International Journal of Scientific Research in Civil Engineering
© 2021 | IJSRCE | Volume 5 | Issue 1 | ISSN : 2456-6667

Formulation of Modified Dense Graded Bituminous Macadam with Low Density and High-Density Polythene Waste with Zycotherm Admixture

Avinash Kumar[1], Ajeet Saxena[2]

[2]P.G. Scholar, Department of Civil Engineering, Radharaman Engineering College, Bhopal, Madhya Pradesh, India

[2]Assistant Professor, Department of Civil Engineering, Radharaman Engineering College, Bhopal, Madhya Pradesh, India

Article Info
Volume 5, Issue 1
Page Number: 15-22
Publication Issue :
January-February-2021

Article History
Accepted : 06 Jan 2021
Published : 16 Jan 2021

ABSTRACT

This study presents the use of waste polythene in flexible pavement construction. Reclaimed plastic waste derived as carry bags from kitchen and pond liner polyethelene as LDPE and plastic bottle caps as HDPE have been used as additive in flexible pavements. In this study we will also add a fix percentage of Zykotherm (ZycoTherm is an odor free additive that increases moisture resistance while lowering mixing and compaction temperature up to 65°F. Purposes of using above materials are to utilize environmentally unacceptable waste material and to develop a better material mix to resist increased traffic load, temperature effect and pressure resulted in cracks in the pavement surface. In the proposed study the plastic waste will be cleaned and cut into a size such that it passes through 2-3mm sieve using shredding machine.

In this study Dense Bituminous Macadam (DBM) mix will be proposed to prepare by using plain bitumen as a control specimen and bitumen mixed with LDPE 2% and 4% & HDPE 2%, 3%, 4%, 5%) as by weight, with fixed percentage of Zykotherm as 1.5% by weight. The Marshall Stability test, Penetration Test, and softening point test, were conducted on control and modified DBM mixes.

Keywords : Soil and Water, Soil Productivity, Soil Quality, Sustainability, Management

I. INTRODUCTION

Bitumen is used as a binder in pavement construction. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per definition given by the American Society of Testing Materials bitumen has been defined as “Mixtures of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide.”

Bitumen found in natural state known as asphalt contains large quantities of solid mineral matter. When petroleum crude is refined in a refinery, they

are separated by fractional distillation in the order of decreasing volatility. On distillation of the residual bituminous residue, straight-run bitumen is obtained. This bitumen is known as penetration grade bitumen or steam refined petroleum bitumen.

The grades of bitumen used for pavement construction is known as paving grades and that used for water proofing of structures is known as industrial grades. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed.

In most parts of India 60/70 and 80/100 grade bitumen is used. Heavier grade cut backs, rapid setting emulsions or heavier grade tars may also be used. The grade of basic bitumen is altered either by controlled refining or by mixing with diesel oil or other oils. For single dressings on WBM base course, quantity of bitumen needed ranges from 17 to 195 kg per 10 m2 areas and 10 to 12 kg per 10 m2 area in case of renewal of black top surfacing. For second coat of surface dressing, the quantity of bitumen needed ranges from 10 to 12 kg per 10 m2 area. Bulk bitumen Lorries with tanks of capacity ranging from 5000 to 15000 litres are used to transport bulk bitumen.

II. Objectives of the Study

To investigate properties of Plastic/ Aggregate.
Experimental assessment on strength of flexible pavement & modified bitumen pavement.
Comparison between test results of conventional & modified bitumen pavement.

1. To identify the best mechanism of adding the polyethylene (dry or wet process) in aggregate.
2. Environment-There is huge problem of disposal and recycling of plastic waste and by using such we protect the environment.
3. Strength- By replacing plastic waste in bitumen it increasing its strength which gives better strength as compare to normal road.
4. Economy- bitumen along with use of plastic, we can reduces the cost, hence economy can be achieved.

III. Literature Survey

Shubham Bansal et al (2017) The research paper focused on utilizing waste materials like discarded waste materials like plastic, polythene bags, bottles, rubber tyres etc as partial replacement of bitumen to develop a modified binder, for making bituminous concrete mix. To simulate with the field conditions, 'Marshall Stability Analysis' was performed on the samples prepared by partially replacing 'Optimum Bitumen Content' with waste plastic (4%, 6%, 8% and 10%) and crumb rubber (5%, 10% and 15%). Experimental results demonstrate that partial substitution of bitumen with waste plastic results up to 16% increment in strength whereas with rubber material, about 50% increment in strength was observed as compared to the conventional mix (CM). Laboratory testing results indicate that by using waste materials, bituminous concrete of required strength and density can be obtained and an environment friendly green pavement can be prepared with less material cost.

The results stated that use of rubber tyres and waste plastic bottles improves the strength and overall durability of the BC mix by increasing its overall performance manifold. Therefore with application of these waste materials in the fixed proportions, targeted characteristics of BC can be achieved. Use of discarded waste materials like rubber tyres and discarded plastic bottles in bituminous concrete mix may aid in minimizing the construction cost of the roads. Moreover it may also contribute in preventing the environmental pollution caused by the dumping of such waste materials in ground.

