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Advances in Aging and Anti-Aging Research on Rubber-Modified Asphalt and Asphalt Mixtures

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Abstract

Waste rubber-modified asphalt has good anti-aging properties and can significantly improve the service life of asphalt pavements. For domestic and foreign scholars of rubber modified asphalt thermal oxygen aging, photo-oxidative aging and water aging some behavioural research, and rubber asphalt aging after the characteristics of the research progress are reviewed. Especially rubber-modified asphalt after light, water and other multi-factor aging situations, the aging situation is more serious, for rubber-modified asphalt mixture aging, rubber asphalt anti-aging process research and analysis means are still very few, the future research must have more thinking.

Keywords

Waste Rubber Modified Asphalt, Thermal-Oxidative Aging, Aging Resistance

1. Introduction

In service, asphalt pavements are frequently affected by the atmosphere, sunlight, water and other external environments, resulting in the aging of asphalt, causing pavements to suffer from infections such as cracks, loosening and potholes, which in turn considerably undermine the road performance and service life of the pavement. Accordingly, it is necessary to strengthen the research on the aging law and the anti-aging performance of asphalt pavements [1]. Research on asphalt aging has always been a hot topic for scholars at home and abroad, and most researchers currently carry out laboratory aging simulations of asphalt to reflect the real road conditions as far as possible. The analysis of the macroscopic properties of asphalt, such as needle penetration, viscosity and rheological properties; as well as microscopic infrared spectroscopy, fluorescence microscopy, TG, DSC analysis, etc... With the development of technology, simulation tests will become closer and closer to the real situation, and microscopic analysis will become more and more significant breakthroughs.

Given this, this paper summarizes the research of domestic and foreign scholars on rubber-modified asphalt, the comparison of varied technologies and process materials, and the performance advantages and disadvantages of rubber asphalt, to provide a basis for successive in-depth research and evaluation of the performance of the developed composite modified asphalt.

2. Research Advances in Aging of Rubber Asphalt and Asphalt Mixtures

2.1. Thermal and Oxygen Aging of Rubber Modified Asphalt

Film oven test, rotating film oven test and pressure aging test are all common methods to simulate short and long-term asphalt thermal and oxygen aging. Short-term aging is to put the asphalt specimen into the oven and change the temperature and heat for a specified period of time; Long-term aging is to put the sample into the pressure aging container after short-term aging and then change the temperature and heat again. After the test, the sample can be extracted. Meng Yongjun and others prepared uncommon graphene rubber composite modified asphalt and subjected it to short-term thermal and oxygen aging, yielding some analysis of aging studies, followed by long-term aging, and the asphalt specimens after long-term aging were evaluated and studied under microscopic tests, yielding oxidation as the cause of asphalt aging [2]. One of the slower studies for long-term ageing, the pressure ageing test was only introduced in the USA at the end of the 20th century [3].

Zhang Zhihao set up the impact of different conditions such as time and temperature on microwave mastic modified asphalt [4], and analyzed the performance changes of mastic asphalt under thermal and oxygen aging through performance tests such as macroscopic performance index of asphalt, and utilized the thermal aging kinetic equation to disclose the change law. Wen Siyuan used RTFOT to verify the thermal aging kinetic equations for different aging times at different temperatures and evaluated the effect of changes in the amount of binder powder admixture on the thermal aging properties of asphalt by grey correlation [5]. Liu Wenchang researched the performance changes of asphalt aging using short-term aging, long-term aging [6]. Nascimento carried out thermal oxygen aging of asphalt mixtures by heating them in ovens at varied temperatures for 2 and 45 days [7]. Prathumrat Nu-Yang investigates the effect of thermal ageing on the morphology and mechanical properties of TPV based on blends of NR and PS. TPV samples were prepared. It was shown by tensile properties and impact strength that an increase in the amount of NR results in an increasing trend in impact strength and elongation at break, while the tensile strength shows a decreasing trend. On the other hand, when the PS content is increased, the trend of tensile strength increases with heat ageing at 70˚C for 3 days. In the case of thermal ageing, the NR/PS blend ratio of 70/30 is optimal [8].

The study of thermal-oxidative aging of asphalt is still a trend for future development. Binder powder plays a key role in the stability performance of asphalt and should be fully considered in the processing of binder powder, particle size and other factors. This paper compares the current particle size of binder powder used in the preparation of composite modified asphalt (**Figure 1**).

