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Characterization of Bitumen and Modified Bitumen (e-PMB) using FT-IR, Thermal and SEM techniques

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Abstract

In last five years WEEE production increases to an alarming rate. At present, there are number of methods to manage it such as dismantling and recovering of reusable parts like costly metals and incineration, pyrolysis, recycling of plastic components and lastly disposal in landfilling etc. but some of these processes are energy consuming and are neither cost effective nor eco-friendly. Therefore, the present study focuses on the effective and sustainable management of e-plastic waste left after recovery of metallic portion from discarded E-gadgets. It deals with the development of modified binder from e-plastic waste with an aim to find an innovative technology for its effective use to produce bituminous mixes used for road construction and to minimize it in the environment. To meet this objective homogenous blend (e-PMB) of e- polymers and bitumen were prepared using an electrically operated stirrer. These blends are then characterized using FT-IR, Thermal and SEM techniques.

Keywords: e-plastic waste, modified bitumen, e-PMB, TGA, SEM, FT-IR

Introduction

E-waste is one of the fastest growing waste streams today and is growing almost three times the rate of municipal waste, globally[1]. The EPA (Environmental Protection Act) estimates that 29.9 million desktops and 12 million laptops were discarded in 2007. That's over 112,000 computers discarded per day. The EPA report estimates that 31.9 computer monitors were discarded in 2007[2]. As there is no separate collection of e-waste in India, no reliable figures are available as yet to quantify the e-waste generation. But according to toxics link, a Delhi-based non-government organization (NGO), says that India annually generates 1.5 billion worth of e-waste. The situation is alarming in India because almost all of it finds its way into the informal sector as there is no organized alternative available at present[3]. In accordance with the National Environmental Policy (NEP) and to address sustainable development concerns, there is a need to facilitate the recovery and/or reuse of useful materials from waste generated from a process and/or from the use of any material thereby, reducing the wastes destined for final disposal and to ensure the environmentally sound management of all materials[4]. E-plastics account for about 15-22% of the weight of WEEE out of which one third is suitable for mechanical recycling and 2/3rd needs to dispose by other means[5]. However, there are number of problems related with e-Plastic recycling such as plastic housings are made from ABS plastic may contain tetrabromobisophenol-A (TBBA), which is a brominated flame retardant[6]. Chloroparaffins have been used as softeners (i.e. additives to allow the plastic to remain flexible) in e-plastic. E-plastic is a mixed plastic has unacceptably poor mechanical, flow and thermal properties. As a consequence, recovered (but mixed) material cannot be reused to make new computer housings[7]. The end products formed tend to be for low grade use such as dustbin sacks. More than 90% of this waste is currently land filled [8]as it represents difficult to recycle the e-waste.

On the other side, the deformation problem of roads has become even more severe and other solutions are now being implemented. New developments in mix design and the use of modified binders are being introduced. It is recognized that the performance limits of conventional bitumen have been reached for a certain category of roads and that the use of polymers in bituminous road binders provides a cost effective solution [9].Therefore, the modified binders have been developed by using e-plastic waste (10% ad 15%) to find its effective use to produce bituminous mixes used for road construction and to minimize it in the environment. This paper deals with interpretation of these modified binders using FT-IR, thermal and structural behavior and compared with plain (conventional) bitumen.

Material and Methods

VG 30 bitumen obtained from Mathura Refinery was used. Keyboard of computer was dismantled very carefully to separate plastics from them. This plastic is termed as e-plastic. Thermal studies show that waste e-plastic degrades above 200°C whereas bitumen melts around 110ºC and degrades above 175ºC. Therefore, blending of e-plastic and bitumen was carried at 160ºC. Required quantity of e-plastic modifiers was added to bitumen. Simultaneously a nominal quantity of additive was added to facilitate mixing of plastic into bitumen. Blending was done in an oven attached with a stirrer, which is controlled by a thermostat at a constant temperature. The mixture of polymers and bitumen was stirred using an electrically operated stirrer for about one hour to yield a homogeneous blend. These blends as well as base bitumen are characterized using FT-IR, Thermal and SEM techniques.

Experimental Studies: Two modified binder formulations are prepared with 10% and 15% of e–plastic waste. These formulations are termed as e-PMB.

