Recycled Asphalt Mixtures with Rejuvenators

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Rejuvenating agents are materials with certain physical and chemical attributes that may be incorporated into mixtures with high oxidisation level or high RAP content. Studies pertaining to rejuvenators can be traced as far as in the late 1970s. The ASTM D4552 was initiated based on the six grades of rejuvenating agents measured based on viscosity at 60 °C, so as to facilitate the selection of rejuvenators in ensuring good performance in the long run. Martin et al. divided rejuvenators into five general categories, namely: Paraffinic oils, Aromatic extracts, Naphthenic oils, Triglycerides & Fatty Acids, and Tall oils. Based on the chemical composition of asphalt and rejuvenators, Tabatabaee and Kurth classified the latter into three classes; insoluble and soluble softeners, as well as compatibilisers. Insoluble softeners have desirable effects on the rheological attributes of aged asphalt but portray durability and instability issues in the long run. Next, soluble softeners display better compatibility with naphthenic aromatic asphalt that has low polarity. Meanwhile, compatibilisers share some similarities with other numerous fractions found in asphalt.

Keywords: asphalt ; reclaimed asphalt pavement ; rejuvenator ; maltene ; asphaltene ; durability

1. Overview

Reclaimed asphalt pavement (RAP) has received much attention recently due to its increased use in hot mix asphalt (HMA) pavements to enhance pavement sustainability. The use of aged asphalt in RAP, which is highly oxidised and has lost its properties due to exposure to traffic loads and climatic conditions throughout its lifespan, can cause asphalt mixtures to stiffen and embrittle, thus negatively affecting the behaviour of asphalt mixtures. This issue may be resolved by including rejuvenating agents that can restore both physical and rheological properties of aged asphalt by increasing maltene fractions and decreasing asphaltene. However, the high restoration capacity of any kind of rejuvenating agent does not assure the durability of restored aged asphalt.

2. Rejuvenators

The tremendous development witnessed in the Malaysian national infrastructure network since the past decade has led to an increase in road construction [1], where flexible pavement dominates the overall surfacing types across more than 87,626 km. Although the life of asphalt pavement generally lasts for 10–15 years, many asphalt pavements need heavy maintenance within 10 years of construction [2]. This means that the huge amounts of aggregate and asphalt consumed during road construction not only cause economic issues but also increase the misuse of non-renewable resources. With the increasing awareness of environmental protection and sustainable development, the use of recycled materials in pavements (reclaimed asphalt pavement (RAP)) is deployed in many countries [3]. Recycling of road asphalt materials has a crucial role in the sustainable development of road construction [4][5]. RAP is composed of valuable constituents of asphalt binder and aggregates [6]; Kandhal et al. [7] used 20–50% of RAP for constructing flexible pavement, which can save 14–34% of construction costs [8]. Nonetheless, the main drawback for using RAP in constructing pavements refers to its deteriorated performance [9]. Evidently, the use of more than 20% RAP can adversely affect the constructed pavement from withstanding thermal and fatigue cracking, one of the main shortcomings noted in using RAP [10]. The reason is ascribed to the ageing of RAP as a result of exposure to the atmosphere throughout its lifespan. The aromatic compounds in asphalt binders become oxidised and more polar carbonyl compounds are created; thus increasing both elastic modulus and viscosity, as well as stiffening the binder [11]. The fractions of saturates, aromatics, resins, and asphaltenes (SARA) are modified when aromatics decrease and asphaltenes increase over time [12]. Upon being exposed to water, heat, and ultraviolet (UV) rays during its lifespan, the asphalt succumbs to ageing that affects its pavement performance [13]. In fact, asphalt ageing is generally divided into short-term ageing (STA) and long-term ageing (LTA); the STA process includes transporting, mixing, paving, and rolling of asphalt. Asphalt becomes aged and hardened when its light components turn volatile due to high temperature [13]. Asphalt ageing leads to poor workability, cohesiveness, fatigue resistance, as well as fatigue and thermal cracking. Hence, it is vital to restore and enhance the viscoelastic and engineering performance of aged asphalt [14].

