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ASPHALT MECHANICAL PERFORMANCE OF RUBBER BITUMEN FOR HOT AND WARM ASPHALT MIXTURES

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Abstract

Rubber bitumen asphalt, also known as rubberized asphalt, is a sustainable and environmentally friendly alternative to traditional asphalt mixes. This study aims to provide an in-depth analysis of the use of the Hungarian Oil Company (MOL) development rubber bitumen in hot and warm mix asphalt (WMA). The study examines the effects of rubber bitumen on various properties of WMA, including workability, compaction, durability, and performance. Additionally, the study evaluates the environmental benefits and economic viability of rubber bitumen in WMA through a life cycle assessment and cost analysis. The findings of this study highlight the potential of rubber bitumen in enhancing the sustainability, lower energy emission and performance of warm mix asphalt.

Keywords: rubber bitumen, warm mix asphalt additive, mechanical properties

1 Introduction

Asphalt pavements are vital components of transportation infrastructure, providing a durable and smooth surface for vehicles. Traditional hot mix asphalt (HMA) has been the predominant choice for road construction due to its excellent performance and reliability. However, the production and placement of HMA require high temperatures, leading to energy consumption, greenhouse gas emissions, and potential worker safety concerns. In response to these challenges, warm mix asphalt (WMA) technology has gained increasing attention in recent years. WMA offers several advantages over HMA, including reduced energy consumption, lower emissions, improved workability, and enhanced pavement performance. By lowering production temperatures, WMA allows for the incorporation of recycled materials and additives, thereby promoting sustainability and resource efficiency in asphalt production.
Asphalt mix made with rubber bitumen as a technology in road construction has been present in Europe and overseas since the 1960s. In recent years, in addition to traditional asphalt mixtures, the production of asphalt mixtures at warm temperatures has also come to the fore in rubber bituminous mixtures, for which various additives are used in the production of the mixture.

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2 Rubber bitumen production and WMA additive

2.1 Production of rubber bitumen and the MOL Technology

Rubber bitumen is a specialized asphalt binder modified with crumb rubber derived from recycled tires. The incorporation of rubber into asphalt binder can be achieved through various methods, including the wet process, dry process, and terminal blending. In the wet process, rubber particles are blended with bitumen using a high-shear mixer at elevated temperatures, followed by homogenization and storage. In the dry process, rubber particles are pre-treated with additives to improve adhesion and compatibility with bitumen before being mixed with the binder. Terminal blending involves the addition of rubber-modified bitumen to conventional bitumen during asphalt mixing. The spread of rubber bitumen, however, did not represent a complete breakthrough in the asphalt industry, due to production technology, quantity and quality problems. However, the development of chemically stabilised rubber bitumen by the Hungarian Oil and Gas Public Limited Company (MOL Plc) has eliminated or reduced to an acceptable level the problems of the previous rubber bitumen products and production technologies, resulting in the production of rubber modified bitumen (RMB) which can be used to achieve asphalt mix quality comparable to the mechanical properties of polymer modified bitumen asphalt mixes. The technology described by the patent is the so-called "technology"., which is a modified wet process, and the manufactured product is chemically stabilized rubber bitumen [1]. The result of MOL Technology cause that 50-60% by weight of the rubber grist used dissolves, so a significantly higher proportion than in the previously applied wet rubber bitumen production technologies.

2.2 WMA additive in rubber bituminous mixture

2.2.1 Asphalt production in different range of temperature

Generally, there are four types of asphalt mixtures, depending on their production temperature. The cold mix asphalt (CMA) produced at 0–30 °C; the half-warm mix asphalt (HWMA) produced at 60–100 °C; the warm mix asphalt (WMA) produced at 110–140 °C; and the hot mix asphalt (HMA) produced at 150–180 °C. Figure 1 shows the classification of the asphalt mixes based on the production temperature [2, 3].