FTIR (Fourier Transform Infrared Spectroscopy) of Modified Binder: FT-IR analysis was carried out using MB 3000 (Horizon) FT-IR analyzer. The wavelength range of the instrument is 485 to 8500 cm^{-1} with resolution better than 0.7 cm^{-1}.The spectra are shown in figure 1-3.

Thermal analysis of modified binder: Conventional (base) bitumen and modified bitumen were subjected to thermal studies. The test was carried out using EXSTAR TG/DTA 6300 thermogravimetric analyzer instrument. The resolution of this instrument is 0.02 g as a function of temperature. Runs were carried out linear heating 5^0C/ min from room temperature to 800^0C under nitrogen at a flow rate of 200 ml / min. TGA, DTG and DTA Curves obtained on e-PMB containing different quantity of e-plastic waste samples are given below in figure (4-6).

SEM (Scanning Electron Microscopy): The instrument used for the study of the microscopic structure of base bitumen and modified bitumen is the LEO 435VP is a high-performance, variable pressure scanning electron microscope with a resolution of 4.0nm. Its 5 axis computer controlled stage is mounted in a specimen chamber measuring 300 x 265 x 190mm and can accommodate specimens weighing up to 0.5kg. Standard automated features include focus, stigmator, gun saturation, gun alignment, contrast and brightness.

Results and Discussion

Three samples of bitumen containing 0, 10, and 15% of e-plastic waste were subjected to FT-IR studies. The FT-IR Spectra of these three samples are shown in figure 1-3.

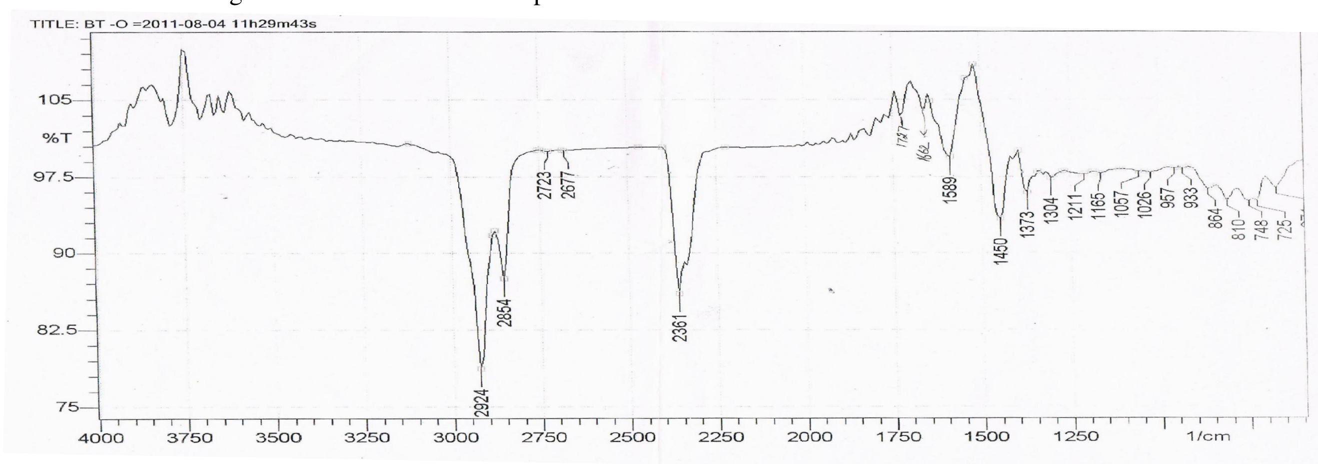

Figure-1
FT-IR Spectra of base bitumen i.e. containing 0% e-plastic waste modifier

