3rd International Symposium on Asphalt Pavements & Environment
16 AUGUST 2015, SUN CITY, SOUTH AFRICA

The influence of temperature on the performance of foamed asphalt recycled pavements

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Asphalt Pavements & Environment

The influence of temperature on the performance of foamed asphalt recycled pavements

Outline:

- Introduction
- The experiment
- Data analysis
- Conclusions

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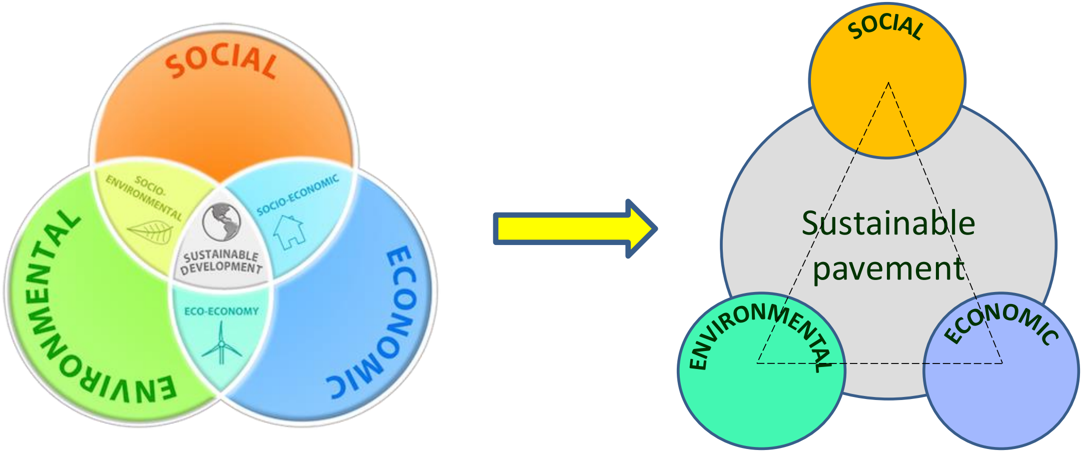
Introduction

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable pavement: **safe**, **efficient**, **economic**, **environmentally friendly**

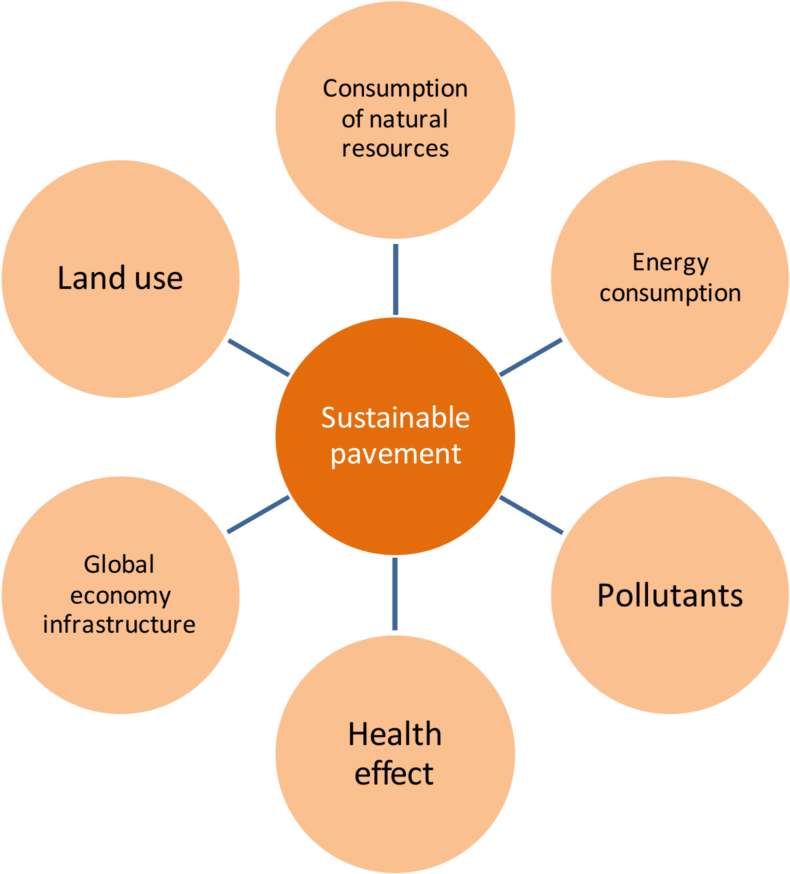


The influence of temperature on the performance of foamed asphalt recycled pavements