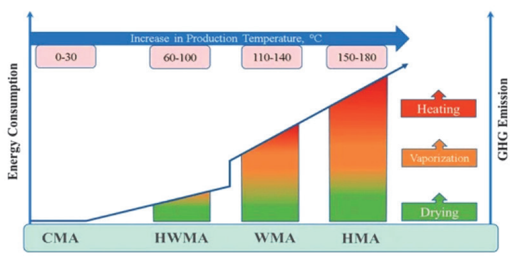

Figure 1 Producing temperature of asphlat mixtures [2, 3]

The goal of high production temperatures during asphalt production is to temporarily reduce the viscosity of bitumen enough to coat the particles and be transported to the work site and installed when transported. Reducing the viscosity of bitumen can be achieved in the following ways:

- using organic additives
- by foaming
- with chemical additives

It is obvious that lowering the production temperature has significant advantages, since on the one hand energy demand is much lower, and on the other hand, as a result, harmful emissions are significantly reduced both during production and installation.

3 Rubber bitumen in hot mix asphalt-the Hungarian experience

The so-called MOL rubber bitumen, developed taking into account international practices, was introduced in Hungary in 2012. Over the past 12 years, nearly 150 km of road renovation and new road sections have been built using rubber bituminous asphalt mix.
As you can clearly see in the picture below (Figure 2), rubber bitumen application clearly performs better than conventional bitumen asphalt mix, and all asphalt is a worthy competitor to polymer-modified bitumen mixtures in mechanical properties.

Figure 2 Asphalt mechanical performance in conventional rubber bituminous and polymer asphalt mixtures [4]

Type of asphalt mechanical test	Normal asphalt mix	Polymer modified asphalt mix	Rubber bituminous asphalt mix
Wheel tracking test	+	++	++
Fatigue resistance test	+	++	+++
IT-CY stiffness test	+	+++	++
Cold behaviour test	+	++	+++
Note: The difference between the + signs represent the positions of the test results of each mixture relative to each other			

In 2019 and 2023, the colleguaes of the Budapest University of Technology and Economics carried out comprehensive tests on roads made with rubber bituminous asphalt installation in Hungary. Even after 4 years, measurements with the KUAB inclination measuring device did not show any significant change in the arrival of rubber bituminous tracks. For wheel tracking test, drilled samples were taken from two road sections, from the track structure of main road No. 7410 and the M25 expressway in order to determine the degree of plastic base change. The choice of the two road sections was justified by the fact that here PMB (polymer modified) and RMB (rubber modified) asphalt layers were installed practically sequentially, with the same base layers of pavement structure [5]. The following two tables (Table 1 and Table 2) show the results of the above tests, from which the excellent performance of rubber bituement layers is clearly visible.

Table 1 Main road No. 7410 wheel tracking test results [5]

	Typical bitumen	Mean specific rut depth, PRD%	
		wearing course	binder course
Main road No. 7410	RmB	1,95	4,23
	PmB (ref.)	2,02	4,73

Table 2 M25 motorway wheel tracking test results [5]

	section	bitumen	Mean specific rut depth, PRD%		
			wearing course	binder course	base course
M25	11+000	RMB	2,53	1,82	2,17
	12+033	RMB	2,61	1,88	1,88*
	13+000	PMB (ref.)	3,28	1,42	2,2

4 Asphalt mechanical tests on rubber bituminous asphalt mixes with WMA additive

As a warm asphalt mix, the rubber bituminous mixture developed by MOL was also tested in the year 2023. Two types of WMA additives were used mixed with RMB:

- GMB: wax (paraffin) type additive containing 2339-B/22 WMA additive-1, has a viscosity reducing effect at high temperatures, thereby reducing the temperature of asphalt mixing. However, when cooled to 50-70 Co, there is no softening effect, it brings about the quality parameters of the unadditive binder or asphalt, possibly it may have a stiffness/modulus increasing effect in the range of the road surface usage temperature.
- 2340-B/22: GMB containing WMA additive-2: surfactant, the mechanism of action of which is that bitumen wets the mineral more easily by reducing surface tension. As a result, at lower temperatures, rock wetting, that is, asphalt mixing, can be carried out.