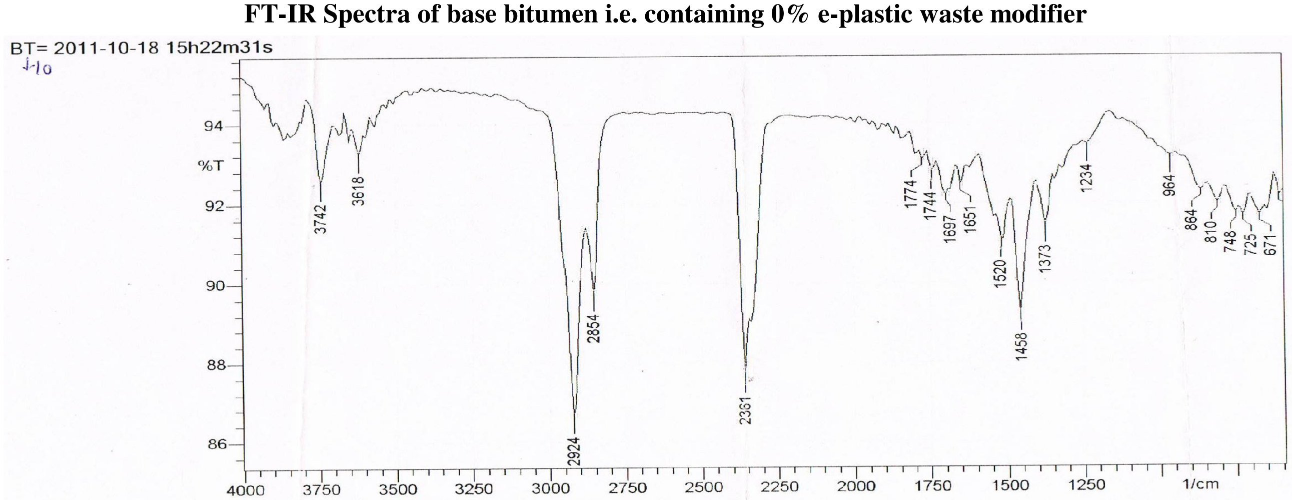

Figure-2
FT-IR Spectra of e-PMB containing 10% e-plastic waste modifier

The comparison of peak position and intensities of various peaks appearing in the FT-IR spectra of base bitumen, e-plastic waste modifiers and the modified bitumen (e-PMB 10% and e-PMB 15%) reveal that the relative intensity of the peaks appearing in the region 3652-3631 cm^{-1} is lower than that in the e-plastic waste modifiers. This indicates that the free O-H group of polymeric species undergoes some type of interactions with bitumen i.e. the O-H group is no more in a free state completely.

Another indication of structural changes in the bitumen on addition of e-plastic waste into base bitumen is disappearance of some peaks (which were very prominent in case of base bitumen) and appearance of some new peaks in the modified bitumen samples (e-PMB 10% and e-PMB 15%). Base bitumen has peak values at 2723 cm^{-1}, 2677 cm^{-1},1727 cm^{-1} 1589 cm^{-1} and a cluster of peaks in the region 1211 cm^{-1} -1026 cm^{-1} which disappear on modification of bitumen with polymer (e-PMB 10% and e-PMB 15%). Modified bitumen have some new peaks such as 1520 cm^{-1} (e-PMB 10%)and 1512 cm^{-1} (e-PMB 15%). However, the appearance of different peaks cannot be assigned with 100% accuracy due to lack of any probable suggestive structures. Here we are dealing with a complex matrix.

