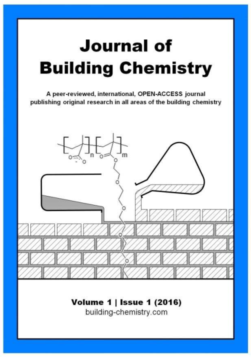

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Modification of asphalt binders by polyethylene-type polymers

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Abstract

This investigation tested the effects of asphalt binder modification, using polyethylene-type polymers. During the research, five different polymers were used: HDPE, LDPE, LLDPE, copolymer EBA (ethylene/butyl acrylate) and terpolymer EBM (ethylene/butyl acrylate/maleic anhydride). Those polyethylene-type polymers were used to in-lab modification of 50/70 raw unmodified road bitumen. Modified specimens were tested in terms of penetration, softening temperature and elastic recovery. Samples were aged using the Rolling Thin Film Oven Test procedure. The gathered data suggest that addition of polyethylene-type polymers to the asphalt binders reduces penetration, and increases softening temperature. In terms of elastic recovery only terpolymer EBM presented significant improvement, reaching a 75% relative elastic recovery.

Keywords: Bitumen; asphalt modification; polyethylene; polymers

1. Introduction

With the increasing amount of freight transported by roads, the latter are put under higher loading conditions. To counteract that, engineers have to design materials with greater mechanical properties that would enable construction of sustainable, safe, economical and long-lasting roads. Bitumen binder modification improving technical properties of binder and those of asphalt mixture, has been in used for quite a long time, however it was mostly limited to the usage of elastomers and SBS (styrene-butadiene-styrene) (Gaweł et al. 2001; (Sarnowski 2015). When selecting proper material and technological solution in asphalt materials for sustainable road construction, various factors should be taken into account, including, environmental impact, durability and costs (Król 2014; Kowalski et al. 2015; Brzeziński and Kraiński 2016).

Application of polymers has been extensively researched all around the globe, in various industries (Plastics – the Facts 2012) including cement concrete (Wiliński et al. 2016) and road materials (Giavarini et al. 1996; Becker et al. 2001; Yousefi 2003; Polacco et al. 2005; Awwad and Shbeed 2007; Firoozifar et al. 2010). Presented papers tend to vary significantly in terms of obtained results as well as the research methodology. Based on the referred publications, common denominators for all modifications have been identified.

Most researches used polyethylenes in a 5% concentration, and achieved uniform dispersion of the polymer in the bitumen using high-shear mixes, typically running at 4000 RPM. Furthermore, the temperature at which the modification has been conducted revolved around 180°C. Additionally some of the researchers used a

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combination of additives such as polyethylenes, alongside SBS (Firoozifar et al. 2010) and polyphosphoric acid $(HPO_3)_n$ (Giavarini et al. 1996).

2. Materials and methods

The aim of this research was to determine, whether polyethylene-type polymers may be used as additives in asphalt bitumen modification. All of the tested modifications were based on the 50/70 neat road bitumen (penetration of this bitumen is between 5 and 7 mm at 25°C). Each additive was added to the bitumen, in an amount corresponding to a 5% concentration by mas in the final blend. Additives marked by sample number: 2, 3 and 4 were obtained from a plastic container manufacturer in a form of raw plastic pellets, whereas additives marked as sample 5 and 6 were commercially available off the shelf products:

- Sample 2: High Density Polyethylene (HDPE),
- Sample 3: Low Density Polyethylene (LDPE),
- Sample 4: Linear Low Density Polyethylene (LLDPE),
- Sample 5: blend of 37,5% bitumen + 62,5% copolymer EBA (ethylene/butyl acrylate),
- Sample 6: blend of 37,5% bitumen + 62,5% terpolymer EBM (ethylene/butyl acrylate/maleic anhydride).

After the modification process, samples were prepared and tested for penetration, softening temperature and elastic recovery. Moreover, both penetration and softening temperature tests have been repeated after binder aging using the Rolling Thin Film Oven Test (RTFOT) according to the EN 12607-1 standard.

