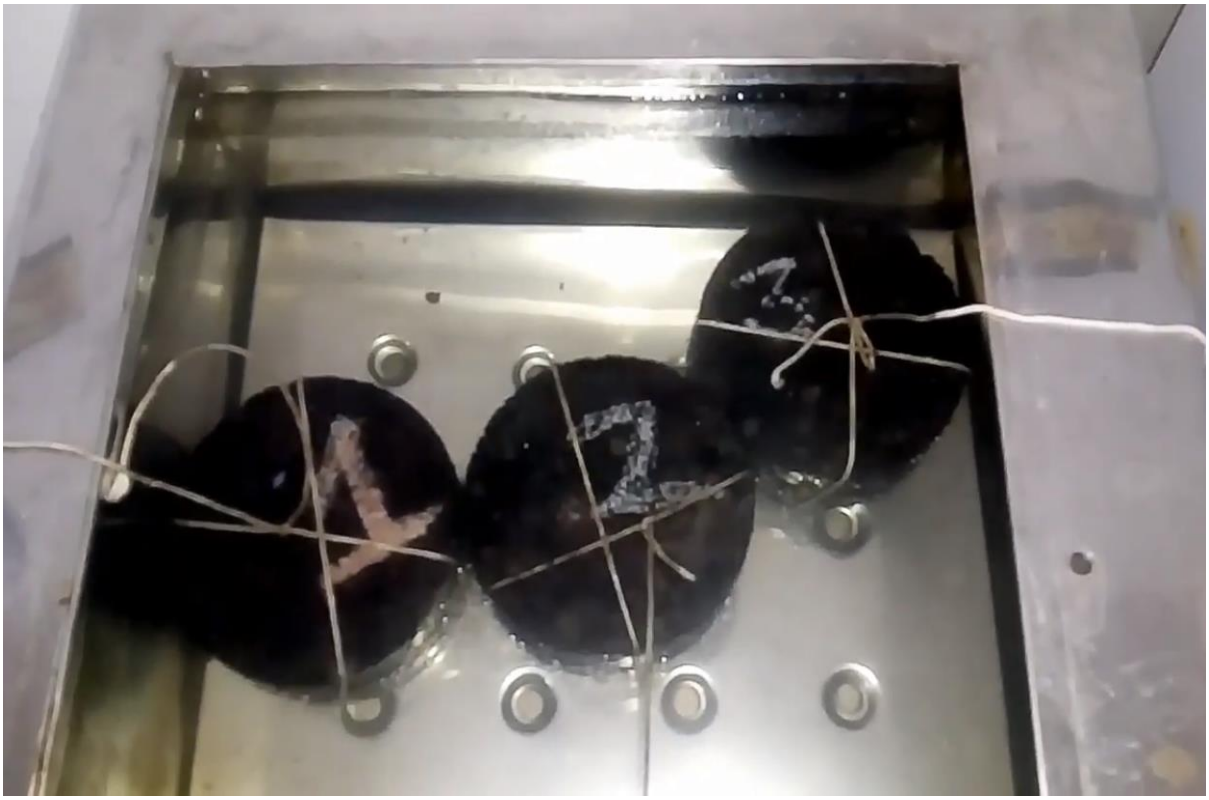

Fig: 6 Marshall Specimen with (1) 100% Bitumen grade 80/100 (2) 94%B+6%P (3) 92%+8%P (4) 90%B+10%P

Table:2 Analysis results of Non-modified Binder (grade 60/70)

Step No.	Parameter	Sample -1	Sample-2	Sample-3
1	Weight of specimen in air	1270gm	1275gm	1271gm
2	Weight of specimen water	761gm	764gm	753gm
3	Saturated surface dry specimen weight	1287gm	1284gm	1279gm
4	Volume of specimen (step no. 3-2)	526cc	520cc	526cc
5	Density of specimen (step no. 1/4)	2.414gm/cc	2.451gm/cc	2.416gm/cc
6	Marshall stability Value(60°C)	9.21KN	10.83KN	9.74KN
7	Flow Value(60°C)	3.19mm	3.26mm	3.18mm

