# Utilization of Waste Plastic as A Modifier in Bituminous Mix

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*Abstract*— Over the past two decades traffic volume and percentage of heavy trucks have enhanced, demanding stronger and long lasting paved surface. In order to enhance the anticipated design life of the pavement, there is a need to investigate the application of new and innovative material for extending the life of paved surface. The regular growth of high traffic intensity in terms of commercial vehicles, and considerable variation in seasonal and day-to-day temperature needs better road qualities. Some modification in the quality of the binder is demanded. This work represents a research conducted to study the characteristics of Bituminous Mix equipped with Polymer - Bitumen collection to be utilized in structure of flexible pavements for efficient use in road construction industry which will result in modified road paved surfaces and also harmless removal of waste plastic in a specific urban roads.

***Key words:*** Aggregate, Bitumen, Waste Plastic, Marshall Mix design

## I. INTRODUCTION

The utilization of waste plastic materials has received a great improvement due to itsplentiful supply and high resistance to insects, fungi, animals, as well as molds, mildew, rot and many chemicals. However the dumping of the waste plastic materials in huge amounts has been a problem all over the country. These waste plastic break down in fire and form hazardous smoke, and toxic fumes or ash, typically comprising hydrogen cyanide. Burning waste plastic to recover the high energy used to create them is generally costly, so most of this waste plastic reaches the garbage dumps, decomposing very slowly. Certain reprocessing is done on them, usually creating pellets for recycle in the industry, but this is done at a much lower scale.

The mixing up of these waste plastic materials with other bio-degradable organic waste materials in the waste of the urban areas is another problem. Thus, more research is require to be centered towards a superior way of managing these waste plastic materials, in order to eliminate the problems generally come across in the current disposal method. It is possible to find useful application for the waste plastic materials, there will be considerable scrap value for this waste product and so they will be gathered and sold by interested persons, in place of being scattered or thrown out in the waste bins or into the road side drains. Bituminous concrete is a combined material commonly utilized in construction projects such as highway, airports and parking lots. It contains of bitumen, used as a binder and mineral aggregate intermingled together, then put down in layers and compacted [1].The amount of aggregate in bituminous concrete mixes is usually 90 to 95 percent by weight and 75 to 85 percent by volume and they are primarily responsible for the load carrying capacity of a pavement. The bitumen is a viscoelastic material with appropriate mechanical and rheologicalproperties for waterproofing and protecting coverings for roads and roofs, because of its better adhesion properties to aggregates [2, 3, 4, and 5]. Normally, the binder comprises 5 to 10 percent by weight of the concrete blend and various grades like 30/40, 60/70 and 80/ 100 are available on the basis of their penetration values. The performance of the road pavement is mainly influenced by the properties of the bituminous binder as bitumen [6]. Though, Roads formed with bitumen binders are exposed to many tough environmental conditions such as heavy traffic loading, entrance of water, chemical attack and widely changing temperatures. Normal bitumen frequently cannot provide the required resistance to these circumstances so modification of the bitumen properties becomes essential. Though, some improvements in bitumen properties have been achieved by selecting the proper starting crude to make bitumen. Unluckily, there are only a few crudes that can produce better bitumen suitable for paving applications [6, 7]. However, practical experience over the last four decades has made known that the modification of the bitumen binder with polymer additives, deals numerous benefits. These contain improved adhesion and cohesion properties, improved fatigue resistance, improved thermal stress cracking, and reduction in temperature susceptibility and reduction of rutting [8, 9, and 10]. As a result, bitumen modified with polymers is a common means of providing optimally performing pavement. This work goals to determine the influence of polythene modified bitumen on the properties of bitumen mix.

Studies in India and countries overseas have showed that qualities of bitumen and bituminous mixtures can be changed to meet requirements ofroadways with the mixing of certain additives or a combination of additives. These materials are called “Bitumen Modifiers” and the bitumen moderated with these modifiers is known as “Modified Bitumen”. Modified Bitumen is probable to give 50 to 100 per cent advanced life of surfacing depends on degree of alterations and kind of additives used. Plastic modified bitumen is developing as one of the important structure of flexible pavements. The plastic modified bitumen display better properties for road structure and plastic waste can discover its usage in this procedure providing better performance of flexible pavements and this can also help solve the problem of pollution due to waste plastic too[11].

