Properties of Bituminous Binder Modified With Polyethylene

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Abstract

Bitumen is used as a binder in construction of flexible pavements since long. With the increase in population and number of vehicles, load on roads have been increased day by day. Thus roads which consist of unmodified bitumen suffer from serious drawbacks in the due course of time like rutting, thermal cracking, fatigue cracking, pothole formation etc. Hence, it is necessary to add a modifier in bitumen to enhance the binding property of later. Polyethylene, which is a non-degradable compound, become waste and creates pollution, owing to its high consumption. This polyethylene (melting point 120-180 °C; thermal degradation above 400 °C) in liquid state becomes sticky in nature and therefore can act as a binder. Also, major parts of both polyethylene and bitumen are hydrocarbon, hence polyethylene wastes (LDPE and HDPE) can be used to modify the bitumen and enhance the binder property of it. Like polyethenes, degradation of other polymeric wastes is also challenging and can be utilized for other purposes for minimizing the wastes and improvement in quality of available products.

1 Introduction

There are two major problems existing in the society: (a) Non degradable polyethylene waste which persists in the environment over longer periods of time (a big health hazard for living beings and associated environmental problems) and (b) Need of modification of bitumen in order to enhance life of roads. Now both bitumen and polyethylene are non-polar in nature and melting point of polyethylene is in a range that it can be mixed with the bitumen. Hence single line solution for these two problems is utilization of polyethylene (and likewise polymeric) waste in modification of bitumen. The most commonly used modifiers in bitumen are polymers [1]. The researches have been performed on various types of polymers as modifier in bitumen such as Polyethylene terephthalate (PET), Low density polyethylene (LDPE), High density polyethylene (HDPE), Polystyrene (PS) etc. [2-5]. Ho et al. (2006) highlighted that the molecular weight and its distribution is an important factor in case of LDPE to act as a good modifier of asphalt [6]. Waste LDPE (5%, 10% and 15%) was mixed with bitumen and modified bitumen/plastic blends were analyzed by Marshal stability test, water absorption test, bulk density, extraction test. It was concluded that LDPE modified bitumen had enhanced strength as well as performance [7]. Singh et al. (2012) used maleated bitumen instead of pure bitumen with recycled LDPE to form polymer modified bitumen. The findings proved that maleated bitumen-recycled LDPE mixtures have enhanced softening point and elastic recovery with better performance during storage and implementation in practical field [8]. Ahmedzade et al. (2013) used gamma irradiated recycled low density polyethylene to modify the bitumen. The research proved that γ-LDPEγ has stiffening effect on bitumen due to which its temperature susceptibility is decreased and performance grade is improved [9]. Kishchynskiy et al. (2016) used recycled polyethylene obtained from processed plastic waste products as modifier in bitumen. Modified bitumen becomes less susceptible to temperature changes, moisture damage as well as rate of thermal ageing decreases [10]. Saroufim et al. (2018) used LDPE, HDPE and EVA as modifier in bitumen. The research proved that the internal structure of the polymer modified bitumen can be found using simple tests and hence the appropriate polymer/bitumen blend can be selected [11].
2 Materials and Methods

2.1 Materials

Low Density Polyethylene pellets (LDPE) were used as modifier in VG-30 Bitumen and both were procured from the local suppliers.

2.2 Mixing and sample preparation

The VG-30 bitumen was modified with 2.0%, 4.0%, 6.0% and 8.0% by mass of LDPE at 170 °C. A high shear mixer moving at 1000 rpm was used and mixing was done for 1.5 hr to get a homogenous binder. Modified bitumen was poured into small containers and kept at room temperature. The containers were covered with aluminum foil and stored for various tests [12]. The LDPE modified bitumen samples were labelled as below:

VG-30 Bitumen + 2.0% LDPE = 2LDPMB
VG-30 Bitumen + 4.0% LDPE = 4LDPMB
VG-30 Bitumen + 6.0% LDPE = 6LDPMB
VG-30 Bitumen + 8.0% LDPE = 8LDPMB

The properties of modified bitumen samples were analyzed like Penetration point, Softening point, Ductility and SEM analysis of LDPMB was performed to find the dispersion of LDPE in bitumen.

2.3 Testing methods

The penetration point of bitumen and LDPE modified bitumen samples was determined with the help of penetrometer. Ring and ball apparatus was used to find the softening point of bitumen and LDPMB. The ductility of bitumen and LDPMB was determined with the help of ductility testing machine. NOVA NanoSEM 450 was used for SEM analysis of LDPMB.

![Figure1 Variation of (a) Penetration Point (b) Softening Point (c) Ductility versus % of LDPE polymer]
3 Results and Discussion

Penetration point of bitumen and LDPMB at temperature 25 °C was determined. Figure 1(a) represents the variation in penetration point of the LDPMB versus different percentages of LDPE. Results of penetration test prove that the penetration point of bitumen decreases with the use of LDPE and with the increase in the percentage of LDPE. Thus bitumen becomes harder after the modification which in turn leads to the enhancement in the resistance of modified bitumen towards permanent deformation and rutting. Softening point of bitumen increases after modification with LDPE and with the increase in its percentage. Thus bitumen becomes less temperature susceptible after modification. This implies that bitumen becomes resistant towards the effect of heat and it will not soften at high temperature. Such modified bitumen can be successfully used in areas with hotter climatic conditions. Figure 1(b) represents the variation in softening point of LDPMB versus different percentages of LDPE. Ductility of bitumen decreases after the modification with LDPE and with the increase in percentage of LDPE upto 4.0% composition of LDPE and then it decreases beyond minimum acceptable value of 40 cm. This means bitumen cannot be modified with LDPE beyond 4.0% mass of bitumen. Bitumen which is having very low value of ductility will not act as a good binder because it will not be able to bind the aggregates properly. So, bitumen having percent of LDPE greater than 4.0% by mass of bitumen will have poor performance in the pavement, hence should not be used. Therefore, 4.0% LDPE by mass of bitumen is the ideal or optimum concentration for the modification of VG-30 bitumen out of the four percentages taken. Figure 1(c) shows the variation in ductility values for the LDPMB versus various percentages of LDPE. Figure 2 (a), (b), (c), (d) shows SEM images of 2LDPMB, 4LDPMB, 6LDPMB, 8LDPMB respectively. SEM analysis confirms homogenous dispersion of polymer at low percentages but at high percentages it is non-uniform showing polymer rich phase.

4 Conclusion
The results of experiments conducted on LDPE modified bitumen clearly proves that the mixing of low density polyethylene in the VG-30 bitumen results in the enhancement in basic physical properties of bituminous binder. 4.0% LDPE by mass of bitumen is the ideal or optimum concentration for the modification of VG-30 bitumen.

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