Available online at: http://www.ijmtst.com/vol4issue6.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 04, Issue No: 06, June 2018

Study on use of Waste Polythene in Bituminious Paving Mix Design

M. Subrahmanya Sarma[1] | B. Srikanth[2]

[1]PG Scholar, Department of Civil Engineering, MVR College of Engineering and Technology, Paritala, Andhra Pradesh, India.

[2]Assistant Professor, Department of Civil Engineering, MVR College of Engineering and Technology, Paritala, Andhra Pradesh, India.

To Cite this Article

M. Subrahmanya Sarma and B. Srikanth "Study on use of Waste Polythene in Bituminious Paving Mix Design", *International Journal for Modern Trends in Science and Technology*, Vol. 04, Issue 06, June 2018, pp: 26-33.

ABSTRACT

Bituminous roads since its inception in 1920 have been a very popular method of road construction. In this method of road construction bitumen is used as a binder in the wearing course. This has the advantages of - low cost of materials used relatively low level of noise production by the traffic, lower maintenance and repair cost. However, it is less durable than other methods of road construction available and isn't the best environmentally safe option. In order to counter these drawbacks various studies have been undertaken. In our study with the increased use of plastic which is non-biodegradable in our daily lives the quantum of refuse entering our landfills and filling our garbage dumps is increased phenomenally. This has increased the waste management challenge. In order to address this misuse, reuse and recycle policy is the way. This project takes up this case and uses plastic in bituminous mix. The bitumen in the bituminous mix has been replaced by plastic to some extent. For this study bituminous concrete (BC) has been taken up as the layer of study. This study is divided into two halves. The first half was to determine the Optimum Bitumen Content (OBC) using the Marshall method. The second half was to replace part of the bitumen with plastic and the stability, flow, Void filled with Bitumen (VFB), Voids filled with air (VFA) and Voids in mineral aggregates (VMA) and arrive at the optimum plastic content (OPC) to achieve maximum stability and flow as per the MORTH (revision 5) specifications. IT has been observed that adding plastic up to an optimum level enhances the stability and flow but beyond a limit it does not add to the strength of the bituminousmix.In our study the optimum bitumen content (OBC) was found to be 5.8% and optimum plastic content (OPC) was concluded to be 8.75% of the OBC.

Key words: Waste Plastic, Bituminous Concrete (BC), Optimum Bitumen Content (OBC), Optimum Plastic Content (OPC), Marshall Method.

I. INTRODUCTION

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub- grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. This gives an

overview of pavement types, layers and their functions, cost analysis. In India transportation system mainly is governed by Indian road congress (IRC).Plastics are always common man's friend. It finds its use in every field and the consumption of plastics increases day by day. Nearly 50% of the plastic consumed is used for packing. The most used plastic materials for packing are carry bags, cups, s and foams. These materials are made from polymers like Polyethylene, polypropylene and polystyrene. (The tubes and wires are made out of poly vinyl chloride). These materials, once used are thrown out or littered by us more because of wrong culture. They mix with Municipal Solid Waste. As they are non-biodegradable, the disposal becomes a problem and they cause environmental pollution as they are disposed either by burning or by land filling. Plastics waste is shredded into small pieces (between 4.75mm – 2.36mm).The shredded plastics waste is added to the stone. It get melted and coated over stone in just 30 seconds. These materials are made from polymers like Polyethylene, polypropylene.

The mix is used for road construction. Land filling of plastics into properly designed disposal sites takes up valuable room in the site for a non-toxic, non-leachable, non-decomposable material. Whether plastic is a menace or not depends how we use it and how we dispose of it minimizing the impacts on the environment. We are collecting the threat (waste plastics) from the source, segregating the waste and shredding, shredded plastic to make a coating over the aggregates used for road construction providing the road a tremendous strength at no extra cost.