Introduction

Main criteria for a sustainable pavement:

- Optimizing the use of natural resources
- Reducing energy consumption and gas emissions
- Limiting pollution
- Improving health, safety and risk prevention
- Ensuring a high level of user comfort and safety



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Introduction

Cold in place recycling (CIR) addresses the above criteria, by supporting a “zero waste” approach to pavement rehabilitation where the existing road material is reprocessed and reused in place, without the necessity for offsite transportation.

The CIR technology utilizing foamed asphalt (FA), has gained popularity during the last few decades for its efficient use of salvaged construction material.

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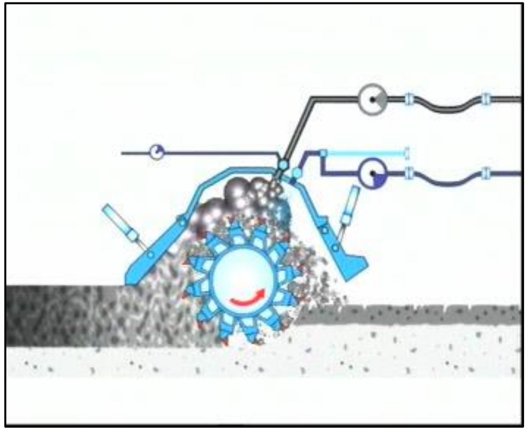
Introduction



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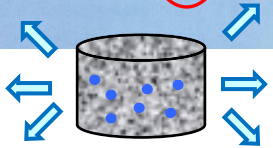
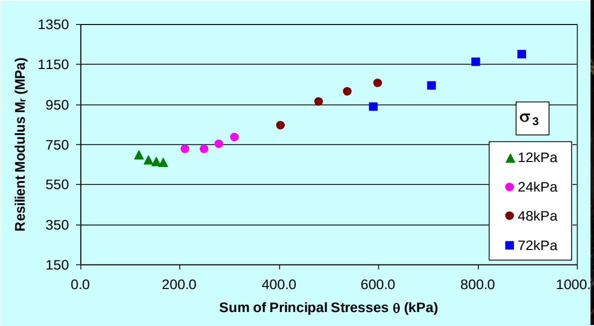
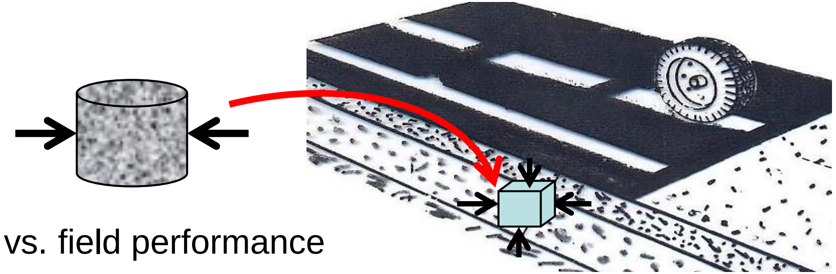


Curing issues



Stress-depended behavior?



