Expansion Ratio and Half Life of Foam Asphalt

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Abstract: ***The significant growth of global road infrastructure and its environmental impact necessitate sustainable construction practices. Foamed asphalt, a key cold mix technology, is gaining popularity due to its cost-efficiency and environmental benefits. This report explores the use of Recycling Asphalt Pavements (RAP) and the significance of Expansion Ratio (ER) and Half-Life (HL) in achieving high-performance asphalt mixtures. These parameters are critical for ensuring viscosity and consistency, which are pivotal for the sustainability and performance of pavement construction.***

Keywords: Recycling Asphalt Pavements, Expansion Ratio, Half-Life, Foamed Asphalt Mixture, Sustainability

1. Introduction

Foamed Asphalt Mixture (FAM) has several advantages. The use of this mixture conserves asphalt and aggregates, decreases energy usage, minimizes waste, and reduces fuel consumption and emission of greenhouse gases. Above all, it significantly reduces the cost of construction. Engineering advantages include the possibility to use a wide variety of aggregates, the binder increases the strength compared to granular material, exhibiting more flexibility compared to cement-treated materials, giving faster strength gains compared to emulsion mixtures, and possible early opening to traffic. Foamed asphalt technology is often perceived as posing significant risks due to its complex behavior." Simplifies and enhances readability. It is therefore necessary and timely to conduct research into FBM performance and hence to provide an up-to-date evaluation of foamed asphalt binder, its characteristics, and the role it plays in mixture performance. It is expected that this research will contribute to unraveling the complications of foamed asphalt behavior and to allowing this material to achieve the high requirements of pavement material. The purpose of this study is to evaluate the foaming characteristics of asphalt and their impact on the sustainability and performance of cold-in-place recycling technologies. This study is significant for advancing sustainable construction practices by leveraging foamed asphalt technology to reduce resource consumption and environmental impact.

2. Literature Review

A brief history of Foam asphalt:

The process of foaming asphalt was developed more than 50 years ago by Csanyi of Iowa State University (1957). The availability of marginal ungraded aggregate and shortage of good aggregate in his state of Iowa inspired the invention of foamed asphalt technology. He studied different methods of producing foam from asphalt and its applicability to paving materials. It was shown in his studies that producing foam from asphalt by injecting steam into asphalt was a simple and efficient technology (Csanyi, 1959). However, this method (injecting steam) proved to be impractical for in-situ foaming, because of the need for special equipment such as steam boilers (Mobil Oil Australia Ltd., 1971) have merged.

In 1968, Mobil Australia, which had taken patent rights for Csanyi's process, modified the original process by injecting cold water rather than steam into hot asphalt. Thus, asphalt foaming technology became significantly more practical and economical. Subsequently, this technology has gained popularity in countries like Australia, Germany, New Zealand, South Africa, and later in the USA and UK.

Asphalt foaming process:

The foaming of asphalt can be acknowledged to be a phenomenon caused by changing water from a liquid state to a vapor at high temperatures which is accompanied by an increase in volume around 1500 times at atmospheric pressure (Halles, 2013). When water comes in contact with hot asphalt, the heat energy is transferred from asphalt to water. This results in water reaching boiling point and changing state and, in doing so, creating a thin-filmed asphalt bubble filled with water vapor. Accordingly, foamed asphalt is produced by injecting water into hot asphalt, resulting in spontaneous foaming in an expansion chamber. However, the original process proposed by Csanyi consisted of introducing steam into hot asphalt through a specially designed nozzle such that the asphalt on ejection was temporarily transformed into foam. An improved production process was developed by Mobil Oil Australia Limited. This improved method involves the introduction of a controlled flow of water into hot asphalt (Figure 1). The expansion chamber was refined by the Mobil Oil organization in the late 1960s and it is still the most used system for producing foamed asphalt. However, the system developed by Wirtgen in the mid-1990s injects both air and water into the hot asphalt in an expansion chamber as shown in Figure 2. Water (1% to 5% of the mass of asphalt) together with compressed air is injected into hot asphalt (140°C to 180°C) in the expansion chamber. This causes the water to turn into vapour which forms tiny asphalt bubbles.

