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Experimental Study of Aging and Dissolution of Crumb Rubber

Arun Kumar[a,b]
Dr P S Charpe[a]
[a]Department of Civil Engineering, Kalinga University, Raipur
[b]Galgotia College of Engineering & Technology, Gr. Noida

Abstract:- The asphalt binder goes through a considerable ageing process, which is often referred to as short-term ageing, during the compaction and mixing phase of the building of a flexible pavement. Asphalt binder goes through a series of chemical and physical changes during this time period, which causes it to harden and causes asphalt surfaces to collapse ahead of schedule. The ageing has on the micro-phases that make up asphalt binder. This means that over time, the different components of the asphalt binder may begin to blend together, losing their distinct properties and becoming more uniform. Additionally, ageing can dissolve the boundaries between the different phases of the material. This means that the physical and chemical properties of the binder can change as a result of ageing, potentially leading to reduced performance and durability. Understanding the effects of ageing on asphalt binders is important for developing effective strategies for maintaining and preserving asphalt pavements. It can help to inform decisions about the types of materials and additives that are used in asphalt mixtures, as well as the timing and frequency of maintenance activities.

I. INTRODUCTION

There is a significant correlation between the rate of formation of sulfoxide and carbonyl groups and the rate at which asphalt binders become more brittle as they become older. Throughout the ageing process, they reported that asphaltene underwent aromatization as well as dehydrogenation. Both Glover et al. [1] and Lu et al. [7] conducted investigations on the chemical processes that occur during the ageing of asphalt. These investigations focused on the development of functional groups such as sulfoxide and carbonyl, the transformation of generic asphalt fractions, and the modification of asphalt's large molecular size components. According to them, the functional groups in asphalt undergo oxidation over time, which results in the formation of sulfoxide and carbonyl groups. In addition, a portion of the aromatic component of the asphalt is transformed into resins, and a portion of the resins themselves is transformed into asphaltene. Both of these processes may be thought of as being peptizing in nature. These two processes raise the amount of asphaltene and resins in the asphalt, which contributes to the asphalt's increased stiffness [7].

The process of ageing CRMA is substantially more complex and difficult than the process of ageing plain asphalt [5]. This is due to the dynamic nature of CRMA as well as the impact that temperature and time have on the development of its physical properties. When heated to high temperatures, CRM particles have the potential to take on the aromatic properties of asphalt and grow to be three to five times their initial size [2]. Despite this, for the course of the contact time, this expansion never grows to its fullest potential size. In addition to the usual typical ageing processes of the asphalt binder, it is feasible for the swelling of CRM particles to continue throughout the asphalt mixing and building process. This would result in further changes in the final physical characteristics of the CRMA after it had been aged [3].

In addition, CRM particles contact with asphalt, and this interaction might result in the exchange of components such as polymeric and antioxidants components. The exchange of these components is conditional on the nature of the interaction. This demonstrates that each of these components has a distinct influence on the deteriorating process of asphalt in its whole. Antioxidants may prevent asphalt's reactive groups from interacting with oxygen and slow down the rate at which they react [4]. In addition, polymeric chains serve the purpose of a retardant by preventing oxygen molecules from interacting with the functional groups of asphalt, which would otherwise lead to the asphalt's degradation. Degradation of the polymeric chains, which may occur as a consequence of the oxidation and volatilization of the asphalt ingredients [6], acts to counterbalance some of the increase in the asphalt's physical hardness that happens with age. This occurs because the polymeric chains are broken down.

II. LITERATURE REVIEW

The short-term ageing of the asphalt binder during the mixing and compaction process is an essential step in the development of flexible pavements [7]. Several factors, including as content in the mix and asphalt type, gradation and aggregate nature, and production-related factors, all influence how asphalt ages during this phase [7]. The ageing process can affect the physical qualities of asphalts differently depending on their origin. That's why the Superpave programme gave careful attention to the ageing of asphalt binder and factored it into the grading method. The Superpave programme investigated various techniques for simulating the ageing of asphalt binders, which occurs during mixing and building. Two instruments, the Rolling Thin Film Oven and Thin Film Oven (TFO), were proposed based on these findings (RTFO) to evalute physical parameter after ageing of asphalt binder. Both approaches result in identical samples, but the RTFO method's time savings make it more attractive to the asphalt sector.

