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Influence of Polyethylene Glycol as a Functional Modifier on the Performance of Asphalt Binder

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Abstract

This study examined the effects of adding polyethylene glycol (PEG) on the conventional properties and temperature susceptibility of Iraqi asphalt binder. The asphalt binder, a 40/50 penetration grade obtained from a local site, was modified by adding PEG at various amounts (1, 3, 5, and 7 wt%) through mechanical blending at a controlled temperature. Conventional binder characterization (penetration, softening point, and ductility) was carried out to compare the properties of the neat and modified bitumens, as the penetration index (PI) was calculated to assess the temperature susceptibility. It was found that as the amount of PEG in the blend increased, the softening point decreased from 54 to 45 C gradually, the penetration increased from 60 to 78 (0.1 mm), while the ductility decreased from 150 to 103 cm, which is an indication that the deformation characteristics of the soft-head asphalt binder were altered by PEG addition. The penetration index also decreased from +0.20 to −1.51, implying that temperature susceptibility increased as the PEG level increased. The most balanced conventional properties were found in the modified binder with 3 wt, ductility of 132 cm and PI of −0.42. Based on the results discussed in this paper, moderate PEG addition may be a promising option for altering the consistency and flexibility of Iraqi asphalt binder, but high PEG content may adversely affect resistance to temperature variations. Further rheological and aging studies are needed to verify its practical suitability for pavement applications.

Keywords. *Polyethylene glycol PEG; Asphalt modification; Rheological properties; polymer-modified; asphalt binder; Iraqi asphalt binder.*

Introduction

Asphalt is one of the most widely utilized materials in pavement construction owing to its excellent adhesion, water resistance, and viscoelastic features. However, the performance of unmodified asphalt binders is highly sensitive to temperature and applied loading conditions. For bitumen binders, excessive softening at high temperatures reduces stiffness and increases vulnerability to permanent deformation [1, 2]. At low temperatures, the asphalt binder tends to be more brittle and more prone to thermal cracking [3, 4]. Additionally, the asphalt binder's mechanical and rheological properties are negatively affected with time due to traffic loading and atmospheric aging [3], which contribute to premature pavement deterioration and shorter service life. Therefore, the addition of polymers, nanomaterials and other functional additives into asphalt binders has attracted a lot of research interest as a promising approach to improve pavement performance and durability [5]. Polymer modification is a promising way of modification that can affect the viscoelastic behavior, microstructural characteristics and temperature sensitivity of asphalt binders [6]. Nevertheless, the performance of polymer-based modifiers is largely governed by several factors, including their chemical composition, molecular weight, dosage, dispersion characteristics, and compatibility with the various constituents of the asphalt matrix [7, 8]. The degree of interaction and compatibility between the polymer and asphalt

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phases plays a crucial role in governing the storage stability, resistance to permanent deformation at elevated temperatures, flexibility under low-temperature conditions, and long-term durability of the modified asphalt binder [9]. Thus, identifying a suitable polymer modifier is a key factor in designing and producing asphalt binders with enhanced performance characteristics and improved long-term durability [10] .

Several polymer-based additives are available, but polyethylene glycol (PEG) has been proposed and investigated as a modifier for asphalt binders based on its special molecular structure, high polarity, and characteristic thermal properties, as well as the possible interactions between PEG and components of asphalt binders [11, 12]. Being a repetitive structure of ethylene oxide units, commercially available in a range of molecular weights for the purpose of tuning the corresponding physicochemical and thermal characteristics in the given application, the addition of such additives may influence the phase morphology and the rheological properties of asphalt binders [13, 14]. Also, its specific melting and crystallization processes may contribute to the regulation of the thermal response and temperature-dependent performance of asphalt materials [12].