2. LITERATURE REVIEW

In the construction of asphalt pavement, hot bitumen is coated over hot stone aggregate mixed, laid and rolled. Bitumen acts as a binder. Yet when water is stagnated over road, it penetrates and results in pot holes, a defective spot on the pavement. The use of anti stripping agents are having limited use only and the process also increases the cost of road construction[5]. Use of plastic (virgin as well as waste) to modify the bitumen and also the use of plastic coated aggregates are being studied to improve performance of the pavement. Bituminous mixes used in the surface course of the bituminous pavements are being improved in their performance by incorporating various types of additives to bitumen such as rubber latex, crumb rubber, styrene, butadiene styrene, styrene – ethylene –butylenes, recycled Polypropylene ,low density polyethylene [6] Polyethylene [7], Ethylene vinyl acetate (EVA) (5%) [8] and polyolefin [9, 10]. Some of the properties improved are durability, fatigue life [12, 13], resistance to rutting, softening point, visco elastic property [11], etc. The major obstacle to widespread usage of polymer modified bitumen in paving practice has been their tendency towards gross phase separation under quiescent conditions [16].

3. BITUMINOUS MIXDESIGN:

The main purpose of bituminous mix design is to determine the economical blend and gradation of aggregates and bitumen which yields a mix having sufficient workability, durability, stability and flexibility to resist traffic loads.

3.1. Different layers in a pavement:

Bituminous base course Consist of mineral aggregate such as stone, gravel, or sand bonded together by a bituminous material and used as a foundation upon which to place a binder or surface course. In bituminous binder course a bituminous-aggregate mixture is used as an intermediate course between the base and surface courses or as the first bituminous layer in a two-layer bituminous resurfacing. Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size , typically less than 25 mm, through fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties.

3.2 DESIRABLE PROPERTIES OF MIXDESIGN:

Adequate stability of mix to withstand the stresses and deformation due to repeated application of wheel loads. Adequate flexibility of the mix to resist fatigue effects and development of cracks during service life of the pavement.

Adequate workability of the mix at mixing, laying and compacting temperatures Possess sufficient air voids to prevent 'bleeding' of the binder as a result of further compaction under wheel loads and also reduction of skid resistance under wet conditions.

Adequate durability to sustain the combined effect of adverse weather and repeated traffic loads.

Adequate resistance to permanent deformation such as rutting due to movement of heavy wheel loads during hot weather.

Adequate skid resistance even after continued traffic movements.

3.3 REQUIREMENTS OF DESIGNMIX:

The stability of the mix corresponding to the design-binder content to be more than minimum specified value. Flexibility or deformation at failure to be within the specified range. Voids content of the designed mix to be within specified range. Durability of the mix under stagnant water to assess water sensitivity.

3.4 GRADATION

Grading refers to the determination of the particle-size distribution for aggregate. Uniformly graded aggregate: - only a few sizes dominate the bulk material. With this grading, the aggregates are not being not efficiently packed Open graded aggregate contains too many small grain sized aggregates and is easy to be disturbed by a hole.

Gap grading is the kind of grading where one or more size of aggregates of an intermediate size are lacking.

3.5 TYPES OF BITUMINOUSMIXES

3.5.1 Hot-mix asphalt (HMA)

Hot-mix asphalt (HMA) is produced in a hot-mix plant by mixing a predetermined amount of aggregate with a fixed amount of asphalt at high temperature. The mixing temperature has to be high so that asphalt is viscous for properly coating the aggregate. A HMA mixture must be spread and compacted when the mixture is still hot so as to have a workable mix. The most commonly used mixes are HMA.

3.5.2 Cold-laid plant mix

"Cold-laid plant mix is produced in an asphalt mixing plant by mixing a controlled amount of aggregate with a controlled amount of liquid asphalt without the application of heat. It is laid and compacted at ambient temperature."

3.5.3 Mixed-in-place or road mix

"Mixed-in-place or road mix is produced by mixing the aggregates with the asphalt binders in proper proportions on the road surface by means of special road mixing equipment. A medium setting (MS) asphalt emulsion is usually used for open-graded mixtures while a slow setting (SS) asphalt emulsion is usually used for dense-graded mixtures."

