Experimental Investigation of Modified Bituminous Mix For DBC Using Waste Polythene

Rohit Kumar[1], Hirendra Pratap Singh[2], Rakesh Sakale[3]
[1, 2, 3] School of Research & Technology, People's University Bhopal (M.P.)

Abstract- *Due to the world's fast urbanisation and industrialization, there is currently a lot of trash being produced. Putting this rubbish in a landfill is not a long-term solution. Glass and plastic garbage collection from homes has expanded significantly. Glass can only be disposed of in landfills or processed again to be used as new glass material because it cannot disintegrate. But when it is processed again, it requires a lot of energy to melt it and create something new. On the other hand, managing plastic garbage is a difficult issue since, if dumped, it would render the soil infertile, which is bad for the ecology. An environmentally benign and long-lasting answer is anticipated to be offered by further incorporating trash into building applications. Any product we use, including concrete, plastic, glass, and even wood, will eventually become waste that needs to be disposed of. Recycling or reusing these wastes as additives, modifiers, or raw materials is the best way to handle them. Glass and plastic are the two waste materials that are utilised the most in daily life. In contrast to plastic, glass never burns nor decomposes. To change the mechanical and physical behaviour of the mix, it is preferable to use this waste material in bituminous construction. This waste-mixed modified combination is superior to traditional mix because it is more durable and has a longer life span. It can tolerate temperature changes, be economical, and be environmentally beneficial. This study examines how the characteristics of asphalt mix are affected by waste plastic used as a binder and waste crushed glass used as a finer ingredient. Additionally, it contrasts the outcomes of various plastic binder percentages with virgin bitumen and the appropriate glass percentage for the mixture. It also provides a percentage difference between conventional and modified mixes. Waste plastics in shreds were put to hot bitumen and manually mixed for 15 minutes at 170 C.*

Keywords- Bituminous mixture, Plastic waste, HDPE, Marshall StabilityTest, HDPE Modified Binder, Optimum Binder Content, Optimum Plastic Content.

I. INTRODUCTION

1.1 GENERAL

India has a road network of over 5,472,144 kilometers (3,400,233 mile) as on 31 March 2015, the second largest road network in the world. At 1.66 km of roads per square kilometer of land, the quantitative density of India's road network is higher than that of Japan (0.91) and the United States (0.67), and far higher than that of China (0.46), Brazil (0.18) or Russia (0.08), (Ministry of Road Transport & Highways).

However, qualitatively India's roads are a mix of modern highways and narrow, unpaved roads, and are being improved (India Transport Sector). As on 31 March 2015, 61.05% of Indian roads were pave (Ministry of Road Transport & Highways) and conditions of a major portion of such roads are deteriorating day by day due to adverse traffic loading , due to ageing of bitumen and extreme weathering conditions. But the upgrading cost of such roads has increased due to non-availability of good quality binding materials as reported in IRC 37 (Indian Roads Congress 2012).

Bituminous material used as adhesives for the binding of mineral aggregates to produce pavement structures and surfacing is a thermoplastic visco-elastic material. So far, the conventional tests have been used for the characterization of bitumen in India, but these tests are not satisfactory for the rheological characterization of the bitumen and give the values indirectly (**Praveen Kumar and Rashi Garg (2008).**

With the modernization of world and rapid economy growth, increases the consumption and generates large quantity waste product like plastics, glass, CRT, tires, industrial and construction wastes also. These wastes creates problem for living human being and make hazards to health.

Now these days generation of waste glass also increases day by day. As per the data collected from a survey in the city approx. 2-3 tons of waste liquor glass bottles were collected by the rag-pickers every day. Although theses waste glass products are 100% recyclable but during the recycling process it demands large amount of energy and produces harmful gases due to its content, on melting. So for this reason to save energy and environment and for the alternative product on construction as aggregate, this waste glass can be use in highway construction on subgrade and surface course also. From the past researches, many researchers found this as good alternative product for aggregate and can be cost effective.

In 2016 India today reported that more than 15,000 tones of plastic waste are generated in India everyday, of which 6,000 tones remain uncollected and littered. There is every possibility that India has the highest recycling rate for polyethylene terephthalate or PET, a kind of plastic used to for manufacturing drinking water bottles and food containers.