Previous studies on the use of PEG to modify the physicochemical and mechanical properties of asphalt binders have indicated that PEG can be used to effectively modify the properties of asphalt binders [13, 20]. Xia and colleagues investigated the modification of bitumen with polyethylene and PEG of different molecular weights and found that the molecular weight of PEG had a significant effect on the crystallization characteristics and rheological stability, as well as the mechanical performance of the resulting modified binders [15]. Incorporation of PEG into the asphalt binder was found to result in significant modification of the traditional physical characteristics of asphalt binders [16]. In addition, Naeem et al. found that the inclusion of PEG into 60/70 penetration-grade bitumen had an effect on the stiffness of the resulting binder, demonstrated by an increase in the softening point and a progressive decrease in both penetration and ductility values as the PEG content increased. The implication of this finding is improved resistance to permanent deformation at high-temperature conditions, but in addition, it has been found that too high PEG concentrations may result in poor ductility and flexibility of the modified asphalt binder. Hence the importance of optimizing the PEG content to achieve a suitable balance between good resistance to deformation at high temperatures and adequate flexibility at low-temperature conditions [11]. Another area of attention for the use of PEG has been its addition into phase-change materials (PCMs) to improve the thermal regulate potential of asphalt binders in pavement applications [17, 18]. This is due to the good phase-transition properties of PEG and its ability to absorb and release the thermal energy generated during its melting and crystallization processes. The main concerns in directly incorporating PEG within the asphalt binder are possible leakage of the polymer or phase incompatibility and unwanted changes in the mechanical properties of the resulting modified binder [19]. However, the experimental findings have shown that the interactions of PEG with the bitumen are complex and that the incorporation of PEG may result in a modification of the rheological response and mechanical performance of the corresponding asphalt mixtures [18, 19]. A important question to raise here is the influence of the PEG on the internal morphology and network structure of the modified binder [16]. The incorporation of PEG in a bitumen/polyethylene/PEG system can have an effect on, not only the evolution and distribution [11], but also the stability of the polymer-rich network. Moreover, studies indicated that the addition of PEG improved the rheological stability of PE/PEG-modified bitumen. The reason for this effect is its influence on the formation and evolution of the phase-separated microstructure. This indicates that PEG can have an influence on the formation and evolution of the multiphase microstructure, thus playing a role that is more than just that of a conventional plasticizing agent.

The objective of this work is to investigate the potential of using polyethylene glycol (PEG) as a polymeric modifier for an Iraqi 60/70 penetration grade asphalt binder. In this respect, the effect of PEG concentration on the conventional binder properties like penetration, softening point, ductility and penetration index (PI) has been investigated to examine the effect of this modifier on the binder consistency, flexibility and temperature susceptibility. In addition,

the optimal PEG concentration offering a proper trade-off of physical properties was determined and the feasibility of using that modifier for pavement applications is estimated.

The most innovative aspect is that Iraqi 60/70 penetration-grade asphalt binder was modified for the first time using PEG and the concentration-effect relationship of PEG about the traditional binder properties was determined. The successful formulation of 3 wt% PEG opens new possibilities for the development and more thorough investigation of the PEG-modified asphalt materials for pavement applications.

Methodology

Materials.

The neat asphalt binder employed throughout this study was a 60/80 penetration-grade bitumen, commonly used in pavement construction, particularly in surface and binder courses. The asphalt binder was supplied by the Al-Doura Refinery, Baghdad, Iraq. PEG-6000 was provided by Sigma-Aldrich.

Instruments used.

The instruments used for the characterization and preparation of the asphalt samples included an STLZ-1 Double-Digit Display Asphalt Penetration Apparatus for determining the penetration grade of the asphalt binder and an STYD-2 Digital Asphalt Ductilometer for measuring the ductility of the asphalt samples. The chemical functional groups and structural changes of the polyethylene glycol (PEG)additive to asphalt binders was investigated using a Shimadzu Fourier-transform infrared (FTIR) spectrometer. The asphalt and PEG were homogenized using a Heidolph overhead mechanical stirrer to ensure uniform dispersion of the modifier throughout the asphalt matrix.

Experimental section

Samples Preparation.

Preparation of the samples was performed according to previous procedure described by [11, 16]. To investigate the effects of PEG on the performance of the neat asphalt binder, a unmodified Iraqi asphalt binder with a penetration grade of 60/70 was initially heated to 180 °C using a 1.0 L stainless-steel mixing vessel equipped with a mechanical stirrer then the mixture was subjected to vigorous mechanical stirring. PEG was subsequently added slowly at different concentration (1, 3, 5, 7 wt%) to the asphalt binder and continuously mixed at 180 °C for 2 h to promote uniform dispersion and interaction with the asphalt matrix. Upon completion of the modification process, the PEG-modified asphalt binders were transferred into small aluminum containers, covered with aluminum foil to minimize contamination and exposure during storage, and subsequently stored at ambient conditions prior to characterization by conventional binder tests.

Rheological tests of unmodified and modified asphalt.