2.2. Photo-Oxidative Aging of Rubber-Modified Asphalt

UV and thermal aging are two different types of aging under thermal and UV intermediate conditions. W J N studied the effect of UV aging on asphalt properties in the field based on the method and process design of a special aging acceleration device to simulate asphalt UV, specifically for UV radiation to do the corresponding research [9]. To address the effect of strong UV radiation on road asphalt aging, Luo conducted experiments by simulating wild aging conditions through a UV aging environment chamber with six UV lamps arranged inside the chamber, with the samples 10 cm away from the lamps and the temperature set at 60˚C [10]. The high temperature, low temperature and fatigue properties of SBS-modified bitumen were investigated. Xinjiang has intense UV light, so Qi Yanni conducted indoor light aging simulation tests and converted the indoor and outdoor intensity in Xinjiang to explore the effect of aging time on the road performance index of rubber asphalt [11]. Chen Liang simulated the actual local light intensity with a cured UV lamp. The performance changes of rubber asphalt after UV aging in high temperature and damp areas were investigated and analyzed using test data indicators [12]. Yang Huili used the test method of artificial strong UV light source environmental chamber to generate UV-resistant modified asphalt, conducted comparative UV aging tests with other common asphalt, and analyzed by microscopic and macroscopic test comparison, and concluded that the performance of UV-resistant modified asphalt is superior [13]. **Figure 2** illustrates the comparison of the UV light equivalent time.

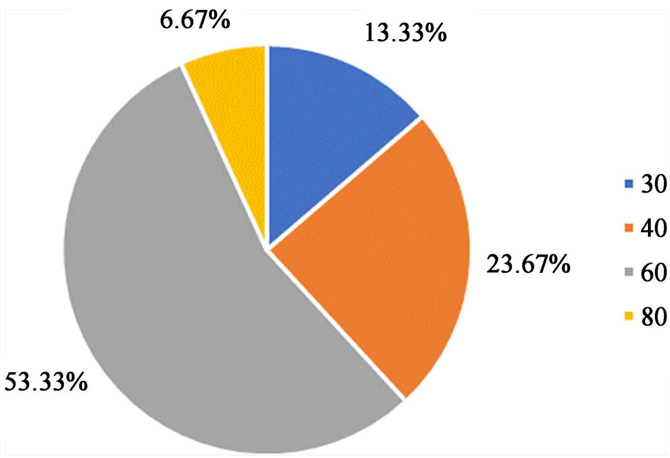

Figure 1. Percentage of different gum powder grades [2] [3] [4] [13] [14] [15] [17] [23] [24] [28].

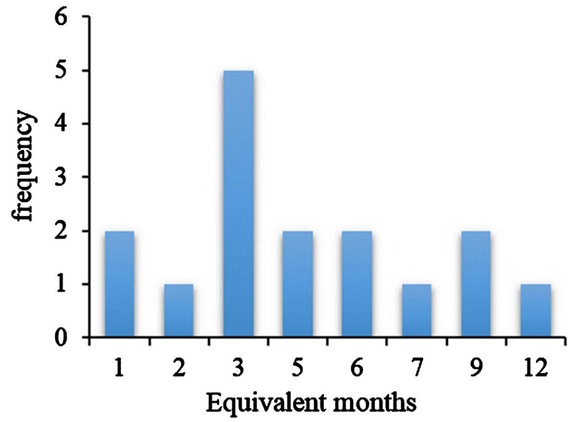

Figure 2. Equivalent outdoor time-frequency for indoor UV light hours [9] [10] [11] [12] [13].

2.3. Water Aging of Rubber-Modified Bitumen

The presence of humidity affects the various properties of asphalt after maturity. Liu Dong used an indoor freeze-thaw cycle method and concluded that rubber-modified asphalt has better resistance to water aging through macro and microscopic tests on asphalt [14]. Wu Meiping introduced different conditions such as water vapour, and chloride salts in water aging tests to recognize the effect of humidity on aging. The lower the pH value is, the larger the impact on the aging performance of rubber asphalt is [15].

Liu Yu added a humidity factor to the pressure aging test and simulated the accelerated aging of asphalt by moisture under the action of moisture factors through hot oxygen water, water vapour and other aging tests and concluded that water in both states could accelerate the aging of asphalt and enhance its softening point [16]. Qian Guoping simulated asphalt water aging by adding water pressure aging at high temperature to form a high-pressure water vapour environment, and concluded that water accelerates asphalt aging. [17] Xiao Peng added humidity to asphalt specimens after short-term aging and re-aged them under an SHRP pressure aging apparatus. It was concluded that the high temperature performance of TOR rubber asphalt became useful with a moderate decrease in water [18]. Yang Guoliang tested warm mix rubber asphalt in hot-oxygen-water immersion aging test, and hot-oxygen-water vapour aging test under hot-oxygen-water aging conditions, and the oxidation reaction was dominated, and the oxygen-containing functional groups were more in the hot-oxygen-water immersion environment than in the hot-oxygen-water vapour environment [19]. Silicone rubber-based insulating polymers have good hydrophobic and durable properties. To investigate weight gain, hydrophobicity and hardness, Mehmood B prepared five different types of HTV silicone rubber-based hybrid composites [20]. All samples were reinforced with micro-alumina and silica fillers of different concentrations. The tests yielded that the samples filled with micro alumina had a smaller percentage increase in weight, less ageing and greater water absorption compared to the other hybrid composites due to water absorption.

3. Research Progress on Anti-Aging of Rubber Asphalt and Rubber Asphalt Mixes

Researchers at home and abroad are now studying rubber asphalt in terms of its resistance to ageing, material processes and other aspects. The main current research avenues are as follows (**Table 1**).