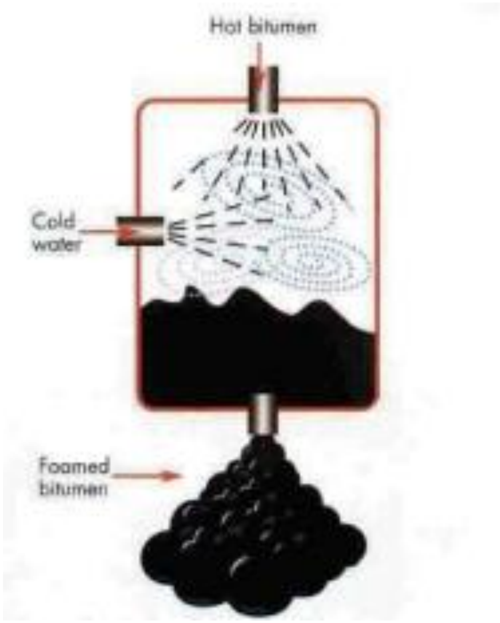

Figure 1: Foaming asphalt by Mobil Oil organization technique (Source: Csanyi, 1957)

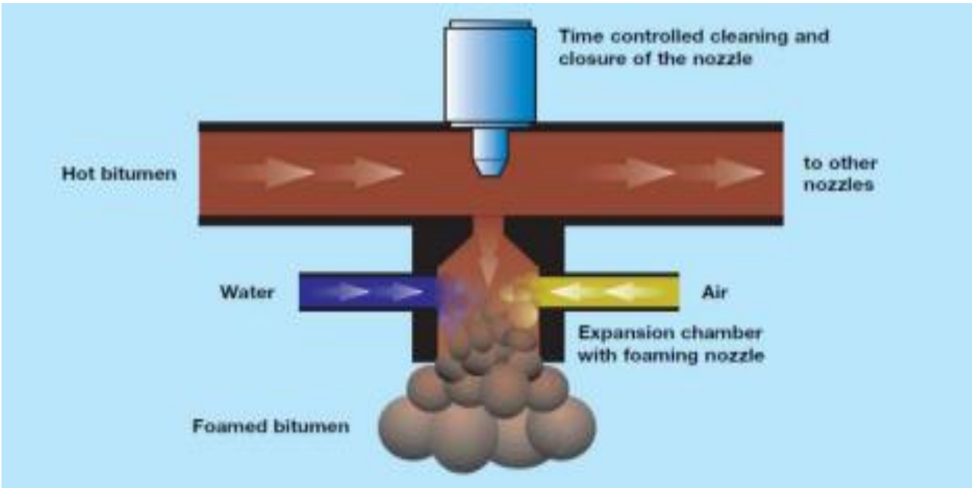

Figure 2: Foaming asphalt by Wirtgen (Source: Wirtgen manual –WLB-10S, 2010)

3. Foamed Asphalt Characteristics

Studying the use of foamed asphalt for cold-in situ recycling includes two aspects: one is to study the foamability of asphalt and the other is to study the properties of the foamed asphalt mixture. Foamability (foaming potential) is the ability of a binder to produce foam of superior characteristics (satisfactory ER and HL). It is expected that foam characteristics are important for better mix performance.

During the foaming process, the foam expands rapidly and reaches its maximum volume. The ratio of the maximum volume of foamed asphalt to the volume of liquid asphalt used is termed the maximum Expansion Ratio. The expansion ratio is a measure of the viscosity of the foam and indicates how well the asphalt will disperse in the mix (Figure 3). The time that elapses from the moment that the foam is at its maximum volume to the time that it reaches half of this volume is termed the half-life of the foam (Figure 3). Accordingly, expansion ratio and half-life have been used to compare the foaming characteristics of asphalt. Brennan (1981) identified that expansion ratio and half-life are affected by (i) the amount of foam produced, and (ii) the foaming temperature of the asphalt. However, these two factors are not enough to explain the formability of the asphalt. One of the dominant factors (other than the two mentioned by Brennan (1981) influencing the foam properties is the water that is injected into the expansion chamber to create the foam. The higher application rate of water results in a higher expansion ratio but leads to rapid collapse of foam i.e., shorter half-life (Figure 4). In the laboratory, the size of the container was found to affect foam parameters. Jenkins (2000) and Sunarjono (2008) have done extensive research on foamed asphalt characteristics and concluded that water application rate and asphalt temperature are the most significant factors affecting expansion ratio (ER) and half-life (HR).