In addition to the mixture with the two additives, two reference mixtures were prepared, a rubber bituminous AC 16 binder course (mF) (RMB 45/80-55 reference) and a polymer-modified AC 16 binder course (mF) (PMB 25/55-65 reference) mixture. The two reference mixtures were mixed according to MSZ EN 12697-35 and compacted at 170 °C, but the two WMA additive mixtures were mixed 20 °C lower [4].

4.1 Wheel tracking test

The tendency of asphalt mixes to deformation under load can be assessed by the wheel trace formed at a constant temperature during repeated passes of the loaded wheel. During the test, the depth of the wheel track formed during repeated passes of the loaded wheel is measured at a given temperature (in our case 60 °C).
There was no relevant difference in the test results: the specific wheel track depth was 2.84-2.85%, while the mixture with RMB+WMA1 gave a slightly worse value of 3.33%. The investigation showed that the rubber bituminous mixtures met the requirements for PmB mixtures and that the WMA additive made it possible to reduce the production temperature by 20 °C [4, 5]. Figure 3 shows the results.

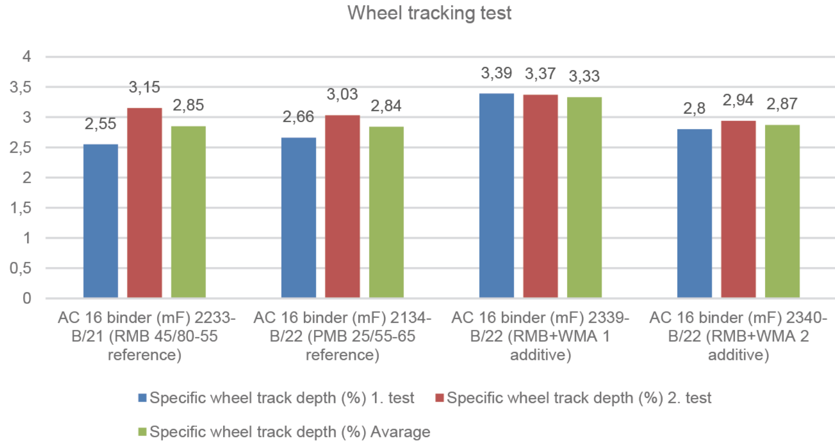

Figure 3 Comparison of wheel tracking test results for different mixtures

4.2 Cold behaviour test

The cold behaviour of asphalt mixes is characterized by studying the cracking temperature of asphalt.This stress increases significantly in the negative temperature range under the influence of vehicle load, which leads to cracking of the pavement, which initially appears only as a hairline. The determination of the cracking temperature of asphalt is carried out on a beam-shaped specimen measuring 50 x 50 x 250 mm. A clamping head is fitted at each end of the impactor for anchorage in the test apparatus. During the test, the impactor is cooled at a cooling rate of 10 °C/h to prevent longitudinal deformation of the impactor. The temperature at which the tensile strength of the impactor is equal to the thermal tensile stress, i.e. where the impactor cracks or breaks occurs, is called the cracking temperature of the asphalt. The lower the temperature at which the material discontinuity occurs, the better the cold behavior of the mixture [6].

In the case of test specimens made of rubber bituminous mixtures, failure, i.e. cracking, occurred at lower temperatures, which means that the cold behaviour resistance of these mixtures is better than that of “conventional” PMB mixtures. It should be emphasized that RMB mixtures made with WMA additive at lower temperatures gave better cold behavior results than RMB mixtures in both cases, moreover, the result of the mixture made with WMA 2 additive approached (practically identical) the cracking temperature of the GmB reference mixture [4].