3.5.4 Penetration macadam

"Penetration macadam is produced by a construction procedure in which layers of coarse and uniform size aggregate are spread on the road and rolled, and sprayed with appropriate amounts of asphalt to penetrate the aggregate. The asphalt material used may be hot asphalt cement or a rapid setting (RS) asphaltemulsion."

4. EXPERIMENTAL WORK AND RESULTS

4.1 GRADATION

After the materials have been tested after conducting all relevant tests as per the MORTH (5^{th}revision) andallapplicablecodesthenextstepwouldbetoproportiontheaggregates.Firstthe design grading is arrived at Based on various factors such as the construction type, thickness of the layer and the availability of aggregates. In our study the gradation proposed by morth has been considered as the design gradation.

	1	2
Nominal aggregate size*	19mm	13.2 mm
Layer thickness	50 mm	30-40 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5	100	
19	90 - 100	100
13.2	59 – 79	90-100
9.5	52 – 72	53 – 71
4.75	35 – 55	53 – 71
2.36	28 – 44	42 – 58
1.18	20 – 34	34 – 48
0.6	15 – 27	26 – 38
0.3	10 – 20	18 – 28
0.15	5 – 13	12 – 20
0.075	2 – 8	4 - 10
Bitumen content % by mass of total mix	Min 5.2*	Min 5.4**

Table 4.1 – Gradation Chart as per MORTH

Notes:

* The nominal maximum particle size is the largest specified sieve size up on which any of the aggregate is retained.

** Corresponding to specific gravity of aggregate being 2.7. in case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is -10°C or lower, the bitumen content may be increased by 0.5 percent." (Ref 9)

45.1.1 Proportioning in Gradation is carried out in three methods

AnalyticalMethod
GraphicalMethod
Trial &ErrorMethod

Generally, the mid-point of the range in gradation table is aimed at. Here we used the trial and error Method for proportioning and to work out the job mix formula. After a number of unsuccessful trials, the following gradation was arrived at:

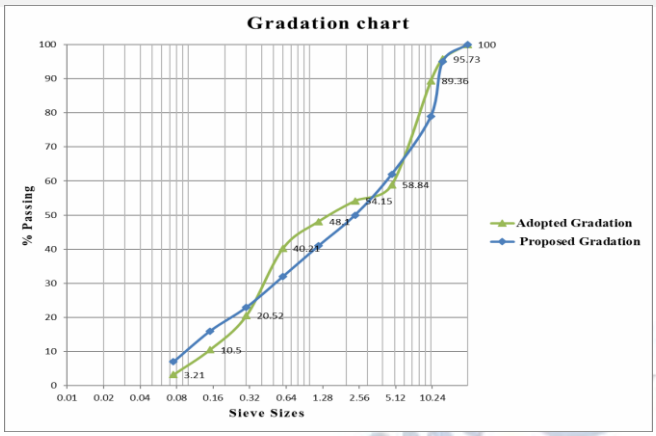


Fig 4.1 – Gradation Chart for Aggregate Mix

In order to achieve this gradation, the components were mixed in the following proportions:

Coarse aggregates: 510 gms Sand : 460 gms Rock powder : 170gms.

4.2 MARSHALL STABILITYTEST:

Marshall Method of mix design was adopted for design of the design of bituminous mix. The entire design of the mix was divided into two parts.

Part I - Where the OBC (Optimum Bitumen Content) was determined. Part II – Where the OPC (Optimum Plastic Content) was determined.

4.2.1 DETERMINATION OF OPTIMUM BITUMEN CONTENT:

As a first step to determination of BC the Marshall specimens were prepared as per the procedurespecifiedHighwaymaterialandpavementtestingbySKKhanna,CEGJustoandA.Veeraraghavan,fifth edition(2013

Fig 4.2 – Marshall Samples

Fig 4.3 – Marshall Testing Machine

ThespecimensweretestedintheMarshallMachineforstabilityandflowvalues.TheMarshall stability of the mix is defined as the maximum load bourn by the mix at the standard test temperature of 60□C when load is applied under standard test conditions. Its unit of measurement is KN. The Flow value is the total deformation of the test specimen at the maximum load, expressed in mm units.