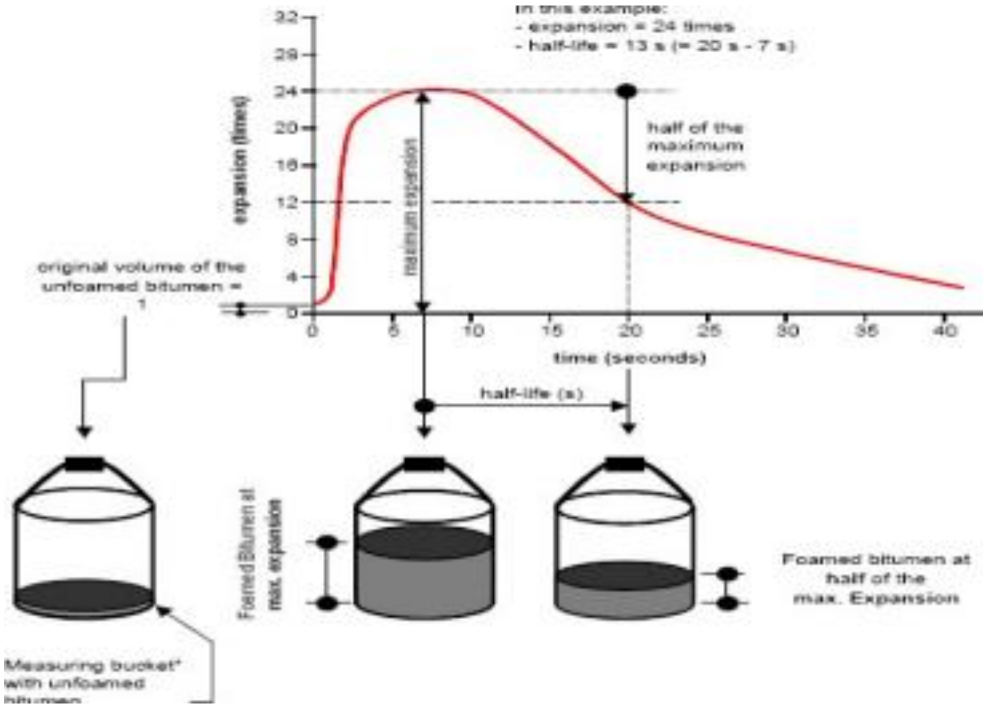

Figure 3: Characteristics of Foamed asphalt (Source: Wirtgen manual –WLB-10S, 2010)

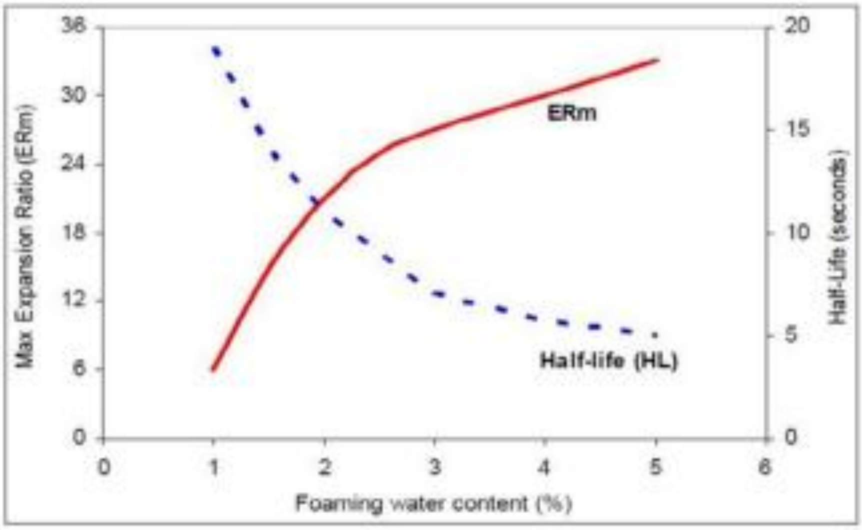

Figure 4: Relation between ER and HL (source: Wirtgen manual –WLB-10S, 2010)

4. Methodology Summary

The process of producing foamed asphalt was found in the early 60's by Dr.Cyansi (1957). Since then, improvement for the existing process has been taking place constantly. A major part of the innovations in the field of Foamed asphalt technology is done by the Wirtgen group which came up with various heavy-built equipment for producing the foamed asphalt. Also, milling and recycling existing pavements using the foamed asphalt technology. Foamed asphalt is produced when hot asphalt is subjected to pressurized air and water (very low volume) resulting in instantaneous foaming. The foamed asphalt is generally characterized based on its Expansion Ratio (ER) and Half-Life (HL). ER represents the viscosity of the asphalt whereas the HL represents its consistency. To produce sound FAMs, good ER and satisfactory HL are necessary.

The methodology of this study is shown in Figure 5.