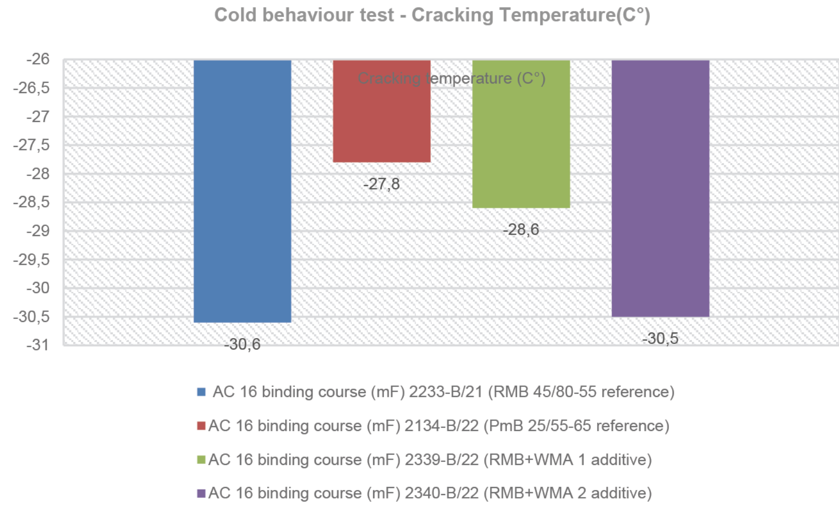

Figure 4 Cracking tempereature of the different asphalt mixtures (Koch-Almássy) [4, 5]

4.3 Fatigue resistance test

At the four points bending test the fatigue curve can only show the results of testing a mixture under the same conditions, i.e. the temperature, load mode and frequency must be the same in all cases. During the tests, a stress-controlled or strain-controlled method may be used [7]. In the present research, the load was carried out in a strain-controlled manner at different load levels, at a frequency of 30 Hz and at 20 °C.
During the test, the measuring instrument is pre-set so that the test ends when the rigidity reaches 50 % of the initial value. In the tests performed, the specific elongation of the two reference mixtures at load repetition 10^6 was slightly but visibly lower than that of mixtures containing RMB + WMA. In somewhat contradiction to previous test results, the fatigue elongation at failure of the RMB reference mixture was slightly worse (lower) than the deformation value of the PMB mixture, however, both WMA mixtures exhibit significantly better fatigue properties than the AC 16 binder mixture made with polymer-modified bitumen [4, 5].
The Figure 5 summerize the fatigue resistance test results.

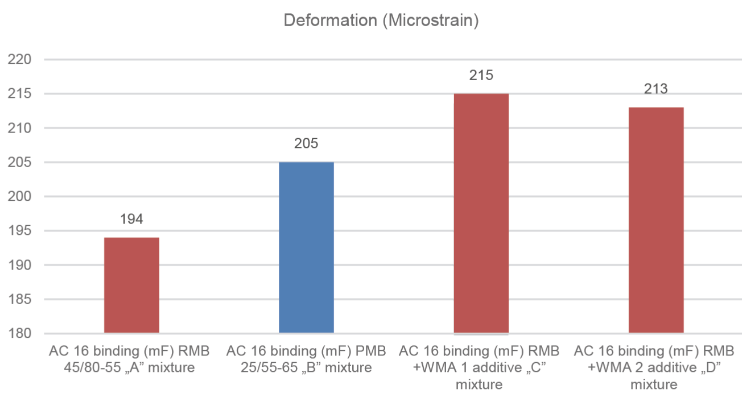

Figure 5 Fatigue resistance test results of the different mixtures

5 Conclusions

In conclusion, the review of rubber-modified warm mix asphalt (WMA) has provided valuable insights into its characteristics, benefits, performance, and sustainability aspects. Key findings from the review include:

- Rubber-modified WMA offers numerous advantages over conventional hot mix asphalt (HMA), including improved rutting resistance, fatigue performance, moisture sensitivity, and environmental sustainability.
- The use of recycled rubber from waste tires in asphalt pavements contributes to waste reduction, resource conservation, and circular economy principles.
- Rubber-modified WMA demonstrates promising performance in various climates and conditions, with enhanced durability and longevity compared to traditional asphalt mixtures.
- Future research and development efforts are needed to optimize mix designs, establish standardization and regulation.

Overall, rubber-modified WMA represents a sustainable and high-performance solution for asphalt pavement construction and maintenance, with the potential to address key challenges in transportation infrastructure.

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