The results below present an assessment of the rheological properties of the PEG-modified asphalt binders, with the aim of analyzing the effects of polymer incorporation on binder consistency, deformation behavior and temperature susceptibility. A characterization of the unmodified asphalt binder under identical test conditions was carried out for comparison. A ring-and-ball softening point test, a penetration test, and a ductility test, as specified by ASTM D36, ASTM D5, and ASTM D113-86, respectively, were conducted to experimentally measure the effects of polymer addition on the physical and temperature-dependent properties of the modified binders [21] [22] [23]. The corresponding experimental results are summarized in Table 4. From these experimental data the so-called penetration

index (PI), used as an indicator of the temperature susceptibility of each binder formulation was computed applying the following equation:

$$\left[\mathrm{PI} = \frac{1952 - 500\ log\ pen - 20\ softening\ point}{50 \log pen - softening\ point - 120}\right]$$

Pen represents the penetration value of the asphalt binder tested at 25 C; SP stands for softening point temperature (C). The penetration index (PI) is an empirical measure of the binder's temperature susceptibility. A relatively small PI indicates a relatively high level of temperature susceptibility; a relatively high PI indicates relatively smaller temperature susceptibility [24].

Results and discussion.

FTIR characterization is therefore an essential step in identifying the polyethylene glycol (PEG) compound to ensure the desired chemical purity, molecular consistency, and functional group integrity of the polymer before combining it with the asphalt binder. Characterizing the PEG baseline structure (i.e., terminal hydroxyl (OH) groups and ether (C-O-C) linkages) is also necessary to avoid phase separation, unforeseen reaction kinetics, or oxidation aging of the binder. An FTIR screening of the PEG is therefore essential to ensure that no impurities or degradation products are present to achieve reproducible rheological performance and thermal stability of the end-modified binder matrix. The Fourier-Transform Infrared (FTIR) spectrum of the polyethylene glycol (PEG) sample (Figure 1) displays key absorption bands characteristic of its polyether backbone structure. A broad hydroxyl (-OH) stretching vibration band is visible in the 3500-3300 cm^{-1}. region, corresponding to the terminal alcohol groups involved in hydrogen bonding. distinct bands at 2881 $cm^{-1}$and 2862 cm^{-1} correspond to the asymmetric and symmetric (C-H) stretching vibrations of the aliphatic methylene (-CH_2-) groups. The weak absorption feature at 2360 cm^{-1} is attributed to ambient atmospheric CO_2 interference commonly present during measurements. In the fingerprint region, the bending/scissoring vibration of the (-CH_2-) groups appears prominently at 1465 cm^{-1} alongside CH_2 wagging and twisting vibrations observed at 1340 cm^{-1}, 1278 cm^{-1}, and 1240 cm^{-1}. The characteristic signature of PEG is confirmed by the strong, sharp ether linkages C-O-C stretching vibration band centered around 1060 cm^{-1} with an adjacent shoulder/peak at 1145 cm^{-1}. Finally, the absorption bands at 960 $cm^{-1}$and 840 cm^{-1} are assigned to CH_2 rocking vibrations, together providing conclusive spectral evidence consistent with the structure of polyethylene glycol. These findings are consistent with previous studies [25, 26]

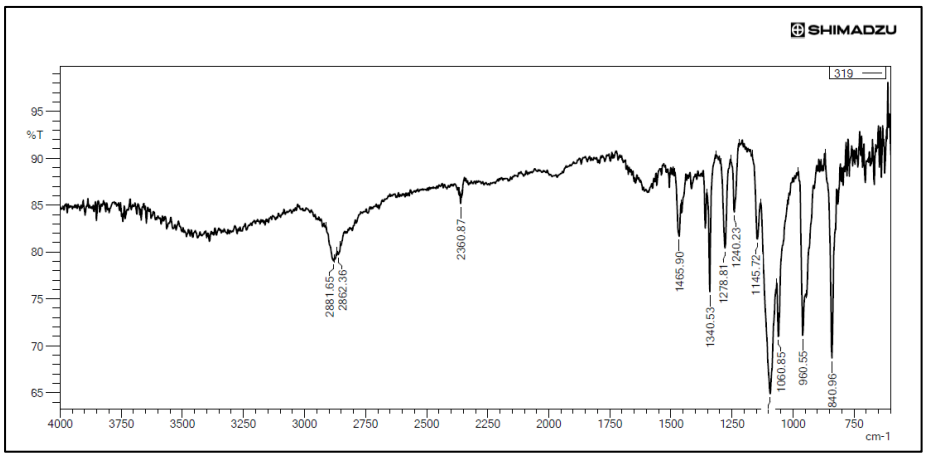


Figure 1. FTIR spectrum of pure PEG.