## II. PRELIMINARIES

### *A. Problem Statements*

The major problems of Indian Roads are fabrication of Pot holes which usually occurs when vehicular loads induce greater value of shear stress than the shear strength of the materials contained in the pavement structure. This is based on viscous elastic properties of the bitumen andvehicular weights. Bitumen binders are required to have high firmness at high temperature to resist rutting.

 

When we saying about pollution in recent years, numerous waste materials result from various mills, factories and house in which millions of waste plastics are produced and plastics are not being readily perishable will remain in the environment in a more or less unchanged state of an appreciable time. So there is a requirement to use the waste plastic in some beneficial purpose. In this study an effort was made to find solution to overcome above discussed problems [12].

### *B. Importance of the Study*

Utilization of waste recycled packaging plastics is of great value, especially for bitumen preservation and for bitumen modification to find its utilization in bituminous mixes for making flexible pavements. Use of waste recycled packaging plastics is of great value, especially for bitumen preservation and for bitumen modification to find its use in bituminous mixes for making flexible pavements [13].

Besides, the polymer additive in bitumen is to avoid pollution problems resulting from waste plastic disposal. By utilizing waste polymers to change the bitumen proved to be an ideal way, not only for concluding the pollution problem in our country, but also for improving the performance of bitumen [14].

### *C. Property of Plastic Coated Aggregate*

For the flexible pavement, aggregate with specific properties is utilized for highway laying. The aggregate is selected on the basis of its strength, porosity and moisture absorption. The aggregate was covered with waste plastic material by the following procedure. The waste plastic materials are bottles, containers, films, pots, thermo-Cole, trays, toys etc. These waste plastic materials are shredded to the desired size of 2.5mm – 4.36mm. The aggregate is heated up 170oC. The waste plastic material was sprinkled over the hot aggregate. Waste plastic got unstiffened and covered over the aggregate. The amount of covering was changed by using various percentages of waste plastics. We can use waste plastic up to 25% to estimate the binding property, while lower percentage of plastics like 1% to 5% to estimate the characteristics like moisture absorption and soundness[15].

### *D. Decrease of Carbon Di Oxide Emergence*

Waste plastic materials are fired with local waste resulting in the formation of greenhouse gases thus increasing global warming. In Dry process, waste plastics are utilized as a covering material by unstiffening the plastic and not by flourishing. So there is no development of greenhouse gases. A minimum of one ton of waste plastics is used for a length of one kilometer single lane plastic bitumen road. This reduces the emission of carbon di oxide up to 3 tons [15].

## III. METHODOLOGY

### *A. Selected Material*

#### *1) Selected Waste Plastic*

In India, we can see these plastic materials which are used for packaging of drinking water in bottles. The cost of these plastic bottles are very less and are easily available near bus stations, hospitals, railway stations, hotels and many other places. People throw these discarded waste plastic bottles in the surrounding area, after the use of water in these plastic bottles. This waste plastic bottles cause's environment pollution to the cities, towns, villages and various road side areas. Also the disposition of this non-decaying and non-biodegradable waste polythene's is a threat for the present society. So, Plastics used in the experiments were water bottles [14].

| | |
|---|---|
| Specific gravity | 0.92 |
| Softening point | 58.22℃ |
| Young modulus | 104.50 M Pa |
| Strain at break | 1372% |
| Strain at peak | 1282.6% |
| Displacement at break | 149.14 mm |
| Displacement at peak | 134.18 mm |
| Load at peak | 0.0162 KN |
| Stress at peak | 19.20 M Pa |

Table 1: Physical Properties of Waste Plastic

#### *2) Type Of Bitumen Grade*

The type of bitumen penetration grade for this study wasVG 10 usually used as a Paving Grade Bitumen appropriate for formation of flexible pavements with superior properties [16].