Laboratory vs. field performance

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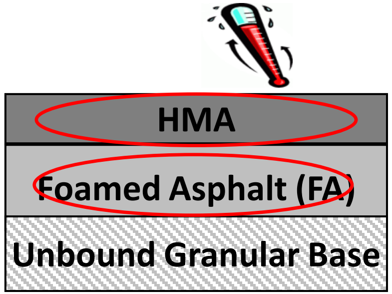
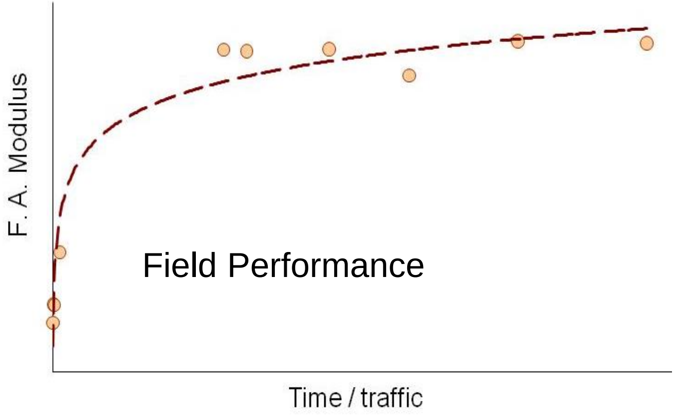
Introduction



Temperature increase
Moduli decrease

Temperature decrease
Moduli increase



Laboratory testing does not provide information about the influence of temperature on the field performance (post-curing condition).

The research aims to investigate potential changes to the structural condition of CIR pavements and therefore to the sustainability of the CIR technique.

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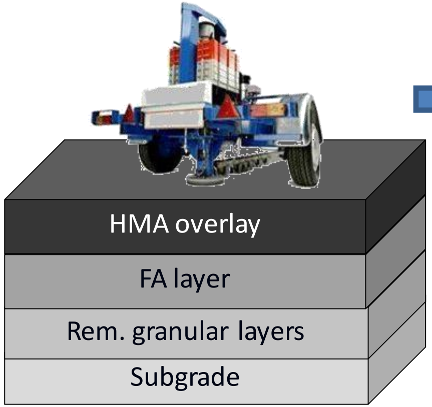
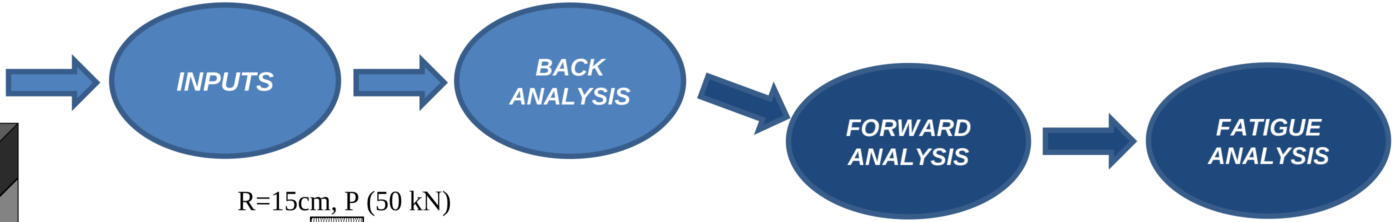
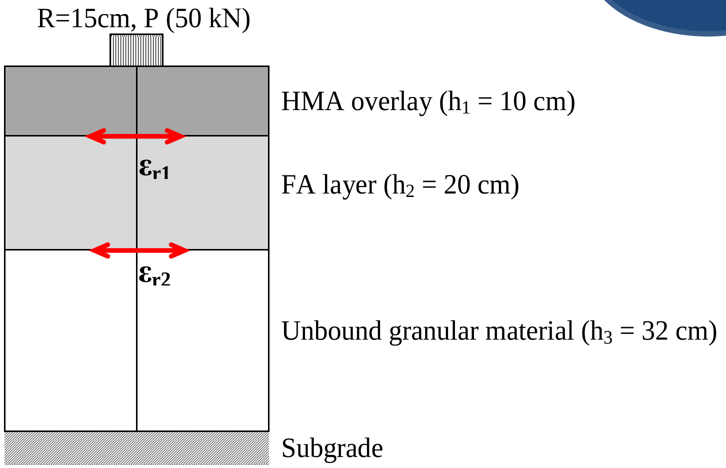
The experiment (analysis)