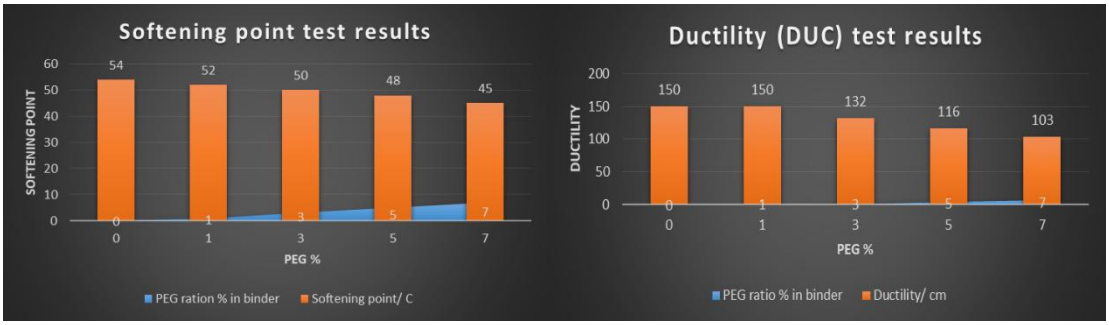
Regarding the processing conditions for polymer incorporation into the asphalt matrix, a mixing temperature of 180 °C was selected as a compromise between achieving adequate fluidity of the 60/70 penetration-grade asphalt and promoting effective dispersion and interaction of PEG within the asphalt matrix. At lower temperatures, the relatively high viscosity of the asphalt binder can restrict polymer incorporation and result in incomplete or non-uniform dispersion. Studies on polymer-modified asphalt show that about 180 °C can provide more homogeneous polymer distribution than lower temperatures, and polymer-modified binders are usually prepared at 170-200 °C [27]. However, excessively high temperatures may accelerate thermal and oxidative aging of the asphalt binder and reduce the stability of polymer-modified systems [28]. Therefore, 180 °C was chosen as a suitable processing temperature, ensuring binder fluidity and polymer dispersion without excessive thermal degradation when PEG modification is applied; the modification lasted 2 h and was followed by 120 minutes of modification.

Table 1 compares the rheological properties of the untreated binder and the PEG-modified asphalt mixtures. Adding polyethylene glycol (PEG) changed the softening point, ductility, penetration, and penetration index (PI), indicating that PEG significantly reduces temperature susceptibility and improves the consistency of the asphalt binder.

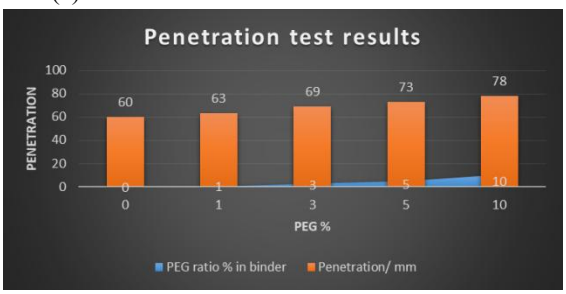
Table 1. Comparative evaluation of conventional properties of PEG-Modified and Unmodified Asphalt Binders.

PEG %	0%	1%	3%	5%	7%
Softening point (SP) °C	54	52	50	48	45
Ductility at 15 °C (cm)	150	150	132	116	103
Penetration at 25 °C (0.1 mm)	60	63	69	73	78
Penetration Index (PI)	0.20	- 0.15	- 0.42	- 0.81	- 1.51

The unmodified asphalt binder (0% PEG) showed a softening point of 54 C, penetration of 60 x 0.1 mm and ductility of 150 cm at 25 C, 15 C and at 15 C; and hence is typical of a medium-hard 60/70-type paving binder (Figure 2a, b and c). The softening point was observed to gradually decrease (for the standard binder) to 52, 50, 48 and 45 C for 1%, 3%, 5% and 7% PEG respectively. Increasing the PEG concentration gradually decreases the temperature at which the binder undergoes noticeable softening. This implies that PEG can reduce the intermolecular interactions in the asphalt matrix and improve mobility of the binder constituents. This reduction in the softening point tends to be more pronounced at higher PEG concentrations, as this appears to further enhance the plasticizing effect of PEG. The lowest softening point (45 C) was found in the sample modified with 7% PEG as it is 9 C less than that for the neat binder. The softening behaviour is mirrored by penetration. The penetration also increases with increasing PEG concentrations, from 60 * 0.1 mm for the neat asphalt binder to 63, 69, 73, and 78 * 0.1 mm for 1%, 3%, 5%, and 7% PEG, respectively. This reflects the decreasing consistency and increasing deformation capacity of the binder at 25 C. The increase of about 30% in penetration observed at 7% PEG compared to neat binder is evidence that the effect of PEG on the asphalt is to make it less hard and more temperature-responsive.