3.1. Anti-Ageing Materials

Farrokhzade F studied the ageing of pure and modified adhesives at medium temperatures. The pure adhesives were modified using CR and SBS. New ageing/cracking parameters were introduced on the basis of the Christen-Anderson model. It was concluded that the addition of sulphur resulted in a significant improvement in the rheological properties, cracking properties and ageing resistance of the SBS binder [21]. Research on the anti-aging properties of rubber asphalt mixtures is currently less studied by scholars, in response to the above Han Minhui did a test on different rubber asphalt mixtures, and then after a comparison. Among the various rubber asphalt aging properties, ARG rubber with better aging resistance was retrieved. And this asphalt has some improvement in high-temperature performance after aging [22]. Ge Hao used high-speed shear to compound different types and doses of inorganic nanoparticles and a 20% doping ratio of rubber powder to retrieve modified asphalt, and the results showed that the nanoparticles had improved the anti-thermal and photo-oxidative ageing properties of asphalt. The results showed that the nanoparticles had improved the thermal and photo-oxidative ageing properties of asphalt, and the modified asphalt with 2wt% of Nano-TiO_2 and 20% of mastic powder could be generated [23].

Fang Binbin prepared two different asphalts by Donald method and high shear dispersion method, and analysed the conventional properties of mastic powder modified asphalt before and after ageing using a series of methods such as microscopic, and concluded that the mastic powder modified asphalt prepared by McDonald method has better anti-ageing properties [24]. Shubham C embeds zirconia in the matrix in CR composites and combines it with other useful composite properties. The in-situ incorporation of zirconia provides excellent reinforcement compared to externally filled zirconia with the same filler content. The data show that 20 in-situ filled zirconia composites have four times higher modulus at 100% strain than unfilled compounds, while the tensile strength is three times higher. The in-situ incorporation of zirconia resulted in a significant increase in thermal stability, and the use of two selected organosilanes

Table 1. Study of anti-aging technology for asphalt.

Asphalt ageing technology	Features
Anti-ageing materials	Modifiers, antioxidants
Anti-ageing process	Oxidative distillation, Impregnation in epoxy oil, Microwave radiation

further improved the performance of the composites [25].

Udomlak Sukatta applied the natural antioxidants obtained from RE to conventional vulcanisation formulations of NR and compared them with two commercial antioxidants. The main phenolic compounds in RE showed high antioxidant activity in all methods. The decomposition temperature of the RE-containing vulcanised rubber was higher than that of the commercial antioxidants and the tensile strength and modulus of the RE vulcanised rubber at 100% strain were similar to those of the commercial antioxidants. In addition, the addition of RE to rubber vulcanisates helps to resist thermal ageing at 70˚C [26].

3.2. Anti-Aging Process

At present, research on the anti-ageing process is not so complete, mainly through oxidation, distillation and other ways to increase asphalt production, etc. The input of these processes can effectively improve the anti-ageing properties of asphalt, and more efforts are needed to develop a more advanced anti-ageing process. In recent years, electromagnetic-based methods have been widely used in the pavement industry. Yin treated waste rubber with microwave radiation technology by impregnating it with epoxidised soybean oil. The polar oils contained in the soybean oil were found to improve the ageing resistance of the bitumen by providing oil to the ageing bitumen through oxidation [27].

Zhang Like carried out non-catalytic oxidation and catalytic oxidation of Brigadier residue separately, followed by reduced-pressure distillation after oxidation. It was concluded that the asphalt by non-catalytic oxidation and then distillation had better anti-aging properties, and catalytic oxidation enhanced the high temperature properties of the asphalt more significantly [28]. Kamali Z investigated the ability of microwave heating and preparation of RAP rejuvenators containing different amounts of WEO to determine the feasibility of electromagnetic methods for the production of RAP mixes. The medium and low-temperature fracture properties and moisture sensitivity of asphalt mixes containing 80% and 100% RAP prepared by EM were determined and compared with those prepared by conventional ventilated boxes. It was concluded that the addition of WEO can significantly improve the fracture resistance of asphalt mixes and that the production of high RAP asphalt mixes using EMR can significantly improve the sustainability of RAP asphalt mixes [29].

4. Conclusions

To further promote the research on aging and anti-aging of asphalt and asphalt mixtures, this paper reviews the current status of research on aging and anti-aging by scholars at home and abroad. The current research on aging has been relatively mature, but the research on anti-aging is still relatively lacking.

1) Rubber modified asphalt thermal oxygen aging research, scholars mainly study the time, and temperature changes on rubber asphalt aging; rubber modified asphalt photo-oxidative aging research, scholars are through the indoor ar-

tificial simulation environment to achieve ultraviolet aging; rubber modified asphalt water aging research, scholars mostly add water to the asphalt specimens to simulate the aging comparison test.

2) Rubber asphalt and rubber asphalt mixture anti-aging research can be divided into anti-aging materials and anti-aging process research. Anti-aging materials research has modifier research, antioxidant research, etc., this type of research in the current scholars in the majority of research. Anti-aging process research can be divided into oxidation distillation, impregnation in epoxy oil, microwave radiation, etc., the current research on the process is less.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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