FWD measurements were carried out during two periods:

- Early spring (mild temperatures) HMA: 16-17°C, FA: 15-16°C
- Early summer (high temperatures) HMA: 28-33°C, FA: 28-30°C







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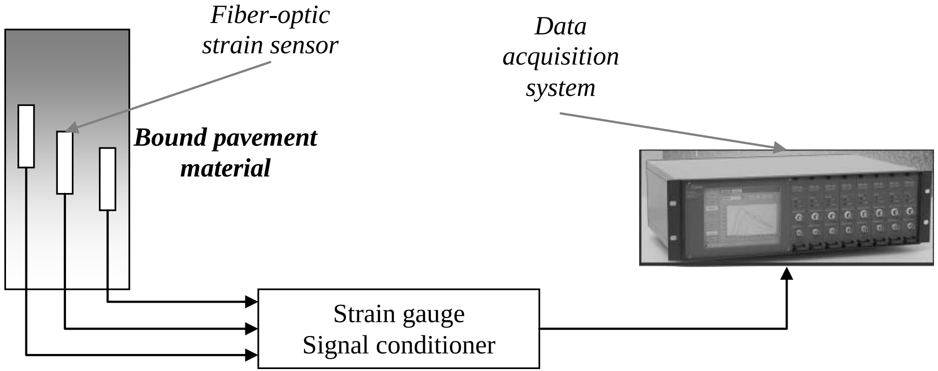
The experiment (evaluation)



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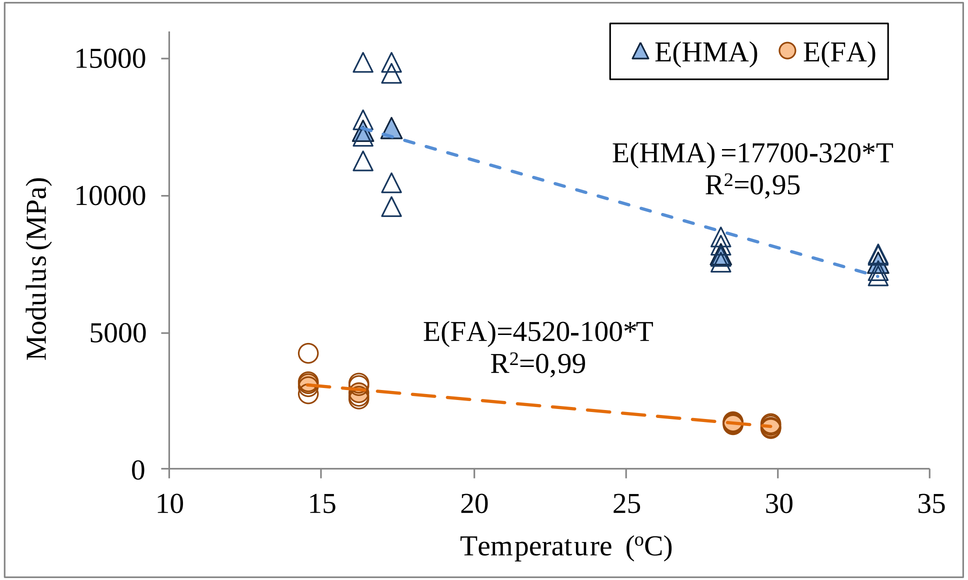
Data analysis (back-calculated moduli)

Back-calculated moduli



HMA moduli were much higher, than the FA moduli.

The reduction of the modulus was 3.2 times faster for the HMA.

FA was less sensitive to temperature changes in comparison to the HMA.