(a) (b)



(c)

Figure 2. Effect of PEG contents on the rheological properties of asphalt, softening point (a), ductility (b), penetration (c).

The ductility results provide further evidence of the effect of PEG on binder behavior. The unmodified binder exhibited a ductility of 150 cm, and the addition of 1% PEG did not produce a measurable change, with the ductility remaining at 150 cm. However, a progressive decrease was observed at higher PEG concentrations, reaching 132, 116, and 103 cm for 3, 5, and 7% PEG, respectively. Despite this reduction, all investigated PEG-modified binders retained relatively high ductility, with the 7% PEG sample maintaining a ductility of 103 cm. The decrease in ductility at higher PEG concentrations may be associated with changes in the balance between the viscoelastic and plastic components of the asphalt matrix and possible interactions between PEG and the polar constituents of the binder.
The PI of the binder varied with PEG addition as follows: +0.20, −0.15, −0.42, −0.81, and −1.51 for the control and 1, 3, 5, and 7% PEG binders, respectively. The more negative the PI (i.e., the more temperature sensitive), the more the binder's consistency varies with temperature. This is in line with the decrease in softening point and the corresponding increase in penetration seen in previous results. The dramatic drop in PI at 7% PEG suggests that the maximum PEG level causes the most extensive change in the binder's rheological behavior as a function of temperature.

Taking an overall perspective with regard to the conventional binder measurements, the unmodified asphalt is gradually converted by the PEG addition from a fairly rigid binder to a more ductile, soft, and less high-temperature resistant, temperature-sensitive material. The 1% PEG-asphalt produced a relatively minor modification; the changes becoming more pronounced from 3% to 7% PEG. In other words, the 7% PEG binder had the maximum penetration (78*0.1 mm), minimum softening point (45 C), the minimum PI (−1.51), and a ductility of 103 cm. So PEG addition is a technique of binder softness and penetration improvement, but over-addition may lead to less high-temperature resistance and to worse temperature susceptibility of the binder. Therefore, from a conventional binder-property perspective, PEG concentrations from 3% to 5% can be said to produce better balanced modifications than the 7%, but the optimum PEG concentration of the binder for practical asphalt road application should be determined together with the viscosity, rheological properties (DSR), storage-stability and thermal susceptibility tests. However, with a good balance between flexibility, ductility, consistency and thermal susceptibility, 3% PEG was found to be the most

effective formulation at improving the overall binder; but to finally say 3% PEG was the optimum PEG binder for asphalt pavement application, this needs to be confirmed with rheological measurements (e.g. rotational viscosity) or with aging tests.

Conclusion

The addition of polyethylene glycol (PEG) had a great effect on the conventional physical properties of the Iraqi asphalt binder. The properties were found to exhibit concentration-dependent modification effects. Increasing PEG percentage decreased softening point and ductility, while penetration and temperature susceptibility increased. The 3 wt% PEG formulation provided the best compromise between consistency, flexibility, ductility and softening point. A high PEG concentration caused excessive binder softening, which could negatively affect deformation resistance at high temperatures. These results indicate PEG can be a promising additive for modifying asphalt binder properties if used at an appropriate concentration. More studies on the aging and rheological properties of the modified binder are recommended to ensure its long-term performance in pavement applications.

Conflicts of Interest

The author declare no conflict of interest.