The addition of rejuvenating agents may address issues that arise due to use of RAP at high dosages [15]. Most of the existing rejuvenators have been vastly explored for the past two decades for their sustainability. Typically, rejuvenators have high maltene content that can balance the composition in aged binder [16]. A rejuvenator is applied to increase the maltene content in aged asphalt, which deteriorates as a result of oxidation from LTA. Low maltene in RAP binder (aged asphalt) can cause asphaltene to flocculate, which leads to high cracking potential. When maltene is added via rejuvenators, the free-moving asphaltenes can enhance the flow property in the RAP binder [16]. The best rejuvenation denotes low-level saturates (saturates are incompatible with asphalt and promote ageing) and high-level aromatics [17][18]. Many studies have proposed rejuvenating and softening agents to restore crucial RAP properties, such as commercial, waste-derived, plant, and refinery-based oils [19]. Softening agents or fluxing (e.g., slurry oil, flux oil, and lube stock) may decrease the viscosity in RAP binder [20][21], whereas rejuvenating agents can re-balance the composition in aged asphalt due to the presence of sufficient maltene components that restore the inner structure of aged asphalt [21]. In any case, rejuvenating agents should satisfy both short- and long-term criteria. Short-term criteria denote the ability to diffuse quickly into the RAP and cause asphalt mobilisation [22]. An instance of long-term criteria is the modification of asphalt rheology to hinder thermal and fatigue cracking (no rutting or softening issue) [22][23], whereas an example of short-term criteria refers to rapid diffusion into RAP to promote asphalt mobilisation [22].

The homogeneity of asphalt with rejuvenators is crucial to meet these conditions [4]: (1) mechanical mixing uniformity, (2) better compatibility, (3) better diffusion of rejuvenator into RAP—this being the key condition for the entire process. The rate of diffusion is affected by rejuvenator-asphalt composition and layer thickness, as well as temperature. Failing to diffuse into RAP in timely manner, a rejuvenator is only useful as a lubricator [4]. However, the durability of rejuvenated asphalt cannot be guaranteed by a rejuvenating agent with high-level restoration capacity. For instance, rejuvenated asphalt ages again and its durability may not be similar to that of virgin asphalt (VA). Moreover, a rejuvenator may perform better at the early stage of its application, but may not necessarily perform better in the long run [24]. Based on their chemical composition, a rejuvenating agent can impart undesired features that deteriorate the performance of rejuvenated asphalt. Although numerous rejuvenators can restore the original rheological and physicochemical properties in RAP binder, they may affect mixture durability in terms of resistance towards ageing and moisture damage [25]. The latter resistance is ascribed to rejuvenators with a highly polarisable water-soluble element. The durability of asphalt mixtures relies on environmental factors, including UV radiation, temperature, and moisture. In temperate climates, along with poor aggregates and asphalt binder quality, pavement failure is attributed to fatigue cracking, excessive traffic loading, permanent deformation, and ravelling. Under aggressive climatic conditions, the distresses are exacerbated by climate-related loads, such as water damage [26]. Meanwhile, some rejuvenating agents are susceptible to oxidation. In order to achieve high RAP mixture with durability similar to that of new pavement material, rejuvenated asphalt should not age faster than VA [27].

Comprehending the durability of rejuvenated asphalt is crucial to hinder the use of unsuitable rejuvenating agents that could affect the performance of pavement. Despite the vast studies on the benefits of rejuvenating agents, only a handful of scholars have investigated the adverse impact of rejuvenators on pavement durability. Notably, rejuvenators should be assessed for both their rheological restoration capability and durability, particularly ageing and moisture damage resistance. Therefore, the present study explored the role of different types of rejuvenators in restoring the properties of aged asphalt and evaluated their effect on the performance of rejuvenated asphalt mixtures. Several recommendations are listed to choose the type of rejuvenator based on past studies in light of physical, mechanical, and durability characteristics.

3. Conclusions

- Most rejuvenators can restore the physical properties of aged asphalt. However, high restoration capacity of these rejuvenating agents does not assure the durability of restored aged asphalt.
- In addition, some rejuvenators can be used in cold regions, but unsuitable in hot regions. Certain rejuvenators have poor resistance to moisture damage.
- In attaining a viable solution from technical and practical stances, some rejuvenating agents are not preferred due to their potential rutting damage, poor practicality, and low durability for their medium- to long-term usage.
- The negative impact of rejuvenating agents can be minimised by including additives, such as polymers, fibers, and CRM.

- The rejuvenators should possess a series of fundamental requirements in terms of performance, availability, and logistics. More importantly, these rejuvenators should have homogeneity in composition.
- Early ageing due to certain rejuvenators demands further exploration, particularly for LTA. Thus, it is compulsory to study the ageing effect on the rejuvenators before introducing them to the industry.

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