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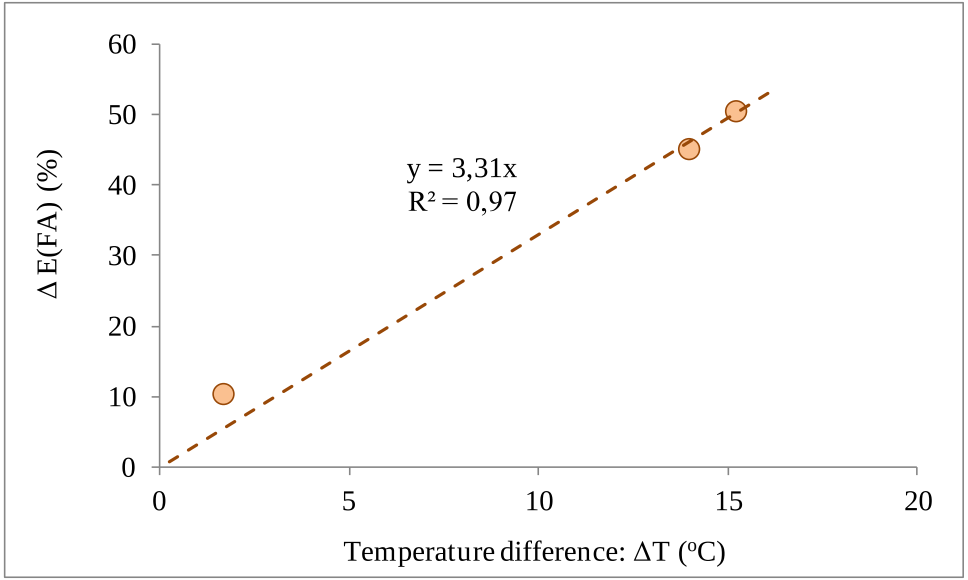
Data analysis (back-calculated moduli)

Back-calculated FA moduli differences vs. temperature difference



$\Delta E(FA) = 3.31 * \Delta T$ (1)

Due to the limited set of data, the equation is indicative

For 1°C temperature increase, a 3.3% reduction of the FA modulus is expected.

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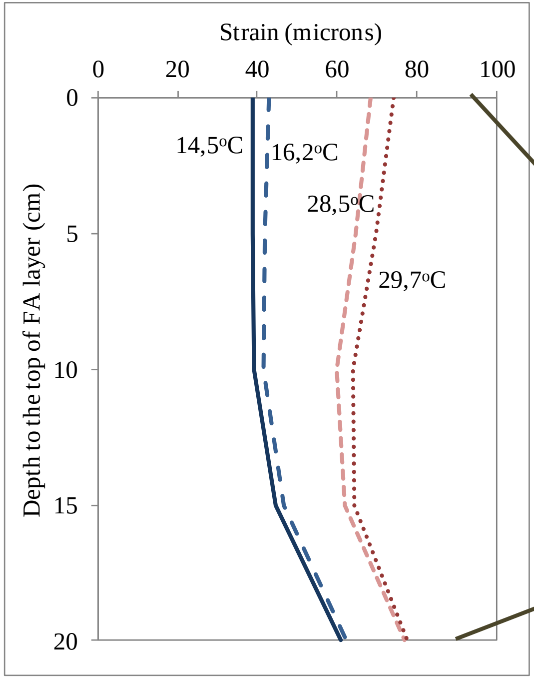
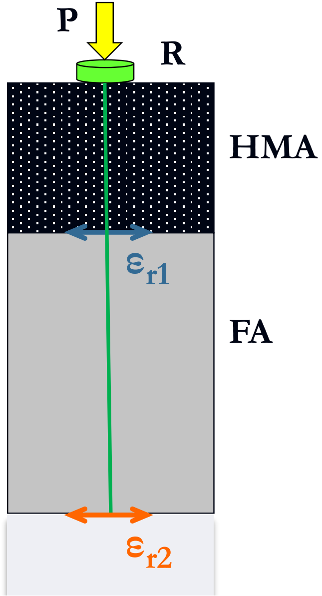
Data analysis (calculated tensile strains)





Critical locations:

at the bottom of the FA layer, as well as

at the interface between HMA overlay and FA layer (top of the FA layer)