Indians discard 15,342 tonnes of plastic garbage per day, of which 60% is recycled, primarily in the unorganised sector, according to a 2013 estimate by the Central Pollution Control Board (CPCB). Despite the fact that India's recycling rate is significantly better than the average for the world at 14%, there are still over 6,100 tonnes of plastic that are either land filled or wind up contaminating groundwater supplies or streams. While some plastics do not degrade at all, others may take up to 450 years, creating a problematic issue that needs to be solved. Approximately 70% of plastic packaging goods are thought to be quickly transformed into plastic waste. Plastic waste is produced in the nation at a pace of 5.6 million tonnes per year (TPA), or 15342 tonnes per day (TPD). India, on the other hand, consumed 159 million tonnes of plastic in 2005–2006, while production was only assessed at 127 million tonnes due to the rapid modernization of polymer technology.

II. LITERATURE REVIEW

Krishnan viswanathan (1996) concluded that addition up to 20 percent glass cullet does not have any noticeable effect on the optimum moisture content and the dry density of the mix. This makes glass cullet a viable material for use in flexible bases. The results from the triaxial tests indicate that there is no appreciable change in the corrected stress observed for samples with different amounts of glass cullet up to 20 percent. It is therefore safe to conclude that glass cullet up to 20 percent can be mixed with conventional granular material for use in structural fills without compromising the strength of the material. [21]

Nan Su , J.S. Chen (2002) investigated that glass contents of 0, 5, 10, and 15%, in terms of the total aggregate weight used in the mixture designs for casting series of 10 cm diameter by 6.35 cm disk specimens. Tests including Marshall stability value, dry/wet moisture damage, skid resistance, light reflection, water permeability, and compaction in accordance with the ASTM and AASHTO procedures and the test results reveal that glass waste is a viable material for asphalt concrete that has been widely used in pavement that offers profound engineering and economic advantages. [28]

Nicholls and Lay (2002) reported on a recycled asphalt mixture with 30 % crushed glass. Compaction tests showed that glass-bitumen mixture performed about as well as the control asphalt mixture (standard mixture) and revealed no issues with workability or compaction. [29]

Hassan H. Jony et.al. (2011) indicated that the glass powder filler can improve Marshall stability values for all mixtures comparing to Portland cement or limestone powder fillers. The percentage of increase ranging from 6% to 36% depending on percentage of filler. The average value of Marshall flow is less than resulted from mixtures with ordinary Portland cement or limestone powder fillers. [14]

M. Ghasemi, S. M. Marandi (2013) investigated that by using recycled glass powder (RGP) in the asphalt mixture can improve Marshall Stability and mechanical properties. It could be also inferred that stiffness and thermal sensitivity improved. Moreover, Marshall Stability, tensile strength and stiffness modulus of asphalt mixtures increased with increase of RGP content. Optimal modification was attained with 3% SBR and 2% RGP. Application of RGP in asphalt mixtures may also have many environmental benefits and prevent accumulation of waste glass in the natural environment. [22]

Ahmed Abbas Jasim (2014) investigated waste glass as secondary aggregate in asphalt mixture. The study covers firstly using glass as aggregates including two percentages of glass content (50 and 100 %) by weight of each sieve, and six sizes of glass (1/2, 3/8, No.4, No.8, No.50 and No.200). Secondly, using glass as additives including three percentages of glass content (1, 2 and 4 %) by weight of total mix, and two sizes of glass (No.50 and No.200) and concluded that Marshall Stability for glasphalt is higher than of the control mixture by (127 and 174) % when using glass size (No.8 and No.200) respectively as secondary aggregate in asphalt mixture. [2]

G.H. Shafabakhsh , Y. Sajed (2014) studied dynamic properties of glasphalt, including fatigue life, stiffness modulus and creep compliance. The data showed that the dynamic properties of glass–asphalt concrete are improved in comparison with ordinary asphalt concrete. The research also demonstrated that it is feasible to use and recycle waste glass in asphalt concrete. [13]

Mehmet Saltan et.al. (2015) used waste glass as mineral filler in hot mix asphalt and concluded that the Marshall stability and flow values for all the filler types (limestone, cullet glass, and domestic glass waste) satisfy the General Directorate specification limits. The Marshall Stability values of the mixtures with cullet glass and domestic glass waste filler are slightly smaller than the mixtures with the limestone mineral filler material. But using glass waste in hot mix asphalt pavements would be very useful in view of waste management. [25]

III. EXPERIMENTAL PROGRAM

In this chapter the material used, their physical properties, mix preparation and test on conventional and modified samples are discussed. This chapter only explains the types of material that we used their physical characteristic and specifications as per code.