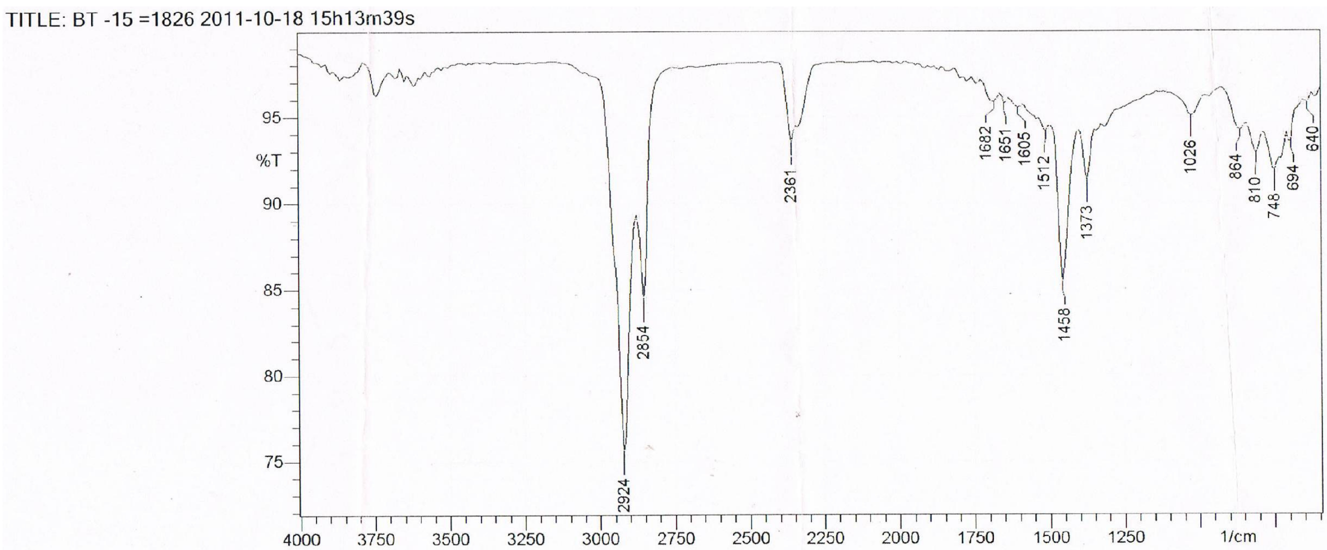

Figure-3
FT-IR Spectra of e-PMB containing 15% e-plastic waste modifier

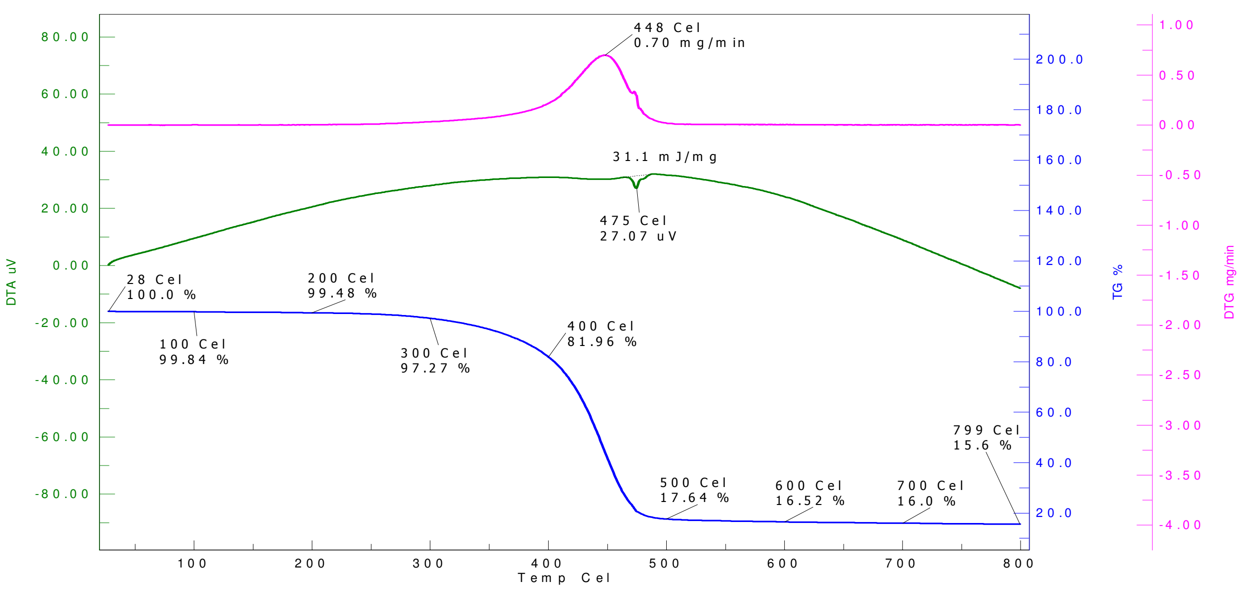

Figure-4
TG, DTG and DTA curves for base bitumen at a heating rate 5^0C/ min in nitrogen atmosphere

The initial decomposition temperatures (IDT) of base bitumen and e-PMB formulations containing plastic waste 10% and 15% are 400, 380 and 370^{0}C and char yield at 798^{0}C decreased from 15.6 to 11.23%. Onset of decomposition Ti values indicated that e-PMB samples are thermally stable up to temperature 200^{o}C and are safe to use for production of bituminous mix during construction of roads because there will be no emissions up to application temperatures. However, at 400^{o}C percent weight loss increased from 18 to 41, which indicated that on increasing percentage of e-plastic modifier weight loss, also increases due to decomposition of polymeric components. The temperature at which maximum decomposition occurs decreased from 448-411^{o}C as observed from DTG curves on addition of 10% and 15% e-plastic modifier to base bitumen.

