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FULL LENGTH ARTICLE

Thermo-mechanical properties improvement of asphalt binder by using methylmethacrylate/ethylene glycol dimethacrylate

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Abstract Various polymer-modified asphalt compositions for paving and roofing applications are known since several years ago. The degree to which a polymer improves the asphalt's properties depends on the compatibility of the polymer and the asphalt. Highly compatible polymers are more effective in providing property improvements. In this research, the influence of in situ polymerization of methylmethacrylate monomer with asphalt in presence of ethylene glycol dimethacrylate (EGDM) as a crosslinker on the rheological and thermal properties of asphalt binder of type penetration grade 60/70 was studied. To achieve this aim, MMA/EGDM(MC) in different ratios as 5, 10 and 15% (w/w) were used to modify the thermo-mechanical properties of asphalt via forming chemical bond, and the changing in mechanical and thermal properties, of the mixes as well as the storage stability were studied. Also, the morphology (SEM), thermal characterization (TGA), dynamic mechanical analysis (DMA), bending and rheological tests were detected. The obtained experimental results revealed that the addition of MC causes both the rheological and thermal properties of the binder to improve and the prepared PMAs has high temperature susceptibility and low curing time. The improvement in the properties of the virgin asphalt will be effective in using this soft type in coating applications instead of highly expensive oxidized one.

1. Introduction

Raw asphalt is an interesting material which can undergo different physical states with variation in the temperature. At room temperature and below 0 °C, asphalt is bright, rigid, and brittle. When heated above 25 °C, asphalt begins to soften (between 60 and 80 °C). However, the softening point depends on the nature and composition of the asphalt. At 120 °C, asphalt behaves like a Newtonian liquid, and finally, at 200 °C, asphalt starts decomposition, generating residues [1].

Modification of bitumen is one of the approaches to improve the asphalt performance when the asphalt produced

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Table 1 Characteristics of Virgin Asphalt.

Characteristics	AC	SP*
Physical characteristics		
• penetration (@ 25 °C, 100 g, 5 s) 0.1 mm	62	60/70
• Softening point (ring and ball) °C	50.6	45/55
• Specific gravity (@ 25 °C) using a pycnometer	1.02	NS**
• Flash and fire points (Cleveland Open Cup) °C	+250	+250
• Ductility (@ 25 °C, 5 cm/min.) cm	+150	+ 150
• Dynamic viscosity (at 60°°C) c.p	599186	NS**
• Penetration Index (P.I)	−0.51	-2: +2
Separation of polymer, (163 C°), 48 h		
Difference in softening point from top and bottom, C° (***)	1	
Chemical composition		
Maltene (wt%)	77.2	
Asphaltene (wt%)	22.8	

N.B
* Standard specification for "General Authority for Roads, Bridges and Land Transportation in Egypt". Item No 102.1.
** Not specified.
*** According to literature, maxim difference is 2.

does not meet the climatic, traffic and other applications structure requirement, as reported by Fitzegarald [2] and Kim [3]. The concept of modifying asphalt binders and mixtures is not new. In its earliest stages, asphalt modification consisted of mixing two or more asphalt binders of different grades from different sources. The problem with this technique, however, lies in the possibility that the asphalt cement will be chemically incompatible [4]. This incompatibility cannot always be effectively predicted, and it can lead to premature asphalt distresses. Today, all forms of asphalts are usually modified. The modified binders are used for a wide rang of applications [5]. Abiola [6] classifies asphalt modifiers as fillers, extenders, polymers, fibers, oxidants and antioxidants, anti-stripping agents, waste materials and hydrocarbons.

Polymer modified asphalts have better mechanical properties and higher durability than the non-modified ones. Since 30 years ago in some European countries, polymers have been added into asphalt [7].

The purpose of bitumen modification with polymers is to achieve the desired engineering properties, such as increased shear modulus and reduced plastic flow at high temperatures and/or increased resistance to thermal fracture at low temperatures.

Polarity of the polymer can enhance its solubility and compatibility with base bitumen [8]. Polar groups present in polymer molecules can react with polar constituents of bitumen. Subsequently, phase separation is prevented, which in turn enhances the material's consistency, and decreases oxidative aging [9,10]. Among polar polymers, a very limited number of studies discuss the fundamental properties of modified bitumens with acrylate polymers. Most frequently used acrylates as bitumen modifying agents in road applications are ethylene vinyl acetate (EVA) glycidyl methacrylate (GMA) terpolymer, ethylene butyl acrylate (EBA) copolymer,. . .etc. [11–13]. General Poly methacrylates are polymers of the esters of methacrylic acids. The most commonly used among them is poly (methyl methacrylate) (PMMA) which has high mechanical strength, high Young's modulus and low elongation at break. It does not shatter on rupture and it is one of the hardest thermoplastics i.e. highly scratch resistant. Also, it exhibits low moisture and water absorbing capacity, and accordingly it has good dimensional stability. Both of these characteristics increase as the temperature rises. PMMA is one of the polymers that are most resistant to direct sunshine exposure. Its strength characteristics exhibit fairly small variations under the effect of UV radiation, as well as in the presence of ozone. These properties of PMMA make it suitable for products intended for long open air operation [14,15].

The use of polymer modified asphalt in different applications has generated a lot of interests in its rheological properties, because of their importance in the manufacture and quality of bituminous applications. As a matter of fact, the development of the early colloidal model of PMA samples was based on the rheological observations. Long before that, ancient users of bitumen observed the strong effect of temperature on its consistency but due to its highly viscous character at room temperature, giving rise to a confusing and somewhat imprecise description such as pasty or semi-solid [3], bitumen rheological behavior remained hard to quantify. In the present paper, the rheological and thermal behavior of blends of bitumen with different concentrations of a PMMA/EGDMA was investigated as effective properties for asphalt to be used in coating applications. In this manner, bitumen/PMMA/EGDMA blends, in contents ranging as 5, 10 and 15 w/w, were prepared and evaluated. The rheological tests, thermal and microstructure analysis revealed that, the addition of reactive polymers, enabled to chemically interact with certain bitumen compounds, and caused some advantages in the resulting binder, regarding both improved storage stability and enhanced in-service performance.

2. Experimental

2.1. Materials used

- *Asphalt Cement*: Local virgin asphalt cement of penetration grade (AC 60/70) produced by El-Nasr Petroleum Company in Suez, Egypt.
- *Chemicals*: Methylmethacrylate MMA, ethylene glycol dimethacrylate (EGDM), Benzoyl peroxide. All the chemicals were supplied from the Fluka chemical company.