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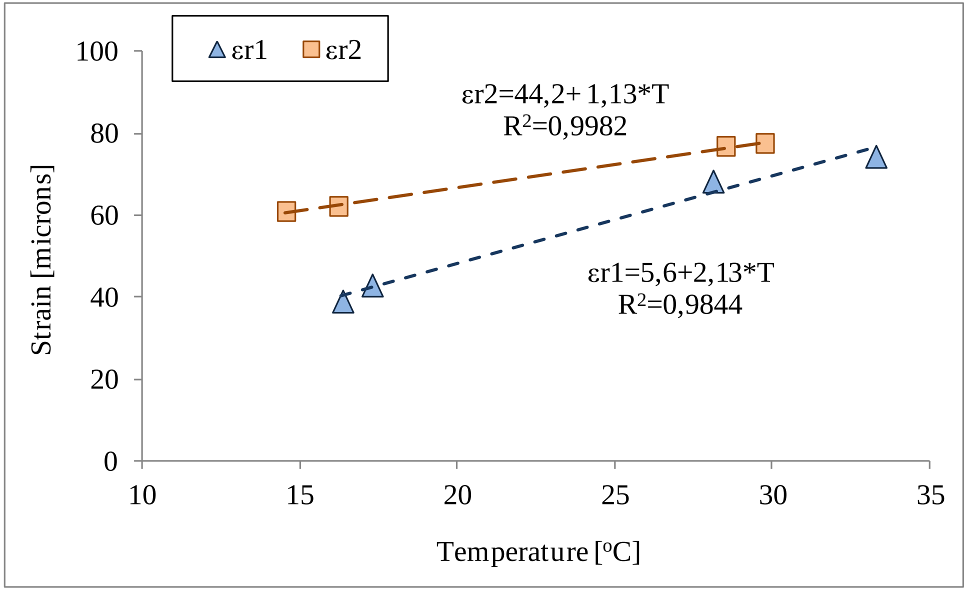
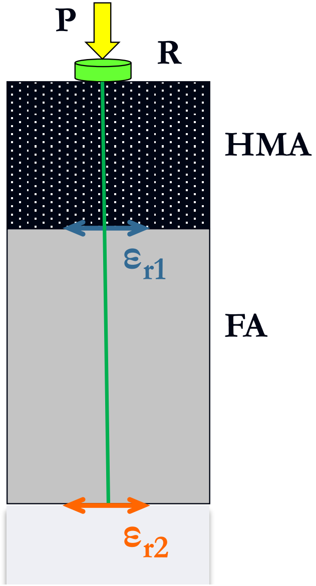
Data analysis (critical tensile strains)

Critical tensile strains





At **mild temperatures:** higher tensile strains at the bottom of the FA layer (εr_2).

At **high temperatures:** similar tensile strain values were calculated.

The tensile strains at the bottom of the FA were less sensitive to temperature changes.

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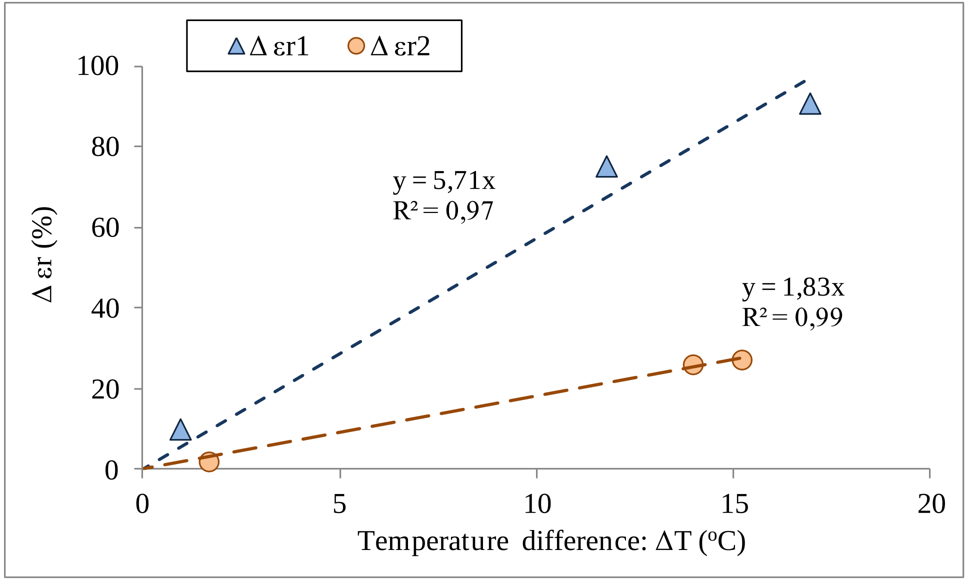
Data analysis (critical tensile strains)