| Characteristics | Method of Test | Test Results |
|---|---|---|
| Specific Gravity | IS1202:1978 | 1.09 |
| Softening Point (℃) | IS1202:1978 | 52 |
| Penetration25℃ (mm) | IS1202:1978 | 92 |
| Ductility | IS1202:1978 | 85 |

Table 2: Physical Properties of Bitumen

#### *3) Aggregate And Mineral Filler*

Aggregate symbolizes the granulose part in bituminous concrete mixes which brings up to 90–95% of the mix weight and conveys to most of the weight bearing & strength properties of the mix. So, the characteristics and quality of the aggregates and mineral filler should be good to ensure a better pavement. The aggregates of various grades were sieved through various IS Sieves and they were retained in various containers with proper marking. There are two kinds of aggregates: Coarse Aggregate and Fine Aggregate. The mineral fillers may be cement or fly ash [17].

| Properties | Unit | Method of test | Test Value |
|---|---|---|---|
| Properties of Coarse Aggregate | | | |
| Bulk Specific Gravity | -- | IS: 2386(1) | 2.68 |
| Apparent specific gravity | -- | IS: 2386(1) | 2.72 |
| Impact value | % | IS: 2386(1) | 18 |
| Flakiness and elongation index | % | IS: 2386(1) | 40 |
| Properties of fine aggregate | | | |
| Bulk Specific Gravity | -- | IS: 2386(1) | 2.68 |
| Apparent specific gravity | -- | IS: 2386(1) | 2.72 |
| Angularity number | -- | IS: 2386(1) | 49 |
| Plasticity index | -- | IS: 2720 | NP |

Table 3: Physical Properties of Aggregate

### *B. Proportion Of Aggregates*

Aggregate gradation is the most important properties in bituminous mixture, which affects completely all the necessary properties like strength, firmness, workability and resistance for moisture damage. Therefore, gradation is the

 

primary consideration of bituminous mix design. The typical aggregate gradation taken for the design of bituminous mix is as per the MORTH Specification [18].

| Sieve Sizes (mm) | Percent passing by weight (Specified) | Percentage passing, By weight (Adopted) |
|---|---|---|
| 19 | 100 | 100 |
| 13.2 | 79-100 | 96 |
| 9.5 | 70-88 | 86 |
| 4.75 | 53-71 | 54 |
| 2.36 | 42-58 | 50 |
| 1.18 | 34-48 | 46 |
| 0.6 | 26-38 | 36 |
| 0.3 | 18-28 | 25 |
| 0.15 | 12-20 | 14 |
| 0.075 | 4-10 | 6 |

Table 4: Aggregate Grading for Bituminous Mix

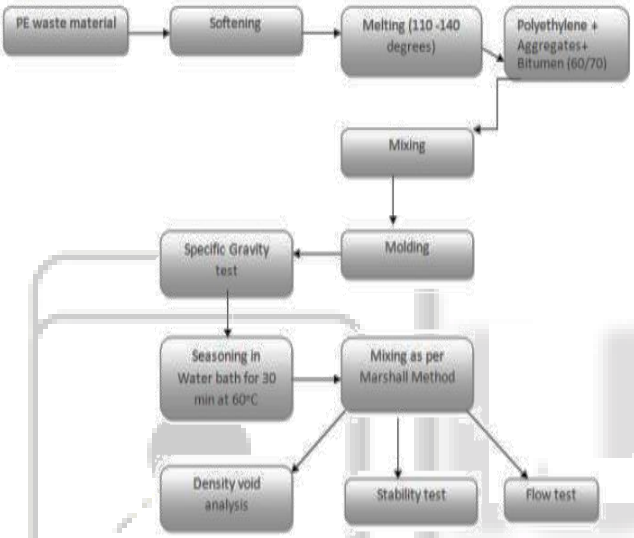


Fig. 1: Process Flow Diagram

*C. Sample Preparation*

*1) Waste Plastic- Bitumen Blend*

The collected polythene wastes were washed, cleaned and dehydrated. The waste plastics were then chopped into very small pieces. The required quantities of waste plastic to be added with specific quantity of bitumen to make various percentage of polythene-bitumen mix were weighted and added in needful percentage by weight of bitumen to the warm bitumen and the mixture was stirred well for about 30 minutes under temperature around 170-180°C[11].