The comparative decomposition data is shown in table 1.

Thermal properties of bitumen and modified bitumen (e-PMB):

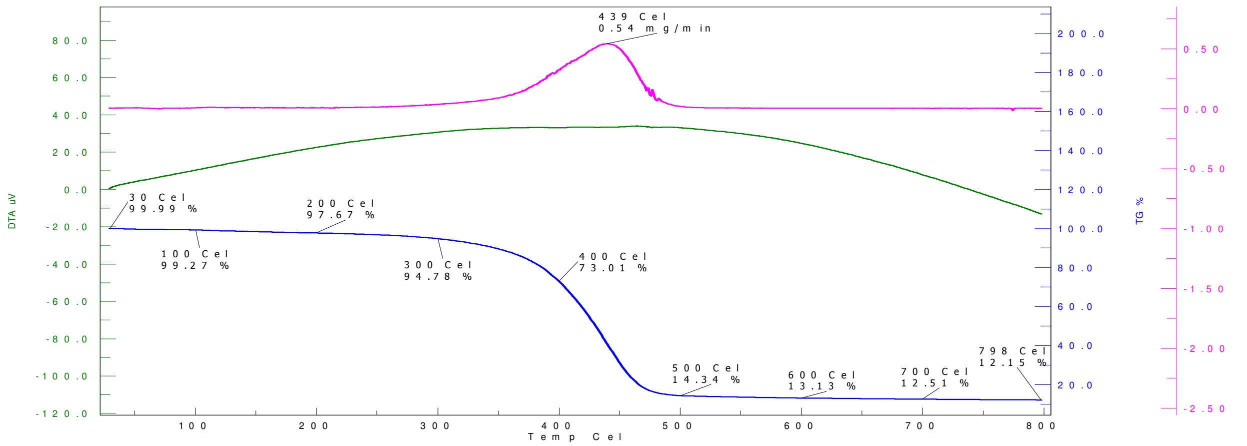

Figure-5
TG, DTG and DTA curves for e-PMB 10% at a heating rate 5^{0}C/ min in nitrogen atmosphere

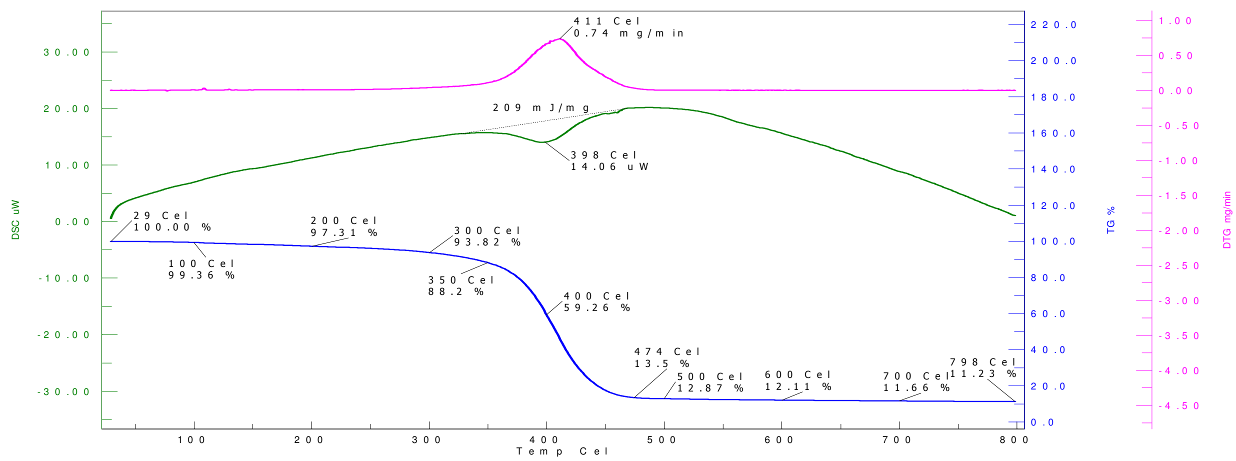

Figure-6
TG, DTG and DTA curves for e-PMB 15% at a heating rate 5^{0}C/ min in nitrogen atmosphere