2.1. Sample preparation

In order to correctly compare data, all of the test samples were modified using the same procedure. The modification has been conducted using a small scale laboratory setup (Fig. 1).

The setup consisted of a small stainless steel vessel, a heating plate, thermocouple probe, and a high-shear mixer running at 4000 RPM (Revolutions Per Minute). The modification process was conducted for 3 hours at the temperature of 180°C.

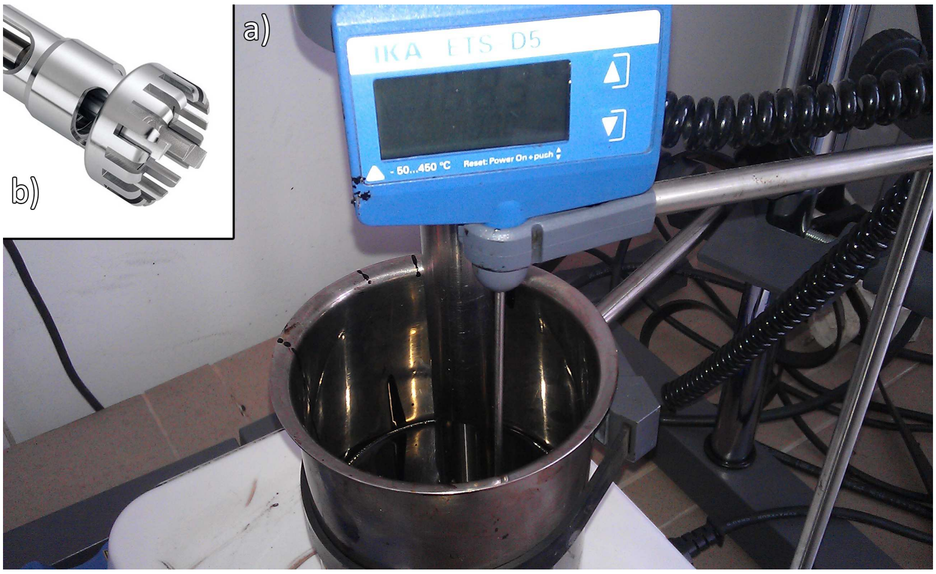

Fig. 1. a) Bitumen modification setup; b) High-shear mixing head.

2.2. Penetration

Penetration test lays at the foundation of the bitumen binder classification system followed in Europe. Tests were performed according to the EN 1426 standard. The principle behind the test is straightforward: a stainless steel needle under constant loading of one hundred grams is pressed into an asphalt bitumen sample for 5 seconds. Test takes place in a water bath at 25°C. At the end, the depth of the needle penetrated into the asphalt bitumen sample is measured. Each tenth of a millimeter stands for one penetration point. Obtained test results are presented in Fig. 2.