Short-term ageing causes asphalt binder to harden due to a variety of physical and chemical changes, which in turn causes asphalt pavements to collapse prematurely [8]. Asphalt binder undergoes micro-phase transformations with age, which Wu et al. studied[9]. Siddiqui et al. used a variety of analytical techniques to study the effects of time on asphalt binder. They found a strong link between the rate at which carbonyl and sulfoxide groups develop and the rate at which asphalt binders harden [9]. They also noted that asphaltene undergoes aromatization and dehydrogenation as it ages [6]. According to their research, asphalt's functional groups oxidise during ageing, giving rise to carbonyl and sulfoxide groups. It has been shown that the aromatic component of asphalt can be converted into resins and vice versa [7].

The Superpave asphalt grading specification recommends the bending beam rheometer (BBR) test for evaluating asphalt binder performance in subfreezing conditions. Samples of asphalt are subjected to a load and deflection test, from which their creep stiffness, S(t), and m-value are determined. The rate at which tension is relieved during asphalt binder flow is expressed as an m-value. It is determined by observing how the asphalt binder's creep stiffness changes with time when a constant tension is applied.

III. SHORT TERM AGING IMPACT

The ASTM D2872-88 compliant rolling thin film oven equipment was utilised to mimic the effects of short-term ageing. In essence, the oxidation of bitumen that occurs due to temperature during manufacture, shipping, laying, and compaction of bituminous mixes is simulated by the short-term ageing process. The bitumen used in the experiments was heated to a pouring point. RTFO bottles containing 35 g of bitumen after 85 minutes of ageing at 160 degrees Celsius with an air flow rate of 4 l/min. The percentage of mass lost was calculated from test results, and samples were re-tested within 72 hours.

Several CRMA specimens with varying amounts of CRM & CRM sizes are generated to examine the impact of swelling CRM particles on rapid CRMA ageing. By controlling the contact conditions to 160°C and 10Hz for a maximum of 2 hours, we were able to restrict the CRM's activity to swelling while keeping dissolution to a minimum.

IV. IMPACT OF AGING TEMPERATURE

The high temperature viscosity of asphalt modified with CRM is much higher than that of unmodified asphalt, which has significant implications for the binder handling, compaction processes and mixing of HMA. Therefore, increasing the temperature has been proposed as a solution to this issue in several scientific reports and scholarly publications. The modified binder ages quite differently at this higher temperature. The typical test temperature for the RTFO test is 163°C (325°F), which is maintained for 85 minutes and see how the higher mixing temperature affected the CRMA's aging. This temperature and duration have been standardized by the ASTM in standard method D2872. After the RTFO test, the aged binder is then tested for properties such as viscosity, ductility, and penetration to assess its performance characteristics.

V. CONCLUSION

To better understand the short-term ageing process of CRM-modified asphalt, researchers examined the effect of CRM dispersion in the asphalt matrix and the component exchange between asphalt and CRM. In this respect, the liquid phase of the CRMA samples was aged using RTFO. The oxidation and physical ageing susceptibility markers were determined by DSR and FTIR tests. TGA analysis was also performed to learn how the addition of CRM affected the volatility of aromatic components in the asphalt samples.

The results reported in this chapter make it clearly clear that the oxidation process that occurs in the liquid phase of CRMA is unaffected by the presence of CRM particles or by their extensive dissolution. However, the synthesis of the oily components of CRM significantly reduces the rate of oxidation of the CRMA liquid phase. Antioxidants seen in CRM's oily components are likely created in the interaction's first stages. Furthermore, The CRM particles do not seem to have any discernible effect on the suppression of the volatilization of the CRMA liquid phase as it ages, & there does not appear to be any difference in the amount of mass loss that occurs between the CRMA specimen and their liquid phase and the plain asphalt.

The study also revealed that the liquid phase of CRMA is very susceptible to deterioration over time. CRM particles continue to absorb light molecular weight components and aromatics of asphalt even after dissolution, leading to their growth inside the asphalt matrix. On the other hand, particles of CRM have a great role in determining the mechanical behaviour of the CRMA when there is a high concentration of CRM (such as 10% or 15%). As a result, the CRMA matrix's vulnerability to ageing is reduced.

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