Aditya Bhardwaj et al (2017) the research paper presented variation of the properties of bitumen on addition of waste plastic at different percentage. The

paper further stated various applications and advantages of Bitumen.

The conclusion derived from the research paper stated that by adding waste plastic to the bitumen the properties of bitumen has been optimized. Not only waste plastic improved the properties of bitumen but also improve the properties of bituminous mix. Thus, the use of waste plastic ultimately improves the performance and quality of flexible pavement. As plastic are non-biodegradable and also harmful to environment thus, disposal of plastic is a matter of great concern therefore use of waste plastic in the road construction is an effective way of disposal of waste plastic.

Michele Porto et al (2019) the research paper presented two principle sections which included investigation of bitumen in terms of chemical structure and microstructural systems and focuses on bitumen modification from different aspects for assessing the effectiveness of the introduced additives and polymers for enhancing the engineering properties of bitumen in both paving and industrial applications

The results stated that while plastomer-modified bitumens was suitable for improving the permanent deformation resistance of the bituminous compounds and asphalt concrete mixtures over high stresses, the absence of elasticity at low temperature limited the application of these bitumins. The field recorded data, as well as experimental works, showed that plastomer-modified bitumens, such as polyethylene and polypropylene, are the most common plastomers resulting in compatibility problems. This was due to their non-polar chemical nature. Despite the thermal and aging stability of plastomer-modified bitumens due to the absence of double bonds, the main problem resides in the stability of the blend (polymer + bitumen) during storage and difficulties to disperse them homogenously in the bitumen matrix. Thermoplastic elastomer copolymers, owing to their elastic component, was usually more effective than plastomers for bitumen modification in pavement applications. The modification ranges from low-modified containing 3% polymer to a high level with polymer content of 7%. Bitumen modification via styrene butadiene styrene (SBS) as the most commonly used elastomer has numerous benefits, including the improved thermal susceptibility, increased softening point, and slight decrease of penetration value at 25 _C. In addition, it was observed that SBS can moderate the increase of stiffness due to oxidation processes. Bitumens modified with thermosetting polymers show a high elasticity and no viscous behavior.

Asphalt mixtures produced with thermosetting polymer-modified bitumen have excellent adhesive ability, excellent resistance to deformation, excellent fatigue performance, and high stiffness modulus. Even though the PmBs with thermosetting plastics have relatively high adhesion to the mineral particles and high strength they are not common for paving applications.

This waS because the technological properties of PmB was almost immediately deteriorated by these polymers due to their hardening properties; secondly, the rigidity of the PmB is increased at low temperatures, which results in increased thermal sensitivity; thirdly, the use of TP complicates the system and raises its price; and, finally, the effectiveness of thermosetting plastics usually appears due to their large quantities in bitumen (more than 10 wt%)

Natural rubber latex has potential for improving bitumen binder performance by enhancing the thermal sensitivity, flexibility, stability, and stripping. In addition, its inherent elastomeric properties proved its high potential in improving long-term pavement performance of asphalt concrete by increasing rutting

resistance, fatigue life, etc. Natural rubber also decreases the optimum binder content in asphalt concretes, increasing its density and stability. However, natural rubber was a highly valuable biomaterial compared to other biopolymers, hence natural rubber has been commercialized into synthetic rubber. This was mainly because of the very large difference between the available produced amount and the demand.

Stability Test

From this study the following results are obtained which is shown in following Tables Marshall Properties of various Bituminous Mixes and marshal curves for this design mix shown from the below figures are as follows:

In all cases percentage of Zycotherm is fixed as 1.5%,andLPDe polythene as 2% and 4% by weight whereas percentage of HDPE polythene percentage varies from 2 to 5 % by weight.

Fig 1 Marshall Stability test

Table 1 : Marshall Properties of various Bituminous Mix:

Sample with 2% LPDE						
Sr. No.	**Type of Mix**	**Flow Value**	**Va (%)**	**VMA (%)**	**VFB (%)**	**Marshall Stability value (kg)**
1	HMA mix with 2 % HDPE	3.5	4.4	7.75	70.3	1560
2	HMA mix with 3 % HDPE	3.8	2.43	8.28	69.8	1640

3	HMA mix with 4 % HDPE.	4.1	3	9.48	68.3	1700
4	HMA mix with 5 % HDPE	4	2.8	8.85	68.9	1686

Sample with 4% LPDE						
Sr. No.	**Type of Mix**	**Flow Value**	**Va (%)**	**VMA (%)**	**VFB (%)**	**Marshall Stability value (kg)**
1	HMA mix with 2 % HDPE	3.7	4.5	7.8	71.2	1590
2	HMA mix with 3 % HDPE	3.9	2.45	8.35	70	1685
3	HMA mix with 4 % HDPE.	4	3.2	10.05	69.15	1752
4	HMA mix with 5 % HDPE	4.2	2.7	9.25	70.25	1690

Determine the specific gravity of the aggregate combination and bitumen.