Based on the stability and flow readings obtained from the Marshall test and the Values of voids, density and VFB calculated using the formulas from theLecturenotesinTransportation System Engineering on Marshall mix design by Prof. Tom V Mathew from IITB (Civil). The following graphs were plotted based on the values obtained

Bitumen %	Gm	Vv	VFB	Stability	Flow
5	2.19	8.75	59.26	3.62	2.2
5.5	2.21	7.14	68.23	9.24	2.63
6	2.25	4.66	76.17	6.94	4.06
6.5	2.23	5.1	75.33	6.27	3.6
7	2.23	4.29	79.62	6.46	3.7

Table 4.2 – OBC Calculations

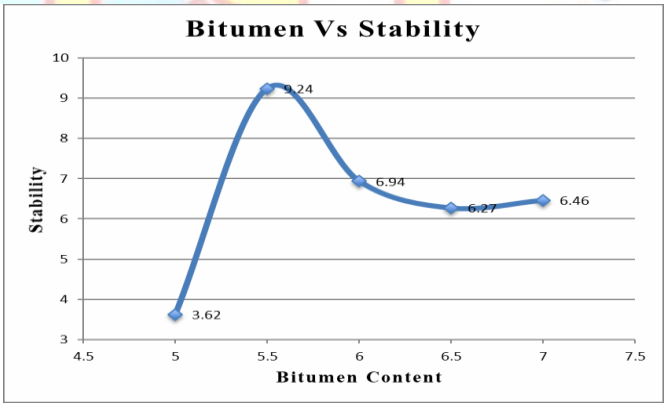


Fig 5.4 - OBC – Stability Graph

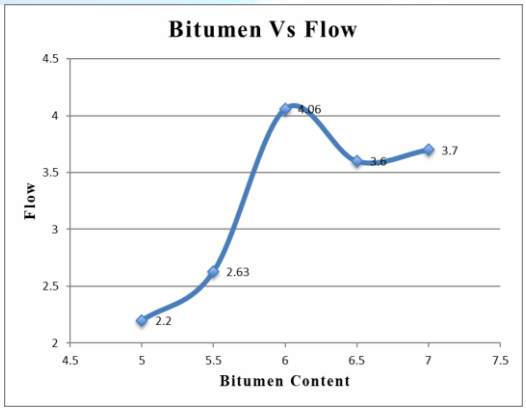


Fig 5.5 - OBC Flow Graph

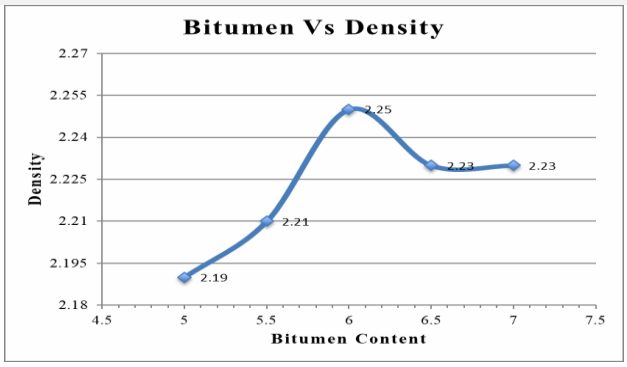


Fig 5.6 - OBC –Density Graph

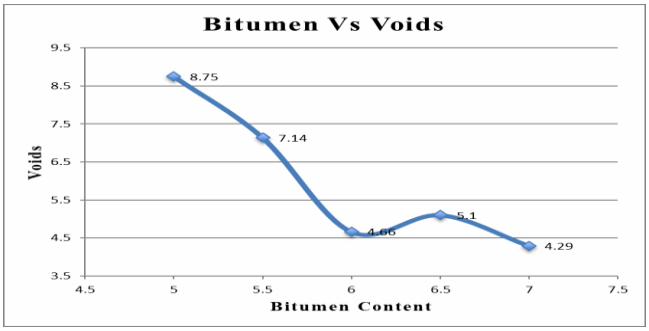
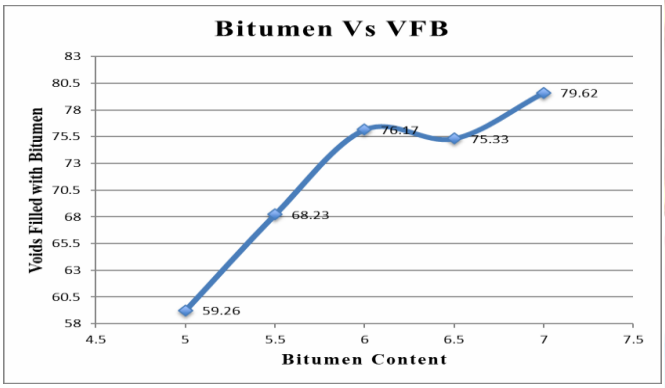


Fig 5.7 – OBC – Voids Graph



Based on the Graphs

Binder content corresponding tomaximumstability =5.5%

Binder content corresponding to maximum bulk specificgravity(G_m) =6%

Binder content corresponding to the median of designed limits of percent = 6% air voids (Vv) in the total mix (i.e. 4%).

Average of theabovevalues = 5.8%

Hence OBC of the design mix is 5.8%

4.3 DETERMINATION OF OPTIMUM PLASTIC CONTENT:

After the optimum bitumen content was arrived at the second part of the mix design was to determine the optimum plastic content. For this purpose, milk packets which are discarded as waste were used. The Specific gravity and softening point were adopted from the manufacturer report as 0.92 and 115°C respectively. The plastic packets were processed into small 2.36 mm and below pieces. These could be added to the mix i) To the aggregates while cooking them for the bituminous mix(DryProcess)ii)Addtheplastictothebitumenwhile heatingittoaddtotheheatedaggregates

Weadoptedthefirstmethod(DryProcess)wherethepla sticwasaddedtotheaggregateswhile heating them before adding the bitumen and mixed thoroughly till all the plastic pieces dissolved and the aggregates looked oily. After this step the procedure remains unchanged from the steps for determining theOBC.

Fig 4.9 MilkBags(Plastic)