3.1 PREPARATION OF THE MIXTURE

For the preparation of mixture the percentage of each type of aggregates is computed. Table 3.8 shows the blending proportion of each type of aggregates. Each aggregate sample was blended for each percentage of conventional and modified mix separately. Aggregates are dried and heated to 120^0C before mixing then 160^0C heated virgin and modified bitumen binder is mixed at 165^0C. The required percentage of bitumen is added to the heated aggregate and mixed thoroughly to obtain a homogenous mix. Standard Marshall mould was heated in an temperature controlled oven then hot mix is placed in the mould then compacted on both side of mould with 75 no. of blows to the specimen. Compacted specimen then separated from the mould and then taken to the water bath for 30mins at 60^0C temperature.

3.2 Marshall Test Method

In this study, Marshall Stability test was used to determine the optimum bitumen, HDPE and glass content. Marshall Stability test is an empirical method for determining the stability, deformation and volumetric properties of bituminous mixture. This test method covers measurement of resistance to plastic flow of 102 mm (4 in.) cylindrical specimens of bituminous paving mixture loaded in a direction perpendicular to the cylindrical axis by means of the Marshall apparatus.

Marshall stability and flow values along with density; air voids in the total mix, voids in the mineral aggregate, or voids filled with asphalt, or both, filled with asphalt are used for laboratory mix design and evaluation of bituminous mixtures. The magnitude of Marshall Stability varies with aggregate type and grading and bitumen type, grade and amount (D 6927- 05), the specimen is loaded diametrically at a deformation rate of 50 mm/min. Here are two major features of the Marshall method of mix design.

(i) Stability, flow tests and
(ii) Voids analysis.

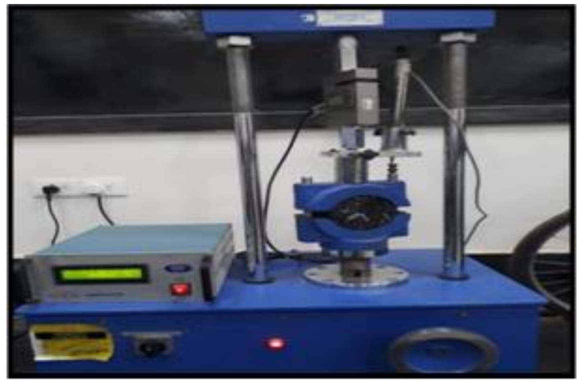

Figure-1 Marshall Test Equipment

IV. ANALYSIS OF RESULTS AND COMPARISION

4.1 INTRODUCTION

In this chapter we will discuss about the experiments results, analysis and percentage change in properties by modification of mixture, effect of different HDPE content on binder and the effect of glass cullet on mixture will discuss. In the whole chapter, properties of Course and fine aggregate, physical properties of virgin and modified bitumen, Marshall Stability of conventional and modified mixture and percentage variation in stability and binder physical properties and their graphical presentation is shown.

4.2 MARSHAL STABILITY TEST

Figure-2 shows the graph of Marshall Stability at different bitumen percentages. It was found from the test results that with increase in bitumen content stability also increases, but at 6.2% of bitumen content the stability was drop. From all the calculations at 5.90% optimum bitumen content stability was maximum i.e. 1070 KN.

Table-1 Marshall Test result of conventional mix

Bitumen (% by weight of aggregate)	Stability (KN)	**Flow** value **(mm)**	**Unit wt. (gm/**cc**)**	**Air Void (%)**	**VMA (%)**	**VFB (%)**
5.3	1020	2.96	2.34	5.10	19.80	75.42
5.6	1145	3.48	2.36	4.25	19.30	79.85
5.9	1222	3.84	2.39	2.90	18.85	85.10
6.2	1030	4.18	2.40	1.40	18.15	85.92
6.5	935	4.50	2.36	3.60	20.15	81.00
OBC (5.9%)	1070	3.79	2.37	3.53	19.25	81.57

