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Life time prediction for low energy and ecological effects bituminous mixtures

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HIGHLIGHTS

- Life time prediction is based on accumulated damage & consumed time for every damage.
- Fatigue has the most important contribution for the total damage of the pavement.
- Higher rutting in modified bitumen (sasobit, cecabase, foam, RAP) compared to reference.
- Bad rutting results concluded that WMA for hot climate needs further investigation.

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ABSTRACT

Road surfaces with low temperature bitumen are usually used due to the lower energy consumption and environmental considerations.

This paper presents a study of the performance of low temperature bitumen, in particular, the long-term behavior and life-time prediction of some low-temperature bitumen. Six bitumen mixture samples were tested with different modifiers such as synthetic Cecabase (C), Sasobit (S), Greenseal (G) and Advera (A) wax. Pavement performance prediction in terms of fatigue cracking and surface rutting is essential for any mechanistically-based pavement design method. In this study full-scale Accelerated Pavement Testing (APT) has been used to simulate field conditions and Equivalent Standard Axles (ESAs). Fatigue response was also analyzed in the laboratory. This paper focus on developing a life time prediction model based on rutting and fatigue to describe the stable and unstable performance of six tested low energy bitumen mixtures.

1. Introduction

Hot mix asphalt (HMA) is the most usual material for road construction. HMA requires heating of aggregates and bitumen to 160 °C or sometimes more [1]. Due to high production temperatures, HMA is highly energy-consuming due to the high temperature of the mixture production and is a source of greenhouse gas emissions affecting the environment [2].

Foamed bitumen is a hot bituminous binder that has been temporarily converted from a liquid state into a foam state by the addition of a small percentage of water and pressurized air. Foam bitumen has been used as a stabilizing agent in pavement since 1956 [3]. After modification its production process from injecting steam to cold water into hot bitumen in 1976 [4], and also introducing new machineries in the market in mid-1990 [5], numerous road and highway stabilization and recycling projects performed using this technology [6].

Warm Mix Asphalt (WMA) is produced at temperatures between 100 °C and 140 °C. Lower processing temperatures can be achieved using chemical additives or by reducing bitumen viscosity through organic modifiers such as synthetic Cecabase (C), sasobit (S), Advera(A) or greenseal (G) wax. The Cecabase (C), sasobit (S), Advera (A) and greenseal (G) have a significant influence to the rheological characteristics of bitumen, enhancing its performance in service temperatures (by increasing its viscosity below 100 °C and elevating softening point temperature). At the same time, Cecabase (C), Sasobit (S) and Advera (A) and Greenseal (G) wax decreases bitumen viscosity in temperatures exceeding 100 °C, permitting lower compaction temperatures to be used [7].

2. Bitumen materials

The objective of this research is to study the performance of asphalt mixtures prepared with some WMA technologies, A, C, G and S in comparison with a reference HMA mixture [8]. Bitumen AC B 16S was used for the reference mixture. Recycled/Reclaimed Asphalt Pavement (RAP) was also tested [8].

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It was used the standard method for determining the Optimus bitumen Content with the ASTM D6927-15 Standard Test Method for Marshall Stability and flow test. All samples were cylindrical specimens compacted using a gyratory compactor. The specimens were prepared based upon the laboratory mixture design, i.e. at optimum binder content (between 4% and 6% of aggregate mass) and an aggregate water content of about 4.5%. The specimens were cured at 40 °C for 3 days to simulate approximately 6 months of field curing as proposed by [9].

The response of bitumen to stress is dependent on both temperature and loading time and the degree to which their behavior is viscous and elastic is a function of both temperature and loading time.

Table 1 explains in detail the composition of the 6 mixtures tested in this research.

3. Mix design

Sasobit is a long chained synthetic wax (chain lengths ranging between 40 °C to 115 °C carbon atoms) that is produced using the Fischer-Tropsch (F-T) process. Sasobit forms a lattice structure inside the asphalt binder at temperatures below its melting point which improves the stability of asphalt mixtures and causing a reduction in the viscosity of binder. The addition of sasobit additive significantly assists in lowering the amount of air voids within mixes in most cases [10].