Determination of specific gravity:

Specific gravity = $\frac{\text{Dry weight of aggregate in air}}{\text{Weight of equal volume of water}}$ = 2.6

Specific gravity of combined aggregate G_{sb} = $\frac{100}{\left(\frac{w1}{g1}\right)+\left(\frac{w2}{g2}\right)+\left(\frac{w3}{g3}\right)+\left(\frac{w4}{g4}\right)}$ = 2.58

Prepare the trial specimens with varying samples prepared

Specimen-1: For HMA mix with 2% HDPE:

Theoretical specific gravity

G_{mm}= $\frac{100}{\left(\frac{4.8}{1.052}\right)+\left(\frac{95.2}{2.56}\right)}$ = 2.39

Mass of sample in dry air = 1250 gm.

Mass of sample in water = 750 gm.

Bulk specific gravity = $\frac{1250}{1250-750}$ = 2.5

V_A = 4.40%

V_{MA} = $\left(100-\left(\frac{2.5*95.2}{2.58}\right)\right)$ = 7.75%

V_{FB} = $\frac{VMA-VA}{VMA}$ = 70.3%

Specimen-2: For HMA mix with 3% HDPE:

Theoretical specific gravity

$G_{mm}= \frac{100}{\left(\frac{4.2}{1.052}\right)+\left(\frac{95.8}{2.56}\right)}= 2.41$

Mass of sample in dry air = 1310 gm.

Mass of sample in water = 780 gm.

Bulk specific gravity = $\frac{1310}{1310-780}$ = 2.47

V_A = 2.43%

$V_{MA} = \left(100 - \left(\frac{2.47*95.8}{2.58}\right)\right)$= 8.28%

$V_{FB} = \frac{VMA-VA}{VMA}$ = 69.8%

Specimen-3: For HMA mix with 4% HDPE:

Theoretical specific gravity

$G_{mm}= \frac{100}{\left(\frac{3.9}{1.052}\right)+\left(\frac{96.1}{2.56}\right)}= 2.42$

Mass of sample in dry air = 1350 gm.

Mass of sample in water = 795 gm.

Bulk specific gravity = $\frac{1350}{1350-795}$ = 2.43

V_A = 3.0%

$V_{MA} = \left(100 - \left(\frac{2.43*96.1}{2.58}\right)\right)$ = 9.48%

$V_{FB} = \frac{VMA-VA}{VMA}$ = 68.3%

Specimen-4: For HMA mix with 5% HDPE:

Theoretical specific gravity

$G_{mm}= \frac{100}{\left(\frac{4.2}{1.052}\right)+\left(\frac{95.8}{2.56}\right)}= 2.61$

Mass of sample in dry air = 1310 gm.

Mass of sample in water = 780 gm.

Bulk specific gravity = $\frac{1310}{1310-780}$= 2.47

V_A = 2.43%

$V_{MA} = \left(100 - \left(\frac{2.47*95.8}{2.58}\right)\right)$ = 8.28%

$V_{FB} = \frac{VMA-VA}{VMA}$ = 68.76%

IV.CONCLUSION

In this dissertation work we presented the study of waste polythene recycling in construction industry where till date use of LPDE polythene has been done but with the help of this study, here we are concluding that use of HDPE is also possible in construction industry as LPDE shows low tensile strength thus ductility is low as well as binding decreases. But in this study we stated that with the use of HDPE polythene and fixed proportion of zycotherm we can increase the HDPE property of the sample as well as the binding property of the sample also increases.

- ✓ This study is valuable for highway construction as it can help in settling the non- biodegradable waste as well as increases bitumen (flexible) pavement life.

- ✓ From the above tests conducted the following conclusions were drawn out:-
- ✓ Marshall Test conducted on bituminous mix with combination 4% HDPE plastic and 1.5% Zycotherm have higher value of stability 1700 kg correspondingly the values of flow is 4.1, percentage air voids is3.0 %, VMA is 9.48% & VFB is 68.30% at 2% LPDE whereas at 4% LPDE stability value is 1752 kg.
- ✓ It is observed that by addition of polyethylene HDPE to the mixture, the resistance to moisture susceptibility of mix also increases. BC with polyethylene results in highest tensile strength ratio in HMA mix.
- ✓ From the study it is concluded that zycotherm increases the binding property of the mix in a natural way.
- ✓ The ductility of the sample increases with increase in HDPE polythene as it provides good tensile strength to the sample.
- ✓ As per the cost cutting in construction this method is very valuable and as it is very helpful in cost cutting of bitumen in a mix.

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Cite this article as :

Avinash Kumar, Ajeet Saxena, "Formulation of Modified Dense Graded Bituminous Macadam with Low Density and High-Density Polythene Waste with Zycotherm Admixture", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 5 Issue 1, pp. 15-22, January-February 2021.
URL : http://ijsrce.com/IJSRCE21511