Table-1
Test Data from TG, DTG and DTA thermograms of different samples at a heating rate 5^{0}C/ min in nitrogen atmosphere

e-PMB samples containing e-plastic waste	Onset of Decomposition (^{0}C)	Initial Decomposition Temperature (^{0}C)	Char yield at 798^{0}C	DTG peak maxima temperature (^{0}C)	DTA maxima (^{0}C)	Nature of DTA peak
0%	289	400	15.6	448	475	Endo
10%	283	380	12.15	439	-	-
15%	277	370	11.23	411	398	Endo

Scanning Electron Microscopic studies (SEM) of bitumen and modified bitumen (e-PMB): Base bitumen and Modified bitumen (e-PMB) containing 10% and 15% of e-plastic waste were subjected to SEM test to check the dispersion of modifier in bituminous phase. The SEM photographs are shown in figure 7-12. These photographs indicate the dispersion of e-plastic into bituminous phase. This dispersion is more prominent in case of e-PMB containing 15% e-plastic waste.

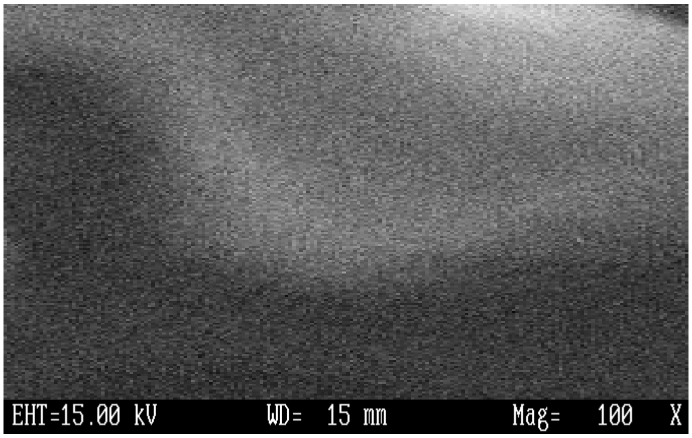

Figure-7
VG30 Plain Bitumen

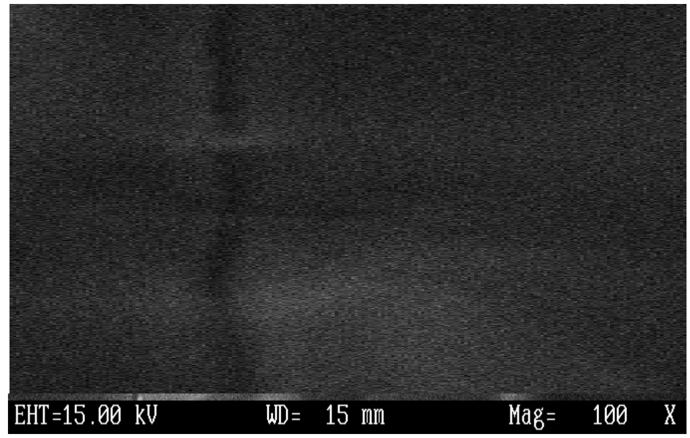

Figure-8
VG30 Plain Bitumen

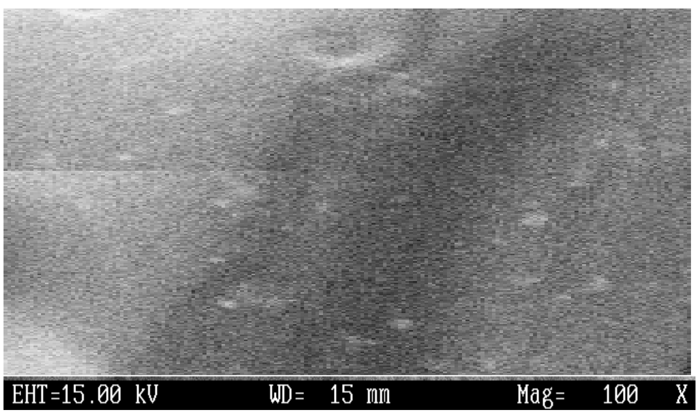

Figure-9
e-PMB binder containing 10% e-plastic modifier

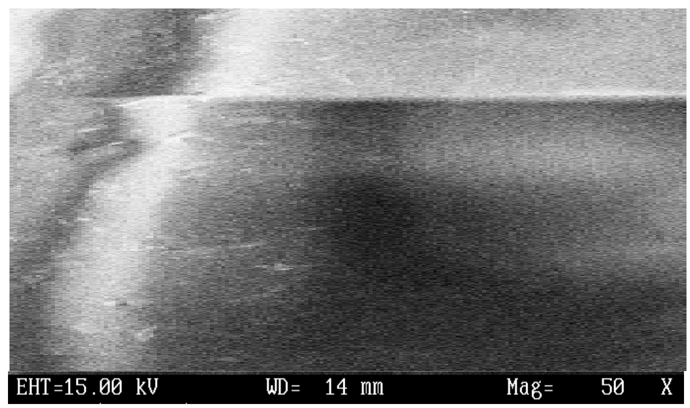

Figure-10
e-PMB binder containing 10% e-plastic modifier