*2) Marshall Mould*

Fig. 2: Marshall Apparatus

The aggregates of various grades were sieved through various IS Sieves and they were kept in various containers with proper marking. The mixing of materials required for mould formation was done as needful quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron container. The mix was kept in an oven at temperature 160 °C for 2 hours. This is due to the aggregate and prepared blends are to be mixed in warmed state so preheating is required. The prepared blend was also heated up to its melting point before to the mixing .The aggregates in the container kept in oven were taken and heated on a controlled gas stove for hardly a minutes holding the temperature. Now mix (60 gm.), i.e. 5% was added to this mix and the whole blend was mixed uniformly and homogenously. This process was continued for 15-20 minutes till they were properly mixed. Then the blend was moved to the Marshall sampling mould. The blend in the mould was then compacted by the Marshall Hammer, 75 numbers of strokes were given on all sides of the sample so a subtotal of 150 numbers of strokes was given per sample. Then we kept these samples with mould individually and then we marked the samplesconsequently to the percentage of polythene added by weight of bitumen [19].

*3) Determination Of Optimum Bitumen Content*

At each grading, Marshall Samples were collected by changing the binder content and then we tested for its volumetric properties. We test the sample in Marshall testing machine and find Marshall Stability Value and flow value. Five separate smooth curves are drawn with percent of bitumen on x-axis and thefollowing on y-axis:

- Unit weight
- Marshall stability
- Flow
- VMA
- Voids in total mix

Optimum binder content is selected as the average binder content for maximum density, maximum stability and certain percent air voids in the total mix [20].

*4) Determination Of Optimum Plastic Content*

The value of plastic content at we obtain minimum Flow Value and maximum Marshall Flow Value is called as Optimum Polythene Content.

*5) Significance Of Volumetric Parameters*

Bitumen holds the aggregates at conditions and the weight is taken by the aggregate mass through the contact points. If complete voids are filled by bitumen, load is exerted by static pressure throughout bitumen, and strength of the mix, therefore, reduces. That is why stability of the mix decreased when bitumen content is raised beyond some value. Also during summer season, bitumen melts and occupies the void space between aggregates and if the voids are not available, bitumen causes bleeding. Thus, certain volume of void is essential in a bituminous blend, even after the final stage of compaction. For obtaining of optimum binder content (OBC), the data of bulk density, stability and air voids are plotted between the binder contents [20].

## IV. RESULT AND DISCUSSION

The required properties of bitumen binders were modified by introducing waste plastic as an additive. Therefore, this procedure of adjustment of bitumen with waste plastic has

 

enhanced resistance to rutting, cracking and pot-hole formation by raising softening point, stiffness and decreasing stripping due to water, thereby improving the general performance of weights over a long time. We observe that optimum bitumen content is 4.5%.