Table: 3Analysis results of Non-modified Binder (grade 80/100)

Step No.	Parameter	Sample -1	Sample-2	Sample-3
1	Weight of specimen in air	1273gm	1275gm	1275gm
2	Weight of specimen water	755gm	762gm	764gm
3	Saturated surface dry specimen weight	1274gm	1280gm	1288gm
4	Volume of specimen (step no. 3-2)	519cc	518cc	524cc
5	Density of specimen (step no. 1/4)	2.45gm/cc	2.46gm/cc	2.43gm/cc
6	Marshall stability Value(60°C)	10.21KN	11.64KN	11.97KN
7	Flow Value(60°C)	3.19mm	3.07mm	4.3mm

Table: 4 Flow-stability Analysis for Avg.test results of non-modified and modified Binder (grade 80/100)

Composition	Marshall stability (KN)	Marshall Flow value (mm)	Bulk density (gm/cc)
Non-modified Binder (grade 60/70) 100%B	9.92	3.21	2.427
Non-modified Binder (grade 80/100) 100%B	11.27	3.52	2.44
94%B+6%p (bit.grade80/100)	12.59	3.42	2.47
92%B+8%p (bit.grade80/100)	**14.27**	**3.11**	**2.43**
92%B+10%p (bit.grade80/100)	13.17	2.68	2.38