Cecabase is the reference modifier for Warm Mix Asphalt (WMA). Cecabase brings workability and easier compaction of the mix, even with Reclaimed Asphalt Pavement (RAP) that is also under study in this research.

Advera is a synthetic zeolite that is formed of alumni-silicates and released as the temperature rises above 100 °C upon the introduction of the additive to the mixture simultaneously with the binder.

Another tested material in this study, RAP, has several advantages, most notably, the preservation of natural and economic resources, thus it is considered an environmentally friendly practice.

The test results indicate clearly that the use of these additives in the modified bitumen will result in a significant increase in rutting resistance, on the one hand, and will enable paving at lower temperatures due to a significant reduction of bitumen viscosity. Table 2 summarizes the mixtures temperatures for all the tested mixtures.

4. Optimum bitumen content

For determining the optimum bitumen content was used the ASTM D6927-15 Standard Test Method for Marshall Stability and flow test. Asphalt mixtures were compacted using a Marshall compactor and tested for stability, bulk density and air voids. Indirect tensile strength test was carried out also to measure the tensile strength of compacted asphalt mix [11–13].

In order to prepare the laboratory mixes, mixing aggregates with foam bitumen, made of specimens of 101 mm in diameter and 65 mm height, were compacted applying Marshall Hammer at 65 blows per sample sides with about 5% by volume void content. The mixture compacity (%) is shown in Fig. 2.

Marshall test was performed to determine the percentage of optimum bitumen content. Fig. 1 summarizes the test results for the optimum bitumen content of all the mixtures.

The air-void content of the mixes in the study, determined from Marshall-compacted specimens, was notably different with the reference mix having significantly lower air-void content than the mixes with additives. The reference mix had the lowest air-void content and the Sasobit mix the highest air-void content. The obtained data suggests that the binders in the WMA mixes at the lower compaction temperature were stiffer/more viscous than the reference mix binder at the higher temperature.

The tests showed that the Marshall stability of the reference mix was significantly higher than the mixes with additives or RAP [14].

4.1. Preliminary ageing method and tests

The ageing schlafen method performed in the lab was the following, see Fig. 3:

Table 1
Composition of the mixtures under study.

	REF-HOT kg	FR-PACK kg	FR-WAX kg	FR-WATER kg	WATER + RAP kg	PA PACK kg
Bitumen 250/330				1215	0.945	
Bitumen 70/100					2.16	
Bitumen 35/50				4995		
Bitumen 50/70	6.2	6.21	6.21			4.462
Filler	5.1	5.13	5.13	5.13		3.8
0/4	54.8	54.81	54.81	54.81	22.275	40.6
Gravel 4/8	29.1	29.025	29.025	29.025	9.315	21.5
Gravel 8/11	16.7	16.74	16.74	16.74	12.285	12.4
Gravel 11/16	23.1	23.085	23.085	23085	20.52	17.1
Cecabase		0.02484				
Sasobit			0.1863			0.138
Bithaftin			0.006			0.0046
RAP					67.5	

Table 2
The following table shows data about the mixture temperatures.

Code	REF-HOT	FR-PACK	FR-ZEO	FR-WAX	PA-HWAM	PA-PACK
Formule	AC B 16S	AC B 16S	AC B 16S	AC B 16S	AC B 16S	AC B 16S
Addit.	–	Cecabase RT	Advera	Sasobit	Fluxant (LEA1)	Greenseal
Addit. Dosing	–	0.4% bitume	0.25%/coated	3%/bitumen	0.4%/bitumen	1%/bitume
Aggreg. Temp	160 °C	130 °C	130 °C	130 °C	150 °C	130 °C
Sand Temp	160 °C	130 °C	130 °C	130 °C	150 °C	130 °C
Filler Temp	160 °C	130 °C	130 °C	130 °C	150 °C	130 °C
Bitume Temp	155 °C	130 °C	130 °C	130 °C	150 °C	130 °C