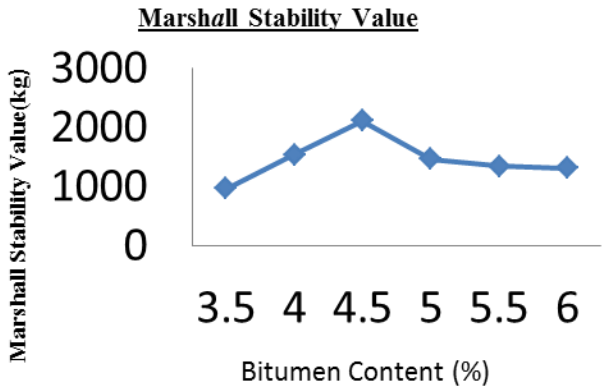


Fig. 3: Marshal Stability Value vs. Bitumen content

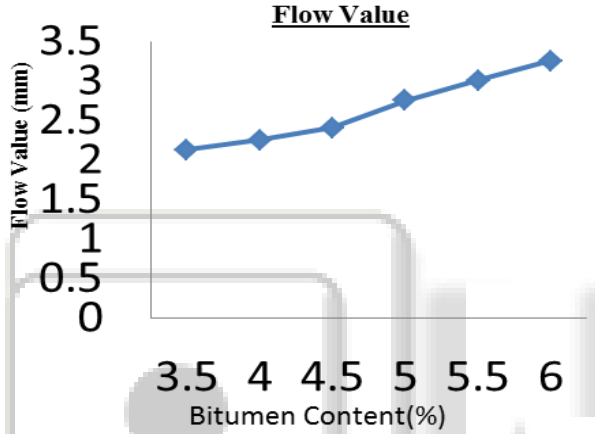


Fig. 4: Flow Value vs. Bitumen Content

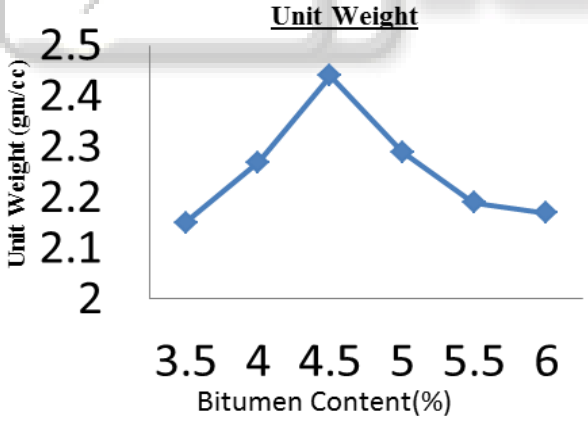


Fig. 5: Unit Weight vs. Bitumen Content

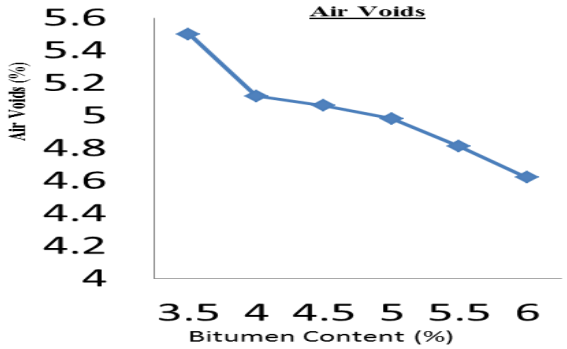


Fig. 6: Air Voids vs. Bitumen Content

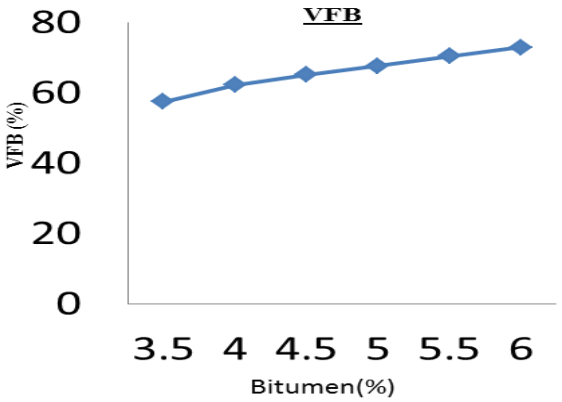


Fig. 7: VFB vs. Bitumen Content

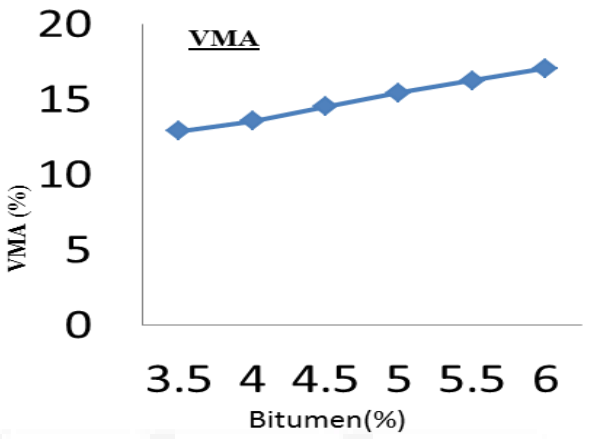


Fig. 8: VMA vs. Bitumen Content

After find the optimum bitumen content, we find out optimum plastic content at optimum bitumen content.