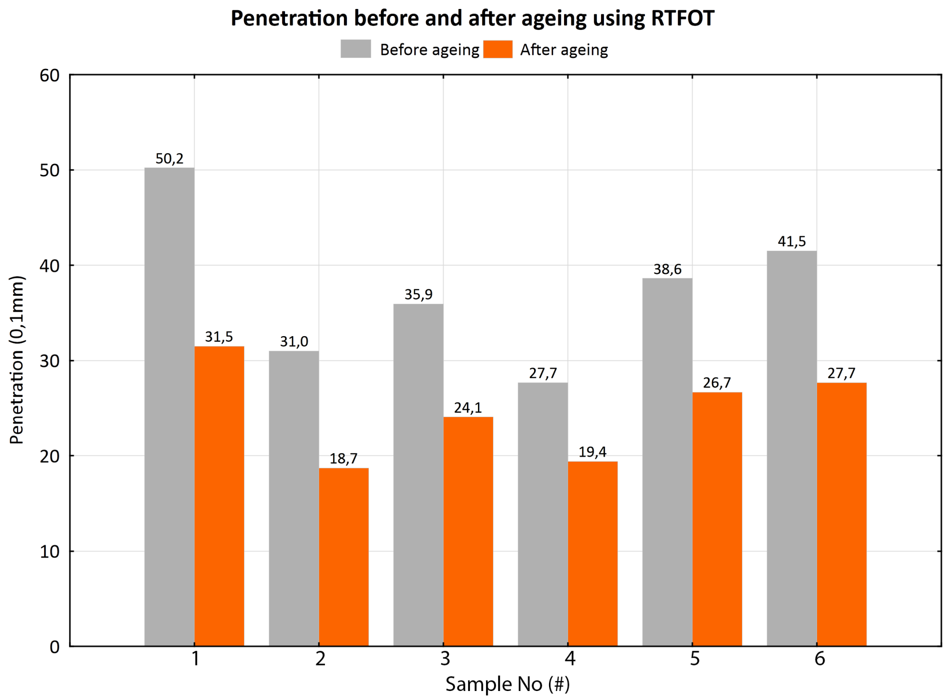

Fig. 2. Penetration before and after gaining using RTFOT.

2.3. *Softening temperature*

The softening temperature of asphalt bitumen is measured according to the EN 1427 standard. Two specially machined brass rings which were previously filled with asphalt binder mix designated for testing are chilled to the temperature of 5°C. During test samples embedded in the brass rings are heated via the heating agent until the bitumen with stainless steel balls placed on the bitumen samples touched the bottom of the holding jig or cross a light beam in case of automated equipment. At this point the temperature of the heating medium is noted separately for each asphalt bitumen specimen. The required distance between the lower surface of the brass rings and the trigger point equals 25 mm. Obtained test results are shown in Fig. 3.

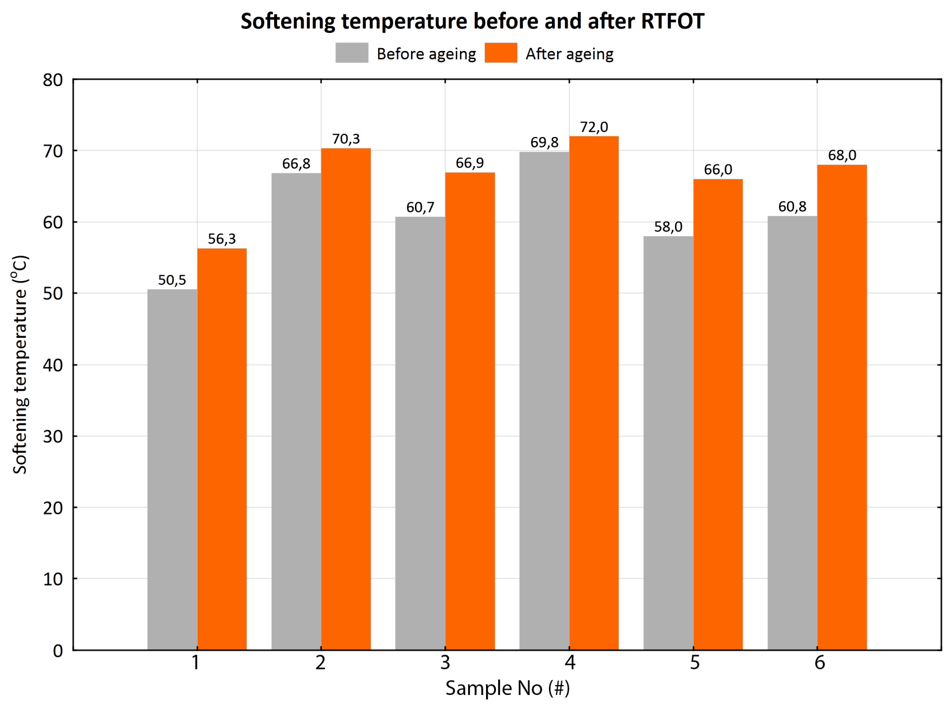

Fig 3. Softening temperature before and after gaining using RTFOT.

Based on the presented data, it can observe that in case of all modified asphalt binders the addition of polyethylenes, polyethylene copolymer and terpolymer respectively caused an increase in the softening temperature as compared to the baseline result obtained for the 50/70 raw unmodified asphalt binder. The highest softening temperature has been observed for the sample with Linear Low Density Polyethylene. The highest increase in terms of softening temperature was measured for the Linear Low Density Polyethylene, which was followed by the High Density Polyethylene.