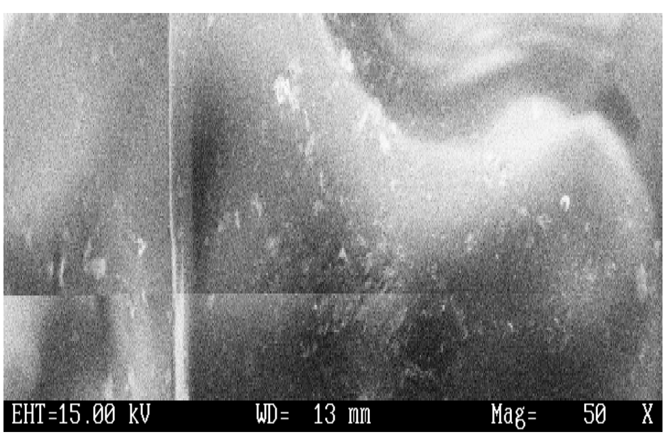

Figure-11
e-PMB binder containing 15% e-plastic modifier

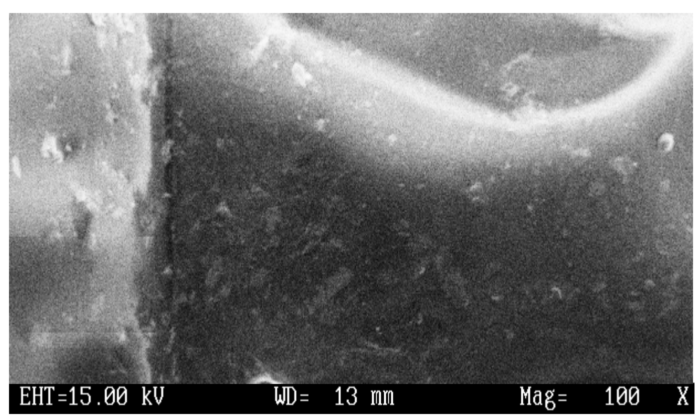

Figure-12
e-PMB binder containing 15% e-plastic modifier

Conclusion

FT-IR spectra of modified blends shows the disappearance of some peaks (which were very prominent in case of pure bitumen) and appearance of some new peaks in the modified bitumen samples (e-PMB 10% and e-PMB 15%) which indicates that structural changes occurs on addition of e-plastic waste into base bitumen. Such structural changes contribute for high performance of e-PMB.

Thermal studies show that the degradation of modified binders occurs above 300°C as there is hardly any weight loss occurs up to 300°C. It also shows that the modified binders are safe to use during construction of roads because there will be no emissions up to application temperatures. The application temperature is normally 160°C maximum at the time of production of bituminous mix.

SEM studies show that e–plastic waste disperses well in bitumen phase resulting in plastic reinforced binders. This led to structural modification in bitumen, which will improve its physical and engineering properties.

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