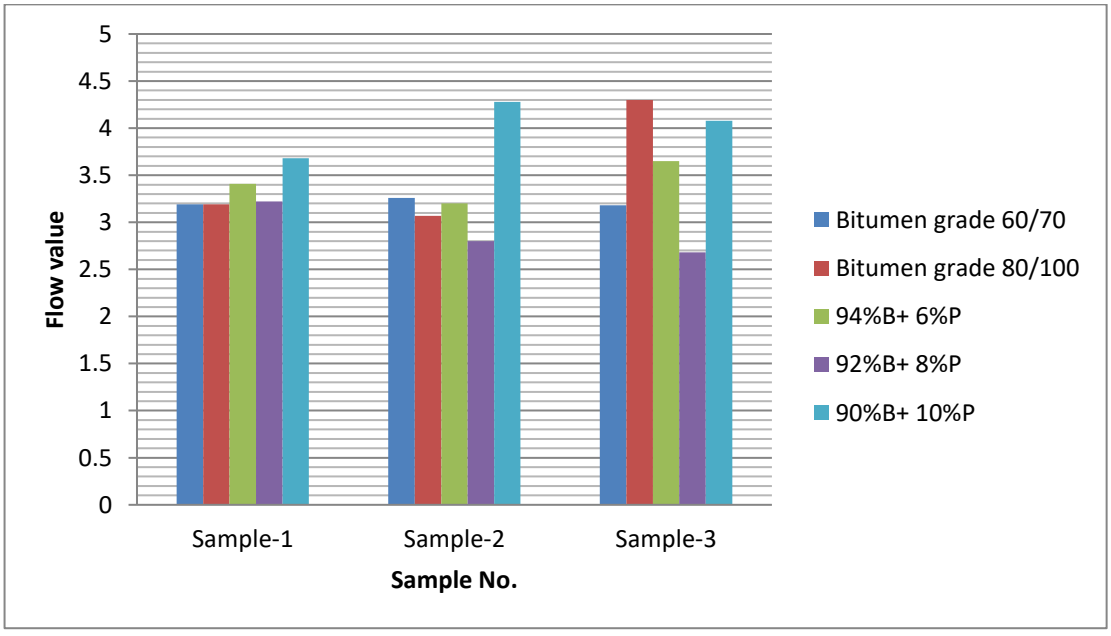

Fig:7 Graph representing flow value of different samples

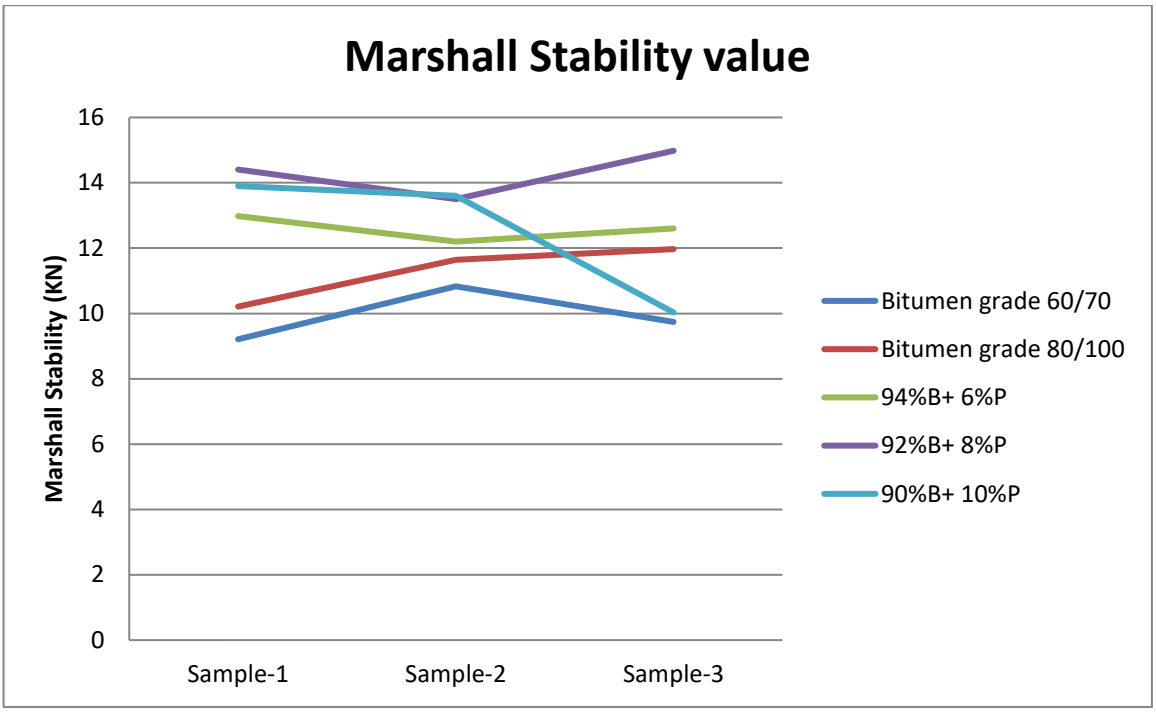

Fig:8 Graph representing Marshall Stability value of different samples

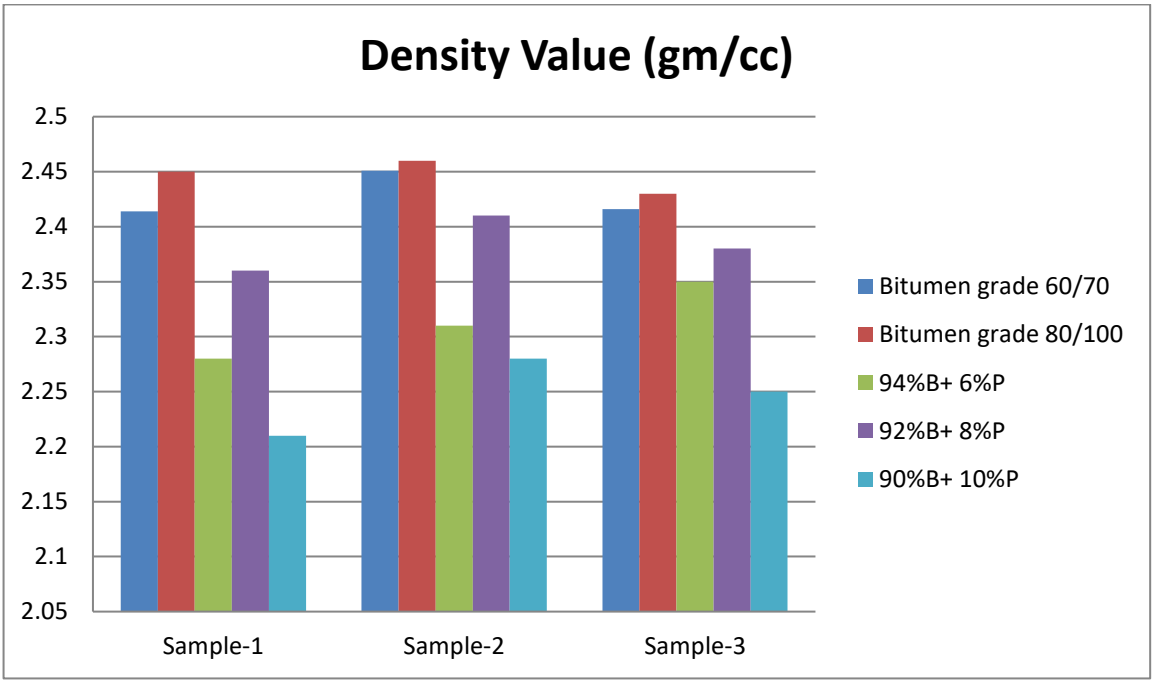

Fig : 9 Graph representing Density value of different samples

3.4. Specimen preparation for paving block

- Mix proportion Bitumen 5% by weight of aggregate mix, Coarse aggregate: Quarry dust ratio = 1:2 and mineral filler 2% by weight of aggregate mix were used as per specification.
- These aggregate sample were heated in oven at temperature 150-175^{o}C also at the same time both bitumen grades are heated at temperature 150-160^{o}C.
- Quantity of bitumen with plastic (5%) by weight of mix was calculated according to the mix proportion and was heated up to 160 °C.
- Aggregates when heated up to required temperature were taken out from oven and mixed with plastic modified bitumen homogenously at mixing temperature of 160^{o}C