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References

1. *Characterizing Temperature Susceptibility of Asphalt Binders Using Activation Energy for Flow*, in *T&DI Congress 2011*. p. 493-503.
2. Joumblat, R., et al., *State-of-the-Art Review on Permanent Deformation Characterization of Asphalt Concrete Pavements.* Sustainability, 2023. **15**(2): p. 1166.
3. Camargo, I.G.d.N., et al., *Effect of Thermal and Oxidative Aging on Asphalt Binders Rheology and Chemical Composition.* Materials, 2020. **13**(19): p. 4438.
4. Qabur, A., H. Baaj, and M. El-Hakim, *Exploring the low-temperature performance of MPP-modified asphalt binders and mixtures using wet method.* Canadian Journal of Civil Engineering, 2024. **51**(5): p. 489-507.
5. Huang, H., et al., *Nanomaterials for Modified Asphalt and Their Effects on Viscosity Characteristics: A Comprehensive Review.* Nanomaterials, 2024. **14**(18): p. 1503.
6. Uddin, W., *Viscoelastic Characterization of Polymer-Modified Asphalt Binders of Pavement Applications.* Applied Rheology, 2003. **13**(4): p. 191-199.
7. Jin, Y., et al., *Microscopic Properties of Asphalt and Polyethylene at an Extraordinary High Dosage through Molecular Dynamics Simulation.* Buildings, 2024. **14**(1): p. 164.
8. Rohayzi, N.F., et al., *Potential Additives in Natural Rubber-Modified Bitumen: A Review.* Polymers, 2023. **15**(8): p. 1951.
9. Emtiaz, M., et al., *A Comprehensive Literature Review on Polymer-Modified Asphalt Binder.* CivilEng, 2023. **4**(3): p. 901-932.
10. Mashaan, N.S. and C. Dassanayake, *Rutting and Aging Properties of Recycled Polymer Modified Pavement Materials*, in *Preprints*. 2025, Preprints.
11. Wang, H., et al., *Effects of Polyethylene Glycol/Porous Silica Form-Stabilized Phase Change Materials on the Performance of Asphalt Binders.* Materials, 2023. **16**(15): p. 5293.
12. Huang, Z., et al., *Preparation and Experimental Study of Phase Change Materials for Asphalt Pavement.* Materials, 2023. **16**(17): p. 6002.

13. Shi, K., et al., *Development on the Rheological Properties and Micromorphology of Active Reagent-Rejuvenated SBS-Modified Asphalt.* ACS Sustainable Chemistry & Engineering, 2022. **10**(50): p. 16734-16751.
14. Zeiada, W., et al., *Rheological properties of plastic-modified asphalt binders using diverse plastic wastes for enhanced pavement performance in the UAE.* Construction and Building Materials, 2024. **452**: p. 138922.
15. Xia, T., et al., *Properties of bitumen modified by polyethylene and polyethylene glycol with different molecular weights.* International Journal of Pavement Engineering, 2022. **23**(11): p. 3941-3948.
16. Naeem, J., et al., *"Modification of bitumen properties using polyethylene glycol and titanium dioxide (TiO2)".* Polymers and Polymer Composites, 2023. **31**: p. 09673911231171485.
17. Chen, Y., et al., *Application of phase change material in asphalt mixture – A review.* Construction and Building Materials, 2020. **263**: p. 120219.
18. Guo, M., et al., *The State of the Art on Phase Change Material-Modified Asphalt Pavement.* Sustainability, 2024. **16**(20): p. 8796.
19. Zhao, H., et al., *Effect of Solid-Solid Phase Change Material's Direct Interaction on Physical and Rheological Properties of Asphalt.* Coatings, 2022. **12**(5): p. 625.
20. Saberi K, F., Y.D. Wang, and J. Liu, *Improving rheological and thermal performance of Gilsonite-Modified binder with phase change materials.* Construction and Building Materials, 2023. **399**: p. 132557.
21. Standard, A., *Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus).* ASTM, West Conshohocken, PA, 2006.
22. ASTM, D., *Standard test method for penetration of bituminous materials.* USA, ASTM International, 2013.
23. ASTM. *Standard test method for ductility of bituminous materials*. 2007. ASTM West Conshohocken, PA, USA.
24. Yan, K., et al., *Laboratory investigation of waste tire rubber and amorphous poly alpha olefin modified asphalt.* Construction and Building Materials, 2016. **129**: p. 256-265.
25. Vrandečić, N.S., et al., *Kinetic analysis of thermal degradation of poly(ethylene glycol) and poly(ethylene oxide)s of different molecular weight.* Thermochimica Acta, 2010. **498**(1): p. 71-80.
26. Xiao, J., et al., *Co-delivery of paclitaxel and CXCL1 shRNA via cationic polymeric micelles for synergistic therapy against ovarian cancer.* Polymer International, 2022. **71**(10): p. 1220-1229.
27. Johnston, J.B. and G. King, *Using Polymer Modified Asphalt Emulsions in Surface Treatments A Federal Lands Highway Interim Report.* Federal Highway Administration, New Jersey Avenue, Washington DC, USA, 2008.
28. Buncher, M., et al., *Asphalt Paving Handbook [2025 Edition Updated With Video Links].* 2025.