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Review

Recent developments in the application of chemical approaches to rubberized asphalt

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HIGHLIGHTS

- Chemical approaches to rubberized asphalt are reviewed.
- Chemical characterization has been used to examine the processing and aging of rubberized asphalt.
- Adding chemical additives can create high performance rubberized asphalt.
- Stabilized properties and environmentally friendly processing are the future.

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ABSTRACT

Although rubberized asphalt has more than a 50-year history, it has not been widely adopted due to difficulties with its processability, unstable properties and high initial cost. Chemical approaches, including chemical characterization and the addition of chemical additives to rubberized asphalt, are useful tools to promote the applications of this technology. Chemical characterization techniques such as infrared spectroscopy, thermogravimetric analysis, gel permeation chromatography, and sol-gel analysis are used to analyze the chemical composition of rubberized asphalt. The development of chemical characterization for rubberized asphalt is described in terms of chemical degradation of rubber in asphalt, and stabilization of rubber in asphalt. The evolution of the chemical composition of rubberized asphalt has been evaluated and correlated for dry and wet processing, and indoor and outdoor aging. Following this, high performance rubberized asphalt realized by modification with different chemical additives is also discussed. The additives are categorized into polymers, inorganic filler, plasticizer and others. Finally, methods that combine several types of different additives that can be used to produce rubberized asphalt with stable properties and in an environmentally friendly manner are described.

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Abbreviations: USA, United States of America; FHWA, Federal Highway Administration; ASTM, American Society for Testing and Materials; ISTEA, Intermodal Surface Transportation Efficiency Act; PG, performance grade; IR, infrared spectroscopy; TGA, thermogravimetric analysis; GPC, gel permeation chromatography; NR, natural rubber; SR, synthetic rubber; CB, carbon black; API, active polymer index; TOR, trans-polyoctenylene; BR, butadiene rubber; BET, Brunner–Emmet–Teller; NBR, nitrile rubber; SBS, styrenebutadienestyrene copolymer; POE, polyolefin elastomer; RTFOT, rolling thin film oven test; UV, ultraviolet aging; TB, terminal blend; PMA, polymer modified asphalt; CRMA, crumb rubber modified asphalt; NMR, nuclear magnetic resonance; PP, polypropylene; PE, polyethylene; PVC, polyvinyl chloride; SEM, electron microscopy; DSC, differential scanning calorimetry; FTIR, Fourier transform infrared spectroscopy; UMO, used motor oil; PPA, polyphosphorous acid; LDH, layered double hydroxide.

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1. Background

1.1. History of rubberized asphalt

Rubberized asphalt is termed as a binder and is produced by adding crumb tire rubber modifier into heated asphalt and mixing for a period of time. During this process, the crumb rubber particles are swollen by the light fractions of asphalt leading to partial degradation and dissolution of the tire rubber into asphalt. Typically, rubberized asphalt shows better fatigue resistance and cracking resistance than conventional asphalt. One of the main benefits of using rubberized asphalt is that it allows for the proper disposal and reuse of a large number of waste tires. Therefore, the production and application of rubberized asphalt has acquired significant attention since its initial discovery [1–3].

McDonald initiated the era of rubberized asphalt in the United States of America (USA) in the 1960 s. A timeline for the development process of rubberized asphalt is shown in Fig. 1. During the 1970s/80s, trial tests of rubberized asphalt using a dry or wet process were conducted. For example, the quality and performance of rubberized asphalt in the Demonstration Project 37 was accredited by the Federal Highway Administration (FHWA). In 1988, a definition for rubberized asphalt was assigned by the American Society for Testing and Materials (ASTM D8). In 1991, the "Intermodal Surface Transportation Efficiency Act (ISTEA)" was issued to promote its widespread use.

However, at this time, there were still several unsolved problems preventing its application on a large scale [2]. Since then, much work has been carried out worldwide to implement rubberized asphalt in pavements.

There are three typical varieties of rubberized asphalts currently being used in the USA. The first is traditional rubber asphalt that is still used in western states such as California and Arizona. This technology is sometimes subsidized by the government because of its high initial cost. Using a life cycle cost analysis, Cheng et al. demonstrated that rubberized asphalt is more cost effective than conventional asphalt for Caltrans projects because rubberized asphalt has a longer pavement life than conventional asphalt [4]. The second type of rubberized asphalt is 5–12% crumb rubber (sometimes combined with SBS) modified asphalt, which meets the required performance grade (PG) standard. This hybrid-modified asphalt is often used in eastern states like Florida to replace conventional SBS modified asphalt. The third is rubberized asphalt in terminal blend form, which is often used in southern states like Texas due to technology already developed and provided by established oil refineries [4–7].

Rubberized asphalt has also been widely investigated in Sweden [2], Russia [8], South Africa [9], Spain [10], Brazil [11],

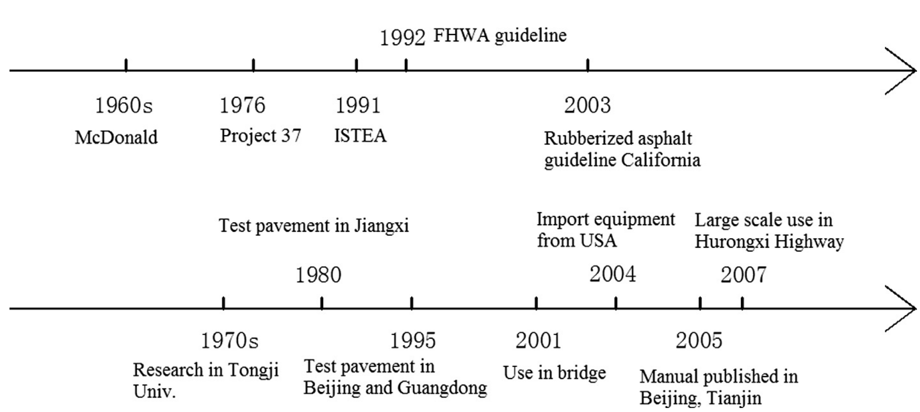

Fig. 1. Comparing the progress of rubberized asphalt in the USA and China.