- After complete cover of aggregate with binders this mix were placed into I-shape mould (shown in fig -19) of size 200mm *160mm *60mm in three layers and each layered were tamped by 25 times.
- Finally de-moulding of specimen was done when the specimen temperature drop at room temperature.
- A total 9 specimen were casted

  These manufactured paving blocks were tested for compressive strength, water absorption, and soundness test

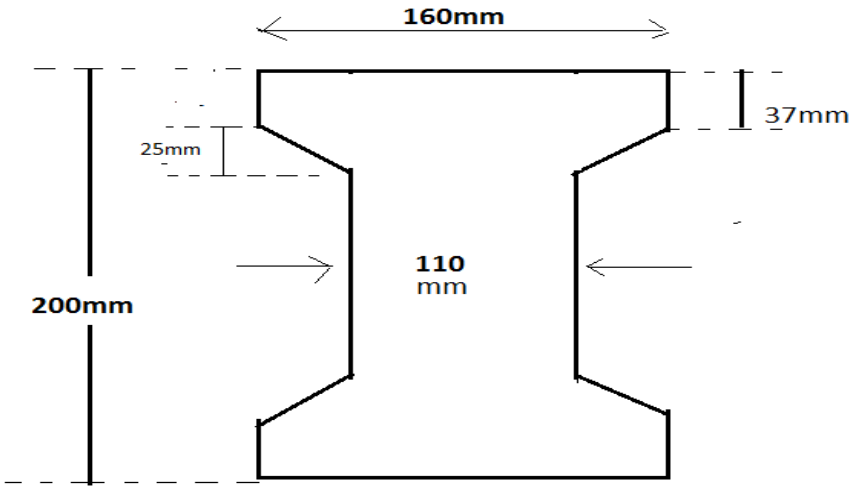

Fig: 10 Dimensions of Paving block

Table :5 Mix proportion

Parameters	Value
Plastic modified bitumen mix bulk density (gm/cc)	2.58
Total weight of block (kg)	4.186
Ratio of CA :FA	1:2
Filler (rice straw ash)	2% by wt of Aggregate mix
Modified binder content	5%
Cross sectional area	(200*110)+(4*37*25)+(4*1/2*25*25) $26950mm^2$
Volume of bituminous block	26950*60 $=0.00162m^3$