It showed that Marshall Stability value grows with polyethylene content up to 3% and after that it reduces. We note that the Marshall Flow value falls upon addition of polythene i.e. the resistance to deformations under heavy wheel masses increases [11]. We also note that unit weight, air voids and VMA falls upon addition of waste plastic but VFB increases.

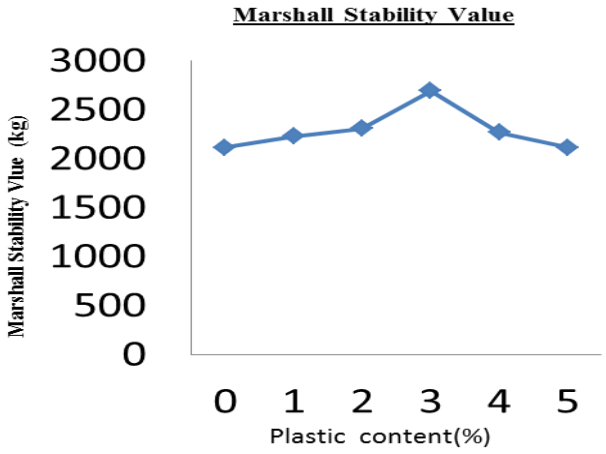


Fig. 9: Marshall Stability Value vs. Plastic Content

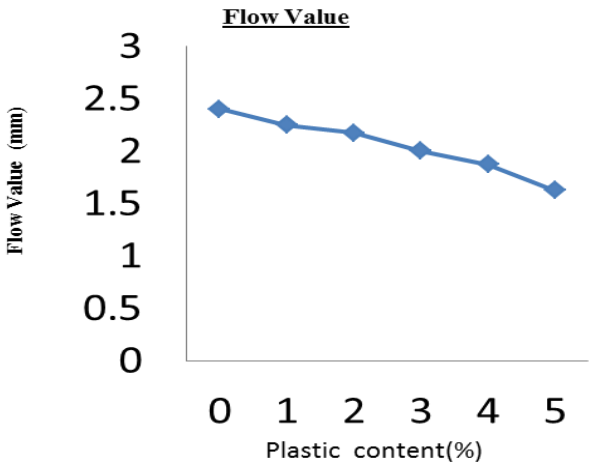


Fig. 10: Flow Value vs. Plastic Content

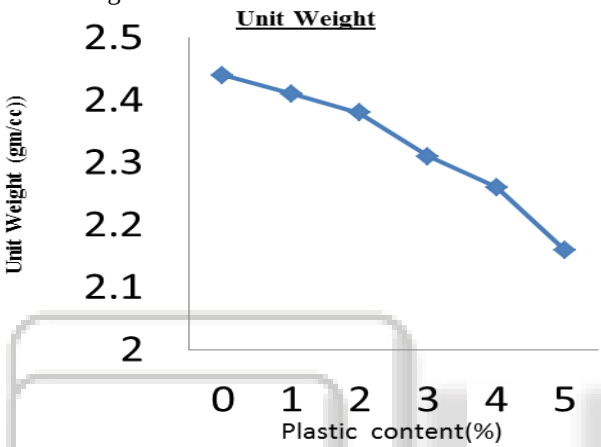


Fig. 11: Unit Weight vs. Plastic Content

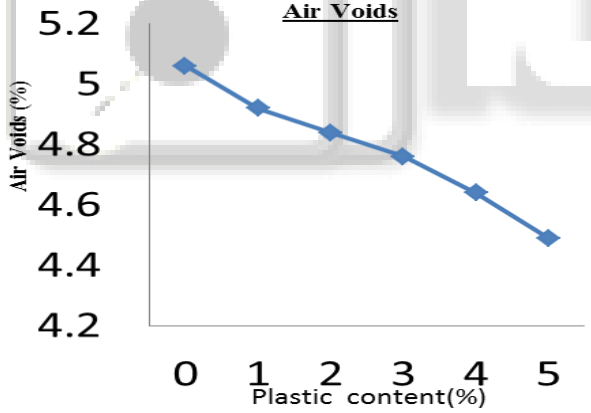


Fig. 12: Air Voids vs. Plastic Content

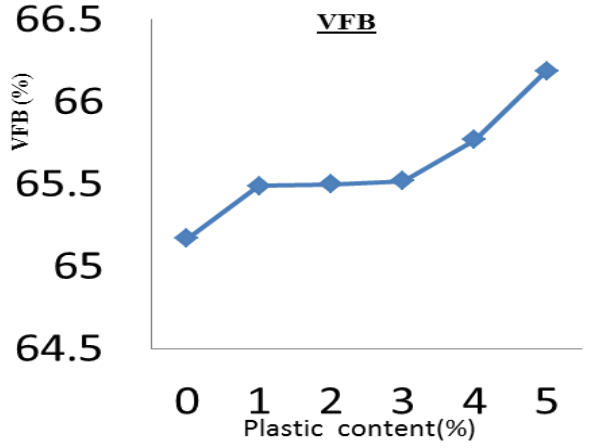


Fig. 13: VFB vs. Plastic Content

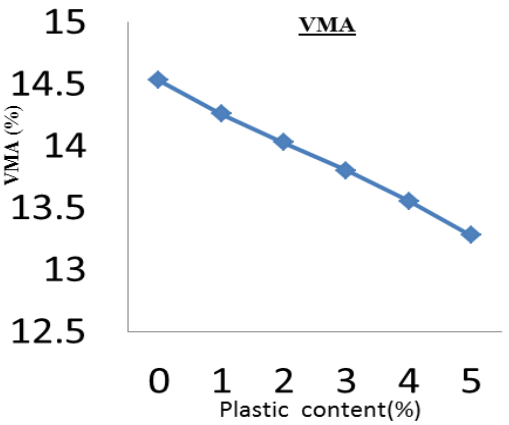


Fig. 14: VMA vs. Plastic Content

## V. UNITS

*A. Here*

- kg represents kilogram
- M represents the unit of meter
- g/cc represent gram per centimetre cube

## VI. HELPFUL HINTS

*A. Figures, Tables and Notations*

*1) Figures*

- Figure 1 represents General process diagram for copper slag production
- Figure 2 represents Marshall Apparatus
- Figure 3 represents variation of MSV with Bitumen Content
- Figure 4 represents variation of Marshall Flow Value with Bitumen Content
- Figure 5 represents variation of Unit Weight with Bitumen Content
- Figure 6 represents variation of Air Voids with Bitumen Content
- Figure 7 represents variation of VFB with Bitumen Content
- Figure 8 represents variation of VMA with Bitumen Content
- Figure 9 represents variation of MSV with Plastic Content
- Figure 10 represents variation of Marshall Flow Value with Plastic Content
- Figure 11 represents variation of Unit Weight with Plastic Content