Tensile strain differences vs. temperature difference



$$\Delta\varepsilon_{r1}=5.71*\Delta T \quad (2)$$

$$\Delta\varepsilon_{r2}=1.83*\Delta T \quad (3)$$

Due to the limited set of data, the equations are indicative

Eq. (3) was evaluated using the results (strains) of another road experiment.

For 1^{o}C temperature increase within the FA layer, 1.8% increase of the tensile strain at the bottom of the FA layer and 5.7% increase at the interface between HMA overlay and FA layer Is expected.

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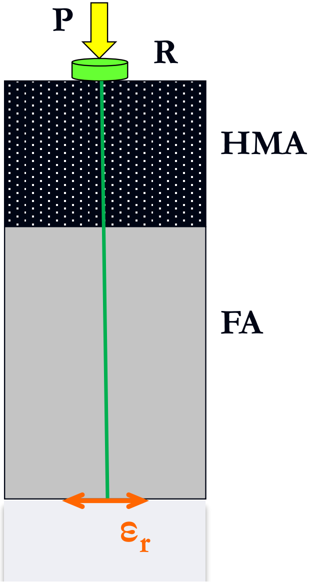
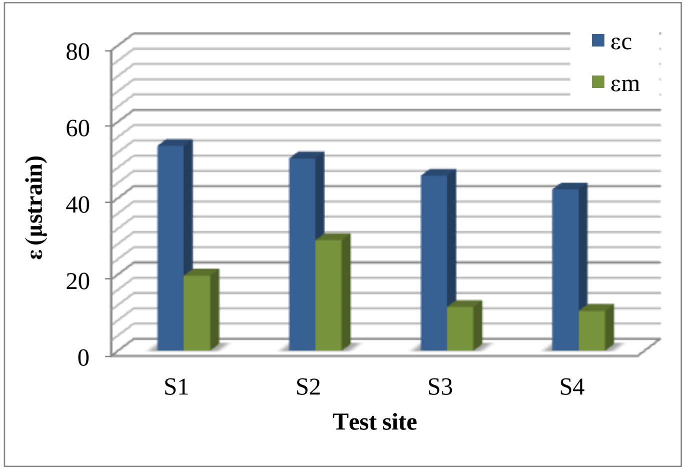
Data analysis (critical tensile strains – evaluation of eq. 3)



- Two types of CIR pavements, i.e. unbound granular layer (test sites S1 and S2), cement bound material (CBM) layer (test sites S3 and S4).
- Finite Element (FE) linear analysis for strain calculation.
- Strain measurements at 16ºC (mild temperature) and 22.5ºC (medium temperature) using Fiber Optic Sensors (FOS) system.



Tensile strains ε_r (16ºC)

