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Modeling of Tensile Creep and Recovery of Polymer Modified Asphalt Binders at Low Temperatures

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Abstract:
The creep and recovery of asphalt modified with Elvaloy 4170 and polyphosphoric acid were studied at low temperatures, by inductive phenomenological methods. Two models of the tensile compliance function were investigated. Both models were derived from the linear viscoelastic retardation spectra and successfully used for the description of the creep and recovery tests in the studied asphalt binders. Large effects due to oxidative aging in a rolling thin film oven were found from the recovered compliance function recorded in a bending beam rheometer at a temperature of - 20 °C. The studied compliance function models worked well at higher and lower temperatures in creep and recovery experiments on conventional and modified asphalt binders for both shear and tensile creep.

Key words:
Polymer modified asphalt, creep and recovery, bending beam rheometer, retardation spectra

1 INTRODUCTION

Asphalt (bitumen) was one of the earliest construction materials. Today, it is used mainly for the construction of roads and highways, although The Shell Bitumen Handbook [1] gives at least 250 ways for its use in various fields of human endeavor. Asphalt is a complicated system both chemically and rheologically. An interested reader should check two reviews on asphalt: the first one is the "Review of the uses and modeling of bitumen from ancient to modern times" [2], and the second more recent review is paper by Lesueur [3].

Conventional paving asphalt is prone to rutting at higher temperatures, fatigue, and low-temperature cracking [2]. In order to improve its engineering properties, asphalt is frequently modified by various polymers. The most successful polymer modifiers are thermoplastic elastomers, especially the styrene-butadiene-styrene (SBS) copolymer [4–8]. The most common plastomer asphalt modifiers are polyethylene and polypropylene. Generally, plastomers are incompatible with asphalt and separation of phases can occur [9]; thus, one can consider functionalized polyolefins as asphalt modifiers. These polymers are ethylene based and called reactive ethylene terpolymers (RETs). RETs also contain ester groups, such as methyl, ethyl or butyl acrylate or glycidylmethacrylate. The disadvantages of RET modifiers are their higher cost and risk of gelation [10, 11]. Considering these disadvantages, acids can also be introduced to ameliorate the engineering properties of asphalt. Because of the subtle conditions of obtaining a stable and fluidlike system of asphalt and RET it is worthwhile to test the proposed compliance model on such a system. Lately the asphalt industry was very interested in lowering the cost of asphalt modified binders by decreasing the amount of polymer modifier by substituting the polyphosphoric acid for the part of polymer. In such "three-component systems" the limiting amounts of modifiers may or may not lead to the structural changes that under temperatures close to the glass temperatures of asphalt may need the phenomenological description with various time scales.

Modification with acids consistently alters the physical properties of asphalt, and the effects are comparable to air blowing [10]. Polyphosphoric acid (PPA) is by far the most important acid introduced in asphalt technology [12]. The impact on the thermal and rheological properties of asphalts have been described by

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be noted that PMAs A2 and A3 showed similar elastic properties when not aged and even after RTFOT aging. A very small improvement in PMA A3 could be observed, which was slightly augmented in the same PAV aged samples.

5 CONCLUSIONS

The tensile compliance function of several asphalt binders was studied at low temperatures with discrete retardation spectra and stretched time continuous retardation spectra. The deformation mode was creep and recovery (complemented by the derived shear compliance from the dynamic material functions) in linear viscoelastic domain. The tensile compliance function D(t) was obtained in a BBR from the indirect tensile creep and recovery experiments at several low temperatures. The retardation spectra from both modes of deformation were compared; and, it was found that all the sets (complete and partial, shear and tensile) could be superposed well on the interval of all retardation times. When the shear and tensile compliance functions were compared, a small difference in their values was observed. This can point to the existence of bulk compliance, i.e. Poisson's ratio different from values close to 0.5 [7]. Both the classic linear viscoelastic model and the model based on the stretched time retardation spectrum for the tensile compliance function worked well for all the tested binders (aged and not aged) at low temperatures) however, the stretched time, gamma distribution model contained less than half of the number of adjustable parameters than the classic linear viscoelastic model. From the observations obtained in this study one should not disqualify binders modified by RET and PPA from the performance competition at higher temperatures. It was shown that these materials are stiff enough at low temperatures (see Figures 1 and 2) and may show less deformation after longer aging. Such hypothesis will be discussed elsewhere. For an enthusiastic reader we would like to mention the recently released publication which discusses the guidelines for the use of PPA for the hot mix paving applications [37].

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