ISSN **[ONLINE]: 2395-1052**

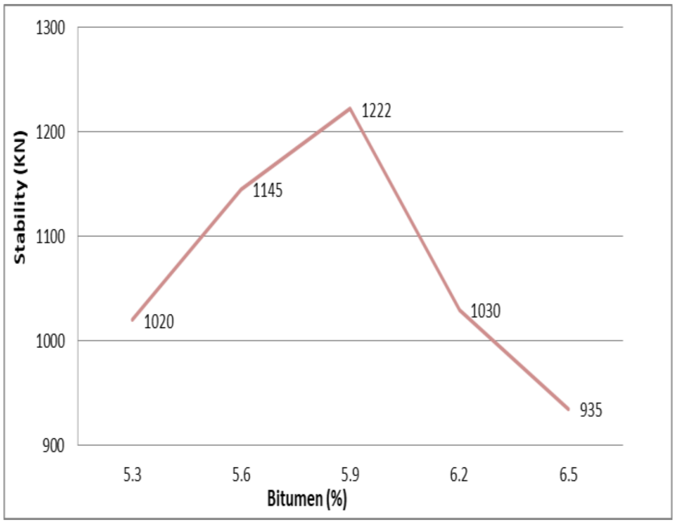

Figure-2 Variation of stability with Bitumen content

Table-2 Marshall Test results of HDPE modified mix

OBC (%)	HDPE % (By wt. of Aggregate)	Stability (KN)	Flow (mm)	Unit wt. (gm/cc)	Air Void (%)	VMA (%)	VFB (%)
5.9	**0**	1225	3.95	2.361	2.41	18.73	87.28
	0.3	1388	2.55	2.364	3.94	20.09	80.40
	0.6	1588	3.18	2.370	3.06	19.32	83.95
	0.9	1665	3.41	2.395	2.26	18.69	87.98
	1.2	1212	3.82	2.312	3.87	19.91	80.79

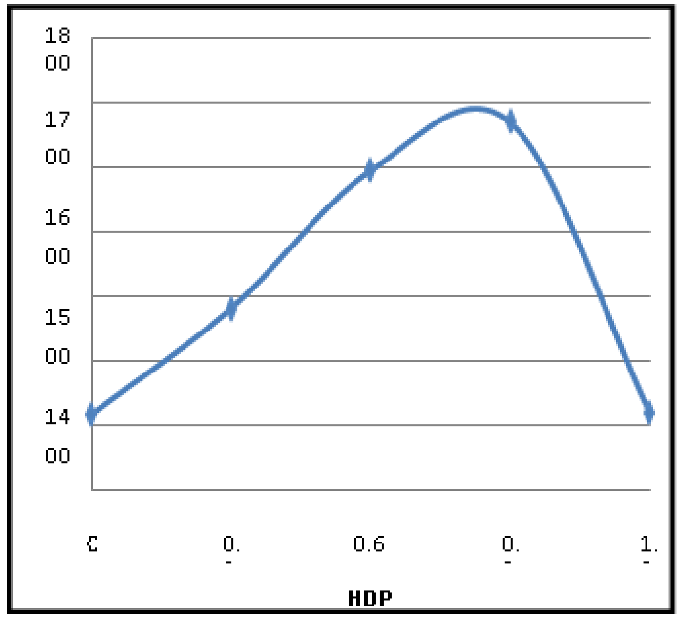

Figure-3 Variation in Stability with HDPE content

Figure-3 shows the variation in Stability for HDPE modified sample. The mix was prepared at OBC of 5.66% bitumen and modified with HDPE plastics by wet mixing process. From the test results it was found that with increase in HDPE content, stability increases at particular percentage of HDPE content then at 1.2% of HDPE content it decreases. At 0.9% HDPE and 5.90% bitumen content the stability value is higher than other percentages of mix. So 0.9% is optimum plastic content for HDPE modified mix.

4.3 COMPARISON BETWEEN CONVENTIONAL AND HDPE MODIFIED MIXTURE

Form the analysis of Marshall Test results on conventional and modified mixtures; we can compare the results of these two mixtures that with addition of HDPE modified binder into the conventional mix stability increases by up to 30% and rate of deformation also decreases. Other volumetric properties like unit wt., air void%, VMA and VFB also get modified in comparison with conventional mix. The optimum dose of HDPE for bituminous binder is 0.9% (by wt.).