- Figure 12 represents variation of Air Voids with Plastic Content
- Figure 13 represents variation of VFB with Plastic Content
- Figure 14 represents variation of VMA with Plastic Content

*B. Table*

- Table 1 represents physical properties of waste plastic
- Table 2 represents physical properties of bitumen
- Table 3 represents properties of aggregate
- Table 4representsaggregate grading for bituminous mix

 

### *C. Notations*

- OBC represents Optimum Bitumen Content
- VFB represents voids filled with bitumen.
- VMA represents voids in mineral aggregate
- VA represents air voids
- MSV represents Marshall Stability Value

## VII. CONCLUSION

The results showed that we can improve the property of bitumen concrete mixes by utilization of waste plastic in bitumen mix. The waste plastic utilized in the mix will get covered over aggregates of the mixture and increases the binding property and reduces porosity, absorption of moisture. The bitumen modified with 3% Polythene Waste is showing better performance as compared to another mixture. The Marshall Stability Value is growingwith a maximum increase percent of 27.27% as compared to Conventional mix when modified with 3% Plastic Waste. It is determined that Marshall Stability value increases with plastic content up to 3% and thereafter it decreases. Thus the utilization of higher percentage of waste polythene is not preferred. When we talking about pollution due to these non-perishable plastics waste where disposition of such materials has become a challenging problem, its usage in construction of flexible pavement will give a better place for their put in the ground and thus resolving the problem of their disposal on one hand and providing a better flexible paved surface with improved performance on other hand.