2.4. Elastic recovery

Elastic recovery is a measurement, of the binder's ability to recover to its initial dimension, after extensive deformation. The test was conducted according to the EN 13398 standard. During the Elastic Recovery Test specially molded specimens of asphalt binders are placed in a water bath at 25°C. The samples are mounted to two mounting blocks, one of them is stationary while the second one can move along the water bath with a constant speed. The rate at which the moving block travels is equal to 5 cm/min. The samples are stretched until they reach 20 cm of elongation. At this point the elongated specimens are cut in the middle and left undisturbed for 30 minutes. After that time, the distance between the specimens' ends is measured, with the resolution of 1mm. Obtained elastic recovery results are shown in Fig. 4.

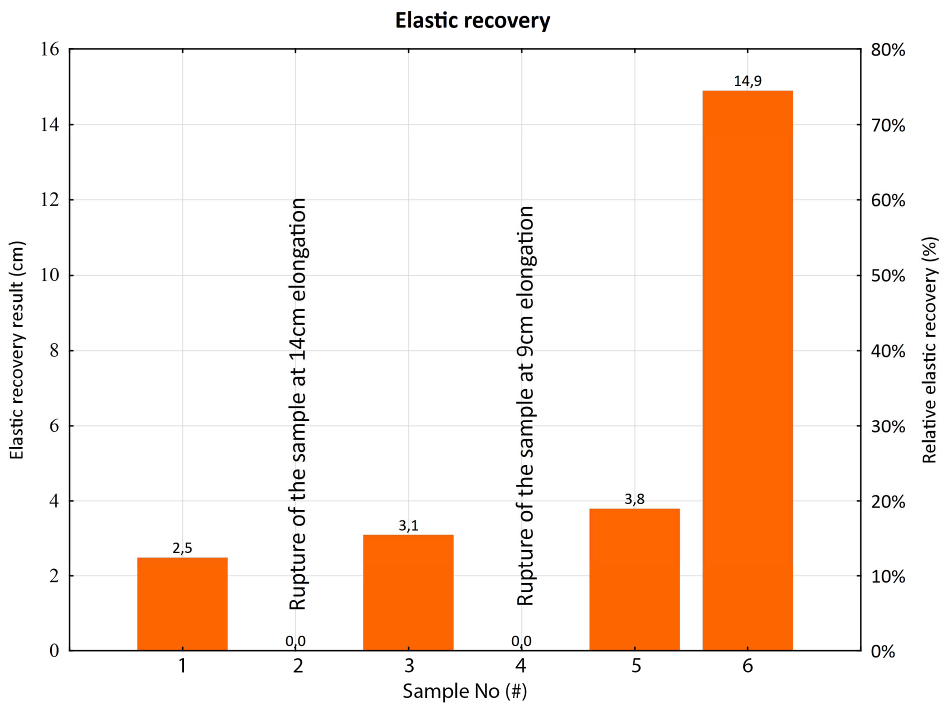

Fig. 4. Elastic recovery (initial elongation 20cm).

Two of the tested samples failed to achieve the required initial elongation of 20 cm and as such failed the test. From all the tested samples only the one modified using a terpolymer EBM showed high elastic recovery properties, other samples either failed to complete the test or scored slightly better than the baseline 50/70 asphalt.

3. Conclusions

The gathered data strongly suggests that addition of polyethylene-type polymers to the bitumens has an effect on the latter's visco-elastic properties. For all of the tested samples a significant drop in the penetration has been observed. Additionally, modification of bitumen binders with polyethylene-type polymers increases their softening temperature in the Ring and Ball method. As expected, addition of polyethylenes of varying density has not impacted the elastic recovery properties. Moreover, the addition of copolymer EBA had little effect on the latter. Surprisingly, terpolymer EBM presented very good results in terms elastic recovery.

In general, modification positively influenced binder property. In addition, ecological aspects of combining polyethylenes into the asphalt binder should also be highlighted.

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