V. DISCUSSION AND CONCLUSION

5.1 DISCUSSION & CONCLUSION

To achieve the objective of this study an experimental work has been performed on virgin, HDPE modified binder, conventional, HDPE modified mix. Separately, effect of HDPE on mixture has been investigated by Marshall Test method and their results are compared and %

change is determined, where volumetric properties are changed with increase in proportion of HDPE. As HDPE is mixed with binder (VG30), which also results in change in physical characteristics of binder and after a certain percentage of HDPE, values cannot be acceptable, which suggests the optimum dose of HDPE plastic waste in VG30 bitumen binder. There are some conclusions which are made from the analysis of test results:

- By mixing of HDPE into the VG30 bitumen, penetration value decreases up to 60% of 1% dose of HDPE, but up to 0.6% of HDPE the value can be accepted. Ductility also decreases with increase in HDPE by73% of 1% HDPE content.
- Softening point increases by mixing of HDPE into bitumen which is good and suitable for high temperature region.
- Decrease in value of Penetration and Ductility shows the hardness and brittleness respectively; of the binder with HDPE mix, which shows the impermeable quality by the modified binder.
- Optimum dose of HDPE in VG30 bitumen is between 0.2 to 0.4%.
- Using Marshall Method of mix design the optimum binder content and optimum plastic has been determined which is 5.90% and 0.9% respectively.
- It has been observed that addition of HDPE waste plastic into the conventional mix can enhance the stability of mixture with lesser flow value in comparison with conventional mix, up to a certain dose of HDPE.

- The existence of waste plastic in bituminous binder course mixture is considered as an ecofriendly material and sustainable management of these waste products in Pavement construction.

5.2 RECOMMENDATIONS

Following recommendations are made from the investigation on incorporation of waste plastic on bituminous mixture:

- In this study only HDPE is incorporated with waste glass, other types of plastics are also need to incorporate with this or other types of waste glass.
- Some other strength characteristic studies are needed to perform on these materials.
- In the present study plastic is added to mix via wet mixing process. Plastic incorporated with glass cullet can also be used for mixture modification by dry mixing process and should compare the results.
- In this study only VG30 grade bitumen was used, future more studies are needed with these materials using other VG grade bitumen.
- Some of the properties like tensile strength ratio, fatigue behavior, rutting resistance, dynamic and static tensile strength and creep behavior are need to investigate.

REFERENCES

[1] Ahmadinia, Majid Zargar, Mohamed Rehan Karim, Mahrez Abdelaziz, Payam Shafigh (2011), “Using waste plastic bottles as additive for stone mastic asphalt” Mater. Des, 32(10), 4844–4849.

[2] Ahmed Abbas Jasim(2014), “By Using Waste Glass as Secondary Aggregates in Asphalt Mixtures”, International Journal of Advanced Research (2014), Volume 2, Issue 1, 41-46.

[3] Awwad and Lina Shbeeb (2007), “The use of polyethylene in hot asphalt mixtures.” Am J Appl Sci 2007;4(6):390–6.

[4] ASTM D6926- 2016, “Standard practice for preparation of asphalt mixture specimens using Marshall Apparatus.”

[5] ASTM D6927- 2015, “Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures.”

[6] Bindu, C.S. Beena, K.S. (2010). “Waste plastics as stabilizing additive in Stone Matrix Asphalt”, International Journal of Engineering and Technology, Vol.2(6), 379-387.

[7] Bindu, C.S. Beena, K. S. (2010). “Use of waste plastic in road construction”, Journal of the Technology World, Vol .V Issue – 1, 91 – 100.

[8] Bureau of Indian Standards (1978a), “Methods for testing tar and bituminous materials: Determination of penetration” IS: 1203, New Delhi, India.

[9] Bureau of Indian Standards (1978b), “Methods for testing tar and bituminous materials: Determination of softening point” IS: 1205, New Delhi, India.

[10] Bureau of Indian Standards. (1992), “Paving bitumen - Specification: Determination of loss of heating” IS: 73, New Delhi, India.

[11] Bureau of Indian Standards (2004), “Polymer and rubber modified bitumen - Specification” IS: 15462, New Delhi, India.

[12] Bureau of Indian Standards (2013), “Paving bitumen - Specification: Determination of loss of heating” IS: 73, New Delhi, India.