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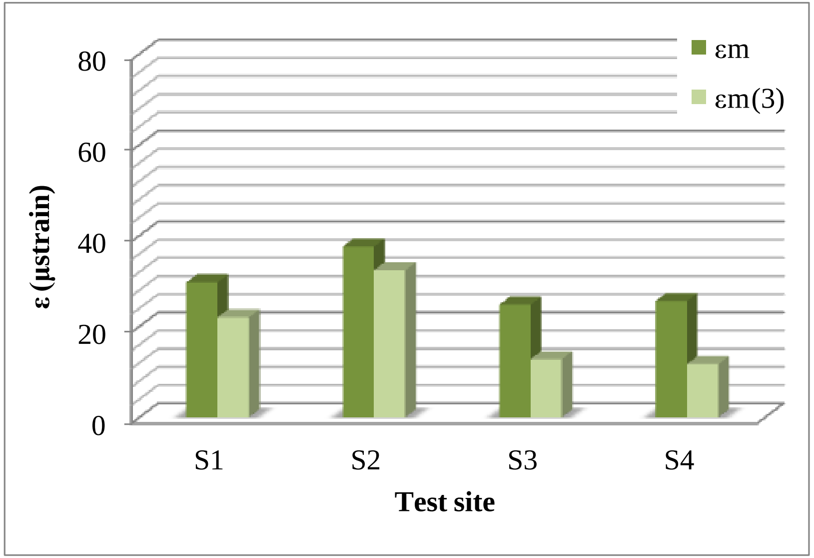
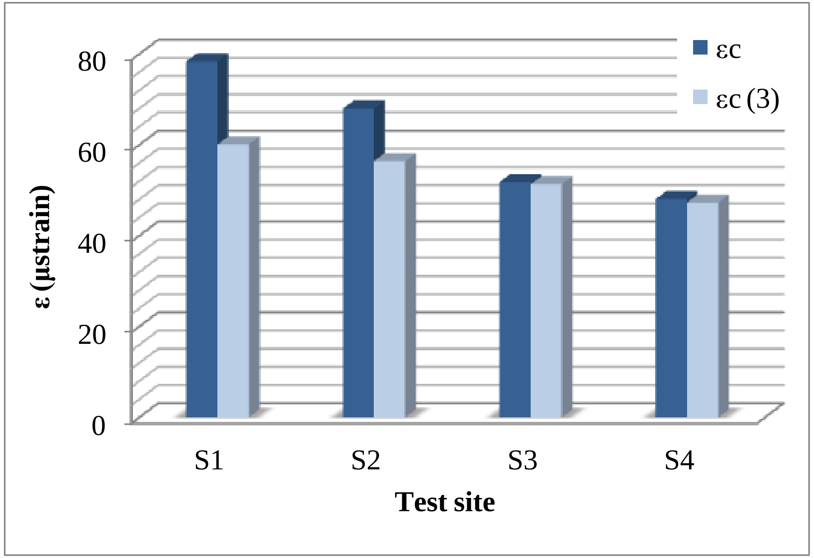
Data analysis (critical tensile strains – evaluation of eq. (3))





Measured strains (e_m) differences ranged from 14% to 54%. Better approximation of the predicted strains for test sites S1 and S2 (with unbound granular layer).

Calculated strains (e_c) differences ranged from 1% to 23%. Better approximation of the predicted strains for test sites S3 and S4 (with CBM layer).

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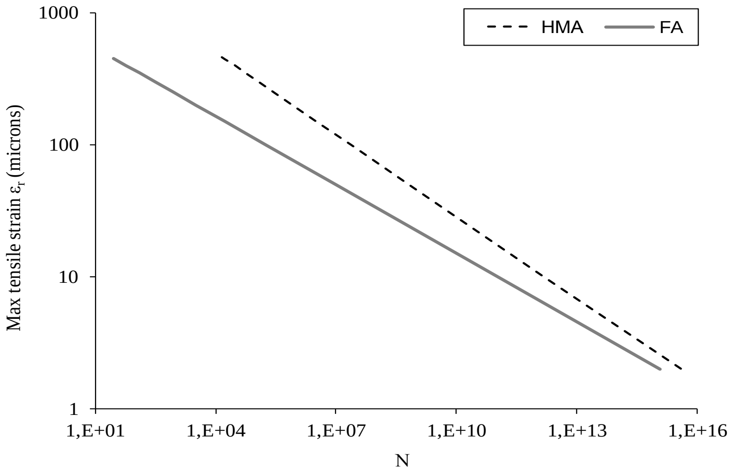