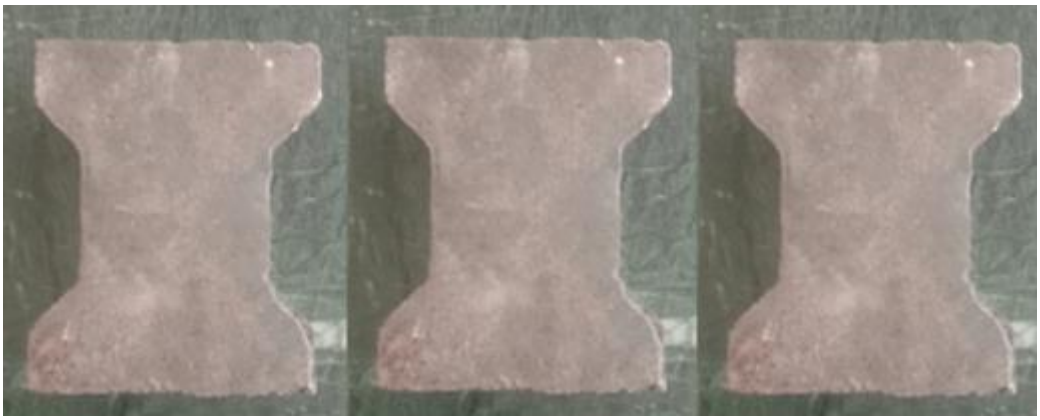

Fig :11 Casted paving block specimen

Conclusion

This study indicates that use of waste plastic bottles improves the strength of bitumen. Thus the application of waste plastic in fixed proportions can help to achieved targeted characteristics strength of Bitumen mix also minimize the construction cost. Moreover it will help to prevent the environmental pollution in Mathura Vrindavan City due to waste plastic dumping

- By the results of above Marshall Experiment we can say that replacement of bitumen (Grade 80/100) with 8% of PET plastic improves the rheological properties as compared to rheological properties of non-modified bitumen grade 60/70. From Marshall Stability we can say at 8% replacement of plastic in 80/100 grade of bitumen gives more stability (14.27KN) as compared to 60/70 grade of non modified bitumen (9.92KN). Flow value at 8% replacement of plastic in 80/100 grade of bitumen gives approx equal to same value (3.11mm) of bitumen grade (3.21mm).

- Thus we can say from that Marshall Experiment, 8% of PET plastic is optimum value which can use in manufacturing of modified paving block with 80/100 grade of bitumen. But beyond the 8% of PET, we can say bitumen starts loses its original properties.

- The addition of PET fiber by 8% of bitumen weight, Modified paving block attains average compressive strength at 3 and 7 days is15.94MPa and 24.2MPa and the water absorption value is approximately 0.27%. In the presence of sodium sulphate (250gm in 1lit water) loss of weight is around 7.7%

- As compare to conventional paving, the compressive strength and water resistance slightly less at 7- days. It was estimated that the manufacturing cost of designed paving block is 12Rs. whereas concrete paving block of same size is Rs. 17. Hence its cost quite low as compared to conventional block. For 6.7 block, 1 PET bottles (38gm) of 1lit volume consumed

Recommendations

This investigation is focused on the conversion of waste plastic into pavement block for Mathura Vrindavan city. The aim of this work is to reduce the rapid accumulation of waste plastic at religious places/ tourist spot by throwing the PET bottles in Mathura Vrindavan city. With the application of this experimental results can make it economical and environment friendly. Following data will show the comparison between conventional and modified results:

Calculation for $10m^2$ area:

- Surface area of paving block = $26950mm^2$
- No. of blocks used in $10m^2$ area = 10000000/26950

  = 371 Blocks
- Plastic use for 2.5 blocks = 14 gm
- Plastic use for 371 blocks =2077.6gm(aprox2.07kg)
- Weight on PET plastic (1lit) = 38gm
- 1PET bottle produce paving block = 6.7 blocks
- No. of PET bottle utilise for 371 block (used in $10m^2$ area) = 6.7*371

  =55.37 Bottels

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