[13] G.H. Shafabakhsh, Y. Sajed (2014), “Investigation of dynamic behavior of hot mix asphalt containing waste materials; case study: Glass cullet” Construction Materials 1 (2014) 96-103.

[14] Hassan H. Jony, Mays F. Al-Rubaie and Israa Y. Jahad (2011), "The Effect of Using Glass Powder Filler on Hot Asphalt Concrete Mixtures Properties" Eng. & Tech. Journal ,Vol.29, No.1, 2011.

[15] IRC 98-2013, "Guidelines for the use of waste plastic in hot bituminous mixes (dry process) in wearing courses."

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

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

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

[19] IS: 2386 (1963), "Methods of test for aggregates for concrete (P-V): Soundness", Bureau of Indian Standards, New Delhi.

[20] Joseph Wartman, Dennis G. Grubb and A. S. M. Nasim (2004), "Select Engineering Characteristics of Crushed Glass" Journal of Materials in Civil Engineering Vol. 16, Issue 6 (December 2004).

[21] Krishnan Viswanathan (1996), "Characterization of waste recycled glass as a highway material" August 1996, http://hdl.handle.net/2346/19867.

[22] M. Ghasemi and S. M. Marandi (2013) "Laboratory studies of the effect of recycled glass powder additive on the properties of polymer modified asphalt binders" IJE transactions a: Basics Vol. 26, No. 10, (October 2013) 1183-1190.

[23] Mahabir Panda and Mayajit Mazumdar (1999), "Engineering properties of EVA modified bitumen for paving mixes", J. Mater. Civ. Eng., 11(2), 131–137.

[24] Mahabir Panda and Mayajit Mazumdar (2002) "Utilization of reclaimed polyethylene in bituminous paving mixes", J. Mater. Civ. Eng., 14(6), 527–530.

[25] Mehmet Saltan, Betul Oksuz and Volkan Emre Uz (2015), "Use of glass waste as mineral filler in hot mix Asphalt" Sci Eng Compos Mater 2015; 22(3): 271–277.

[26] Metin Guru, Deniz Arslan, M.Kursat Cubuk and Meltem Cubuk (2011), "Improvement of bitumen and bituminous mixtures performances by triethylene glycol based synthetic polyboron" Constr. Build. Mater. 25 (2011) 3863–3868.

[27] MORTH, Specification for Road and Bridge work 5th revision 2013.

[28] Nan Su and J.S. Chen (2002), "Engineering properties of asphalt concrete made with recycled glass" Resources, Conservation and Recycling 35 (2002) 259–274.

[29] Nichols J.C. and Lay J. (2002), "Crushed Glass in Macadam for Binder Course and Road Base", Proceedings of 4th European Symposium on Performance of Bituminous and Hydraulic Materials in Pavements, BITMAT 4, University of Nottingham, U.K., 11-12 April 2002, pp. 197-212.

[30] Praveen Kumar and Rashi Garg (2011), "Rheology of waste plastic fibre- modified bitumen", International Journal of Pavement Engineering Vol. 12, No. 5, October 2011, 449–459.

[31] Priyanshi Bhargava and Tapas Singh (2018), "Use of waste polythene in modification of bituminous mix for DBC– A Review", International Journal of Engineering Sciences & Research Technology, Researcheird, ISSN: 2277-9655, 177-178.

[32] Sandeep Karmakar and Tapas Kumar Roy (2016), "Effect of waste plastic and waste tires ash on mechanical behavior of bitumen" Journal of Materials in Civil Engineering Vol. 28, Issue 6 (June 2016).

[33] V.S. Punith and A. Veeraragavan (2007),"Behaviour of asphalt concrete mixtures with reclaimed polyethylene as additive", J. Mater. Civ. Eng., 19(6), 500–507.

[34] V.S. Punith and A. Veeraragavan (2010), "Evaluation of reclaimed polyethylene- modified asphalt pavements" ,J. Test. Eval., 38(5), 10.1520/ JTE102418.

[35] V. S. Punith and A. Veeraragavan (2011), "Behavior of Reclaimed Polyethylene Modified Asphalt Cement for Paving Purposes", Journal of Materials in Civil Engineering, Vol. 23, No. 6, June 1, 2011.

[36] Y. Issa (2016), "Effect of adding crushed glass to asphalt mix", Archives of civil engineering Vol. LXII, issue 2, 2016.