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## REFERENCES

[1] http://en.wikipedia.org
[2] González U. O. 2008. Rheological property of bitumen modified with polyethylene and polyethylene based blends.
[3] Garcia-Morales M., Partal P., Navarro F.J., Martinez-Boza F., Gallegos C., González N., González O. and Muñoz M. E. 2004. Viscous properties and microstructure of recycled over modified bitumen. Fuel. 83(1): 31-38.
[4] Polacco G., Stastna J., Biondi D. and Zanzotto L. 2006. Relation between polymer architecture and nonlinear visco elastic behavior of modified asphalts. Current Opinion in Colloid and Interface Science. 11: 230-245.
[5] Navarro F.J., M., Partal, P., Garcia-Morales M., Martín-Alfonso M.J., Martinez-Boza F., Gallegos J.C., González N., Bordado M. and Diogo A.C. 2009. Bitumen modification with reactive and non-reactive (virgin and recycled) polymers: Acomparative analysis. Journal of Industrial and Engineering Chemistry. 15(4): 458-464.
[6] Yuonne B. and Yajaira R. 2001. Polymer Modified Asphalt. Vision technologica. 9(1): 39-48.
[7] Garcia-Morales M., Partal P., Navarro F.J. and Gallegos C. 2005. Effect of waste polymer addition on the rheology of modified bitumen. Fuel. 85(11): 936-943.
[8] Abtahi S.M., Sheikhzadeh M. and Hejazi S.M. 2010. Fiber-reinforced asphalt-concrete - A review. Construction and Building Materials. 24(16): 871-877.
[9] Gonzalez O., Munoz M. E. and Santamaria A. 2006. Bitumen/polyethylene blends: using m-LLDPE to improve stability and viscoelastic properties. Rheological Act Journal. 45(5): 603-610.
[10] Pe´rez-Lepe A., Martý´nez-Boza F.J., Gallegos C., Gonza´lez O., Mun˜o M.E. and Santamarý A. 2003. Influence of the processing conditions on the rheological behavior of polymer-modified bitumen. Fuel. 82(11): 1339-1348
[11] Imtiyaz Khan and P.J.Gundaliya, "Utilization of Waste Polyethylene Materials in Bituminous Concrete Mix for Improved Performance of Flexible Pavements", International Journal of Scientific Research, volume 1,Issue-4, ISSN No-2277-8179, PP-57-58, September 2012
[12] Dhurjati Mukherjee, Plastic Bags & Waste, APT Recycling may Solve Crisis, India News & Feature Alliance, New Delhi, July29, 2009
[13] Garg, S.K., A Support Manual for Municipal Solid Wastes, Environmental Engineering, Central Pollution Control Board, Vol. II, July, 2003
[14] Guidelines for the use of Plastic Waste in Rural Roads Construction, National Rural Roads Development Agency, Ministry of Rural Development, Government of India
[15] S. Rajasekaran, Dr. R. Vasudevan and Dr. Samuvel Paulraj,"Reuse of Waste Plastics Coated Aggregates-Bitumen Mix Composite For Road Application- Green Method", American Journal of Engineering Research,Volume No-02, Issue No-2320-0847, PP-01-13, 2013
[16] IS: 1205, 1978. Methods for Testing Tar and Bituminous Materials: Determination of Softening Point. Bureau of Indian Standards, New Delhi, India
[17] IS: 2386 (Part I). 1963. Methods of test for aggregates for Concrete. Bureau of Indian Standards, New Delhi, India
[18] Ministry of Road Transport and Highways (MORTH) 2013. Specifications for Road and Bridge Works, Fifth Revision, Indian Roads Congress, New Delhi, India.
[19] ASTM D 1559. 1989. Test Method for Resistance of Plastic Flow of Bituminous Mixtures Using Marshall Apparatus. American Society for Testing and Materials, Philadelphia, USA
[20] Dr. S.K. Khanna and Dr. C.E.G.Justo, Highway Engineering, Ninth edition, Nem Chan Bros, Roorkee, U.K., India, 2011.

 