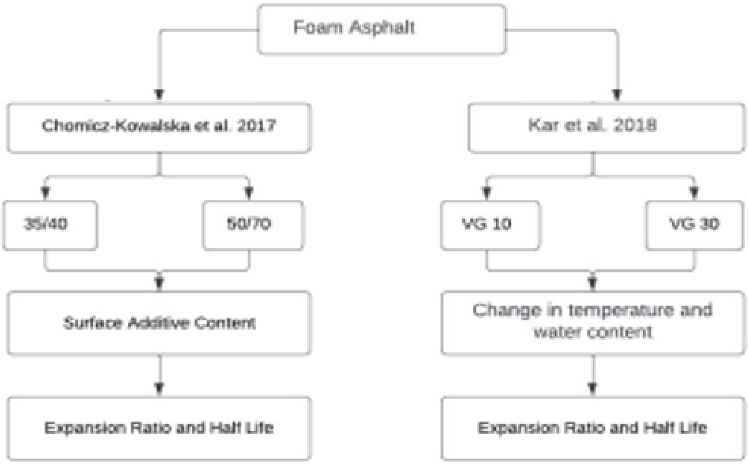

Figure 5: Methodology of the study

5. Results and Discussions

Table 1: ER, HL, and FWC for various asphalts

Asphalt Type	Surface Additive Content	ER	HL(Sec)	FWC
Soft (35/40)	0	10.34	9.9	3
	0.2	14.4	17.45	2.5
	0.4	17.78	19.52	2.5
	0.6	20.12	20.34	2.5
Stiff (50/70)	0	10.26	13.23	2.5
	0.2	17.64	16.93	2.5
	0.4	19.38	18.94	2.5
	0.6	20.58	19.44	2.5

From Table 1, it is noted that the ER and HL are high for stiffer asphalt compared to the Soft one. This represents that the stiffer binder is good for developing a foaming asphalt. Surface Additive is a material that increases the ER and HL in the foaming asphalt. Soft binder needs surface additives to develop enough foaming.

Table 2: ER, HL, with varying Temperature and water content

Bitumen	Temperature (°C)	Water Content (%)	ER	HL(Sec)
Soft(VG10)	120	9	11	11
	130	8.5	15	15
	140	8	15	15
	160	6.5	14	14
	180	4.5	14	14
Stiff(VG30)	120	-	-	-
	130	10	16	16
	140	10	18	18
	160	6	19	19
	180	3	18	18

From Table 2, it is noted that with the increase in temperature, the foaming content and the half-life increase. In addition, with the decrease in water content, the ER and HL decrease for all types of binders. For VG 30, the maximum ER and HL is 160°C, whereas for VG 10, the maximum ER and HL is at 130°C.

6. Conclusions

Foamed asphalt technology continues to gain global traction due to its environmental and economic advantages. This study highlights the critical role of binder type, temperature, and water content in optimizing foaming characteristics. These insights contribute to advancing sustainable road construction practices by improving the performance and applicability of foamed asphalt mixtures.

References

[1] Brennan, M. A laboratory investigation on the use of framed asphalt for recycled bituminous pavements. Interim Report Purdue Univ (1981)., West Lafayette, IN.,

[2] Csanyi, L.H., Foamed asphalt in bituminous paving mixtures. Highway Research Board Bulletin, 1957. 160: p. 108-122. 5.

[3] Csanyi, L.H., Foamed Asphalt. American Road Builder Association (ARBA), 1959. 240: p. 3-14. 6.

[4] Halles, F. Thenoux, G., & González, Á. Stiffness Evolution of Granular Materials Stabilized with Foamed Bitumen and Cement." Transportation Research Record: Journal of the Transportation Research Board 2013, 2363, P.105-112.

[5] Jenkins, K. J., Molenaar A. A., De Groot, J. L. A., & Van de Ven, M. E. C. Developments in the uses of foamed bitumen in road pavements. HERON 2000, vol. 45 (3).

[6] Kar, S. S., Swamy, A. K., Tiwari, D., & Jain, P. K. Impact of low viscosity grade bitumen on foaming characteristics. Journal of the South African institution of civil engineering 2018, 60(2), P.40-52.

[7] Mobil Oil Australia Ltd. Foamed bitumen: A new development. Technical Bulletin 1971.

[8] Sunarjono, S. The Influence Foamed Bitumen Characteristics on Cold Mix Asphalt Properties., University of Nottingham 2008.

[9] Wirtgen, Cold Recycling Technology. 2010.

[10] Chomicz-Kowalska, A., Mrugała, J., & Maciejewski, K. (2017, October). Evaluation of the foaming performance of bitumen modified with the addition of surface-active agent. In IOP Conference Series: Materials Science and Engineering October 2017, Vol. 245, No. 3, p. 032086. IOP Publishing.