Fig 4.10 GranulisedPlastic

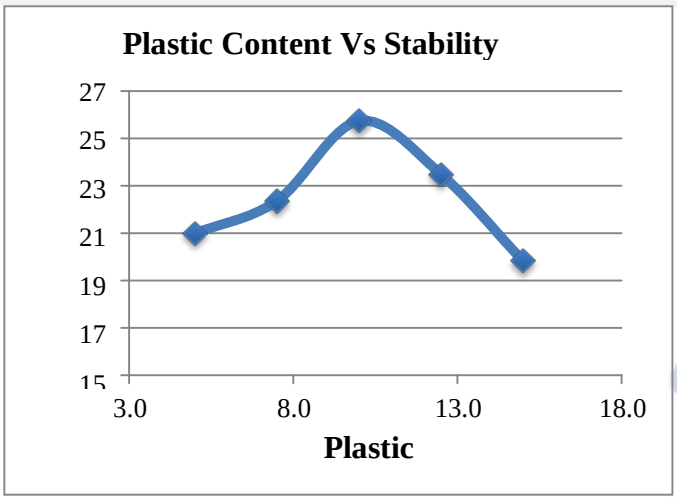


Fig 5.11 – OPC – Stability Graph

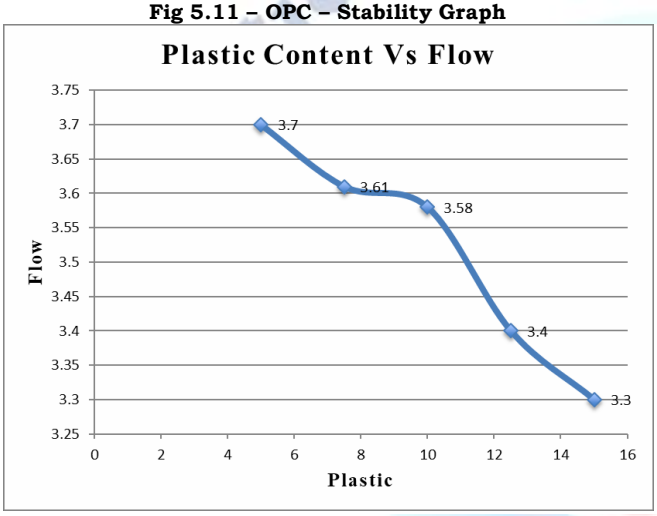


Fig 5.12 – OPC – Flow Graph

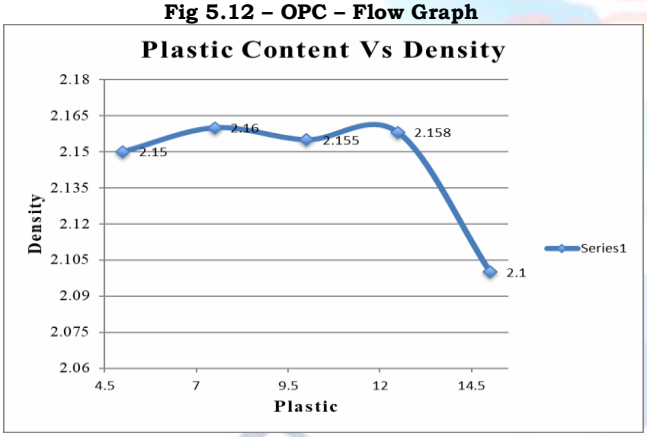


Fig 5.13 – OPC – Density Graph

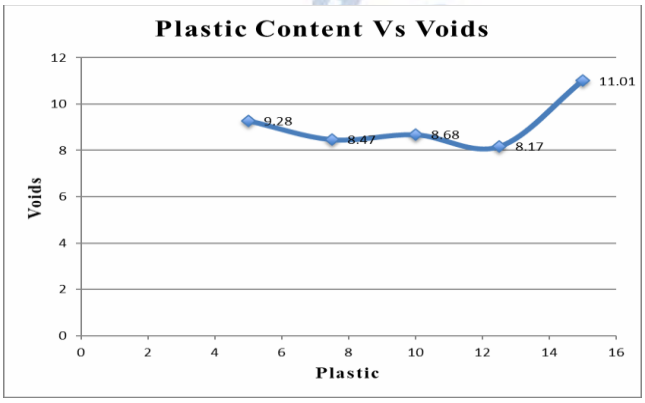


Fig 5.13 – OPC – Voids Graph

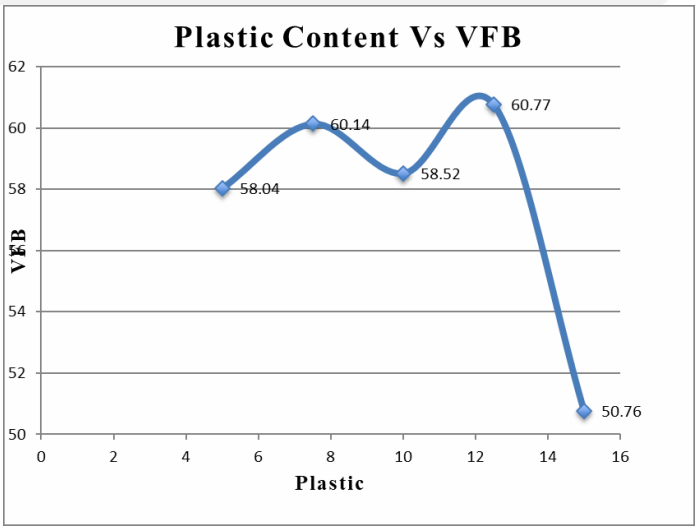


Fig 5.14 – OPC – VFB

Based on the graphs:
Plastic content corresponding tomaximumstability = 10%
Binder content corresponding to maximum bulk specificgravity(Gm) = 7.5%
4. Average of theabovevalues = 8.75%

4.4 RESULTS ANDDISCUSSIONS:

After conducting various tests first on the various components of the bituminous mix in order to ascertain their suitability for use in the mix, thereafter the gradation process the Marshall briquettes were made and tested to find out the OBC. The OBC of our study was 5.8%
As a second part to our study a part of the bitumen was replaced by waste plastic which had been cleaned and granulated into appropriate size. After Marshall test on the second set of Marshall briquettes using waste plastic and bitumen the OPC was concluded to be 8.75%. The stabilityofthebriquetteswasfoundtobeatleasttwotimeswiththeaddedadvantageofsavings inbitumen.

5. CONCLUSION

In Conclusion with the rapid increase in plastic waste generation as a consequence to its increasedusageinallwalksoflifeeventhegovernment ofIndiahasinitiatedstepsforresearch in reusing, recycling and disposal of this waste material. The Ministry of Environment Forest & Climate Change, Ministry of Road Transport and Highways to name a few have taken up various studies for effective and viable methods for the use of plastic in non-traditional ways. IRC too has revised its code books and IRC:SP:98-2013 GUIDELINES FOR THE USE OF WASTE PLASTIC IN HOT BITUMINOUS MIXES(DRY PROCESS) IN WEARING COURSES has been initiated.
Future scope : Many properties of SMA, BC and DBM mixes such as Marshall Properties, have been studied in this investigation by using only penetration grade bitumen and polyethylene.

However, some of the properties such as fatigue properties, resistance to rutting, dynamic indirect tensile strength characteristics and dynamic creep behavior needed to be investigated. In present study polyethylene is added to them mix in dry mixing process.¬ Polyethylene can also be used for bitumen modification by wet mixing process and comparisons made. Microstructure of modified bituminous mixture should be observed by using¬ appropriate technique to ascertain the degree of homogeneity.

Combination of paving mixes formed with other types of plastic wastes which are¬ largely available, wastes to replace conventional fine aggregates and filler an different types of binders including modified binders, should be tried to explore enough scope of finding suitable materials for paving mixes in the event of present demanding situations.

REFERENCES

[1] AASHTO T 283, "Standard method of test for resistance of compacted asphalt mixtures to moisture-induced damage", American association of state highway and transportation officials.

[2] AASHTO T 305, "Drain-down characteristics in un-compacted asphalt mixtures", American association of state highway and transportation officials.

[3] Ahmadinia E., Zargar M., Karim M. R., Abdelaziz M. and Ahmadinia E. (2012), "Performance evaluation of utilization of waste Polyethylene Terephthalate (PET) in stone mastic asphalt", Journal of Construction and Building Materials, Volume 36, pp. 984–989.

[4] Airey G. D., Rahimzadeh B. and Collop A. C. (2004), "Linear rheological behaviour of bituminous paving materials", Journal of materials in civil engineering, Volume 16, pp. 212-220.

[5] Al-Hadidy A.I. and Yi-qiu T. (2009), "Effect of polyethylene on life of flexible pavements", Journal of Construction and Building Materials, volume 23, pp. 1456– 1464.

[6] ASTM D 1559, "Test method for resistance of plastic flow of bituminous mixtures using Marshall Apparatus", American society for testing and materials.

[7] ASTM D 6931 (2007), "Indirect Tensile (IDT) Strength for bituminous mixtures", American society for testing and materials.

[8] ASTM D 792-08, "Standard test methods for density and specific gravity of plastic by displacement", American society for testing and materials.

[9] ASTM D882–12, "Standard test method for tensile properties of thin plastic sheeting", American society for testing and materials. 83

[10] Attaelmanan M., Feng C. P. and AI A. (2011), "Laboratory evaluation of HMA with high density polyethylene as a modifier", Journal of Construction and Building Materials, Volume 25, pp. 2764–2770.

[11] Awwad M. T. and Shbeeb L (2007), "The use of polyethylene in hot asphalt mixtures", American Journal of Applied Sciences, volume 4, pp. 390-396.

[12] Bindu C.S., Beena K.S. (2010), "Waste plastic as a stabilizing additive in SMA", International Journal of Engineering and Technology, Volume 2, pp. 379-387.

[13] Casey D., McNally C., Gibney A. and Gilchrist M. D. (2008), "Development of a recycled polymer modified binder for use in stone mastic asphalt", Journal of Resources, Conservation and Recycling, Volume 52, pp. 1167–1174.

[14] Chen (2008/09), "Evaluated rutting performance of hot mix asphalt modified with waste plastic bottles".

[15] Das A. and Chakroborty P. (2010), "Principles of Transportation Engineering", Prentice Hall of India, New Delhi, pp 294-299.

[16] Fernandes M. R. S., Forte M. M. C. and Leite L. F. M. (2008), "Rheological evaluation of polymer-modified asphalt binders", Journal of Materials Research, Volume 11, pp. 381-386.

[17] Firopzifar S.H., .Alamdary Y.A. and Farzaneh O. (2010), "Investigation of novel methods to improve the storage stability and low temperature susceptivity of polyethylene modified bitumens", petroleum & Coal, Volume 52, pp.123-128.

[18] Gawande A., Zamare G., Renge V.C., Tayde S. And Bharsakale G. (2012), "An overview on waste plastic utilization in asphalting of roads", Journal of Engineering Research and Studies Vol. III/ Issue II. 84

[19] Habib N. Z., Kamaruddin I., Napiah M. and Tan I. M. (2010), "Rheological properties of polyethylene and polypropylene modified bitumen", World Academy of Science, Engineering and Technology, Volume 72, pp. 293-297.

[20] Herndon D. A. (2009), "Moisture susceptibility enhancement of asphalt mixtures using phosphonylated recycled polyethylene".

[21] Ipc-tm-650 test methods manual (1995).

[22] IRC SP-79 (2008), "Tentative specification for SMA", Indian roads congress, New Delhi.

[23] IS: 1203 (1978), "Methods for testing tar and bituminous materials: determination of penetration", Bureau of Indian Standards, New Delhi.

[24] IS: 1205 (1978), "Methods for testing tar and bituminous materials: determination of softening point", Bureau of Indian Standards, New Delhi.

[25] IS: 2386 (1963), "Methods of test for aggregates for concrete (P - I): Particle size and shape", Bureau of Indian Standards, New Delhi.

[26] IS: 2386 (1963), "Methods of test for aggregates for concrete (P-III): Specific Gravity, Density, Voids, Absorption, Bulking", Bureau of Indian Standards, New Delhi.

[27] IS: 2386 (1963), "Methods of test for aggregates for concrete (P-IV): Mechanical Properties", Bureau of Indian Standards, New Delhi.

[28] Jain P. K., Kumar S. &Sengupta J. B. (2011), "Mitigation of rutting in bituminous roads by use of waste polymeric packaging materials", Indian Journal of Engineering & Materials Sciences Vol. 18, pp. 233-238.

[29] Kar D. (2012), "A laboratory study of bituminous mixes using a natural fibre", Unpublished PhD thesis, NIT RKL.

[30] Karim R.., Islam N., Sajjad M. and Habib A. "Polyethylene, a potential solution to strength loss of bituminous pavement under water", International symposium on geodisasters, infrastructure management and protection of world heritage sites, pp. 204- 207.

[31] Khan I. and Gundaliya P. J. (2012), "Utilization of waste polyethylene materials in bituminous concrete mix for improved performance of flexible pavements", Journal of applied research, volume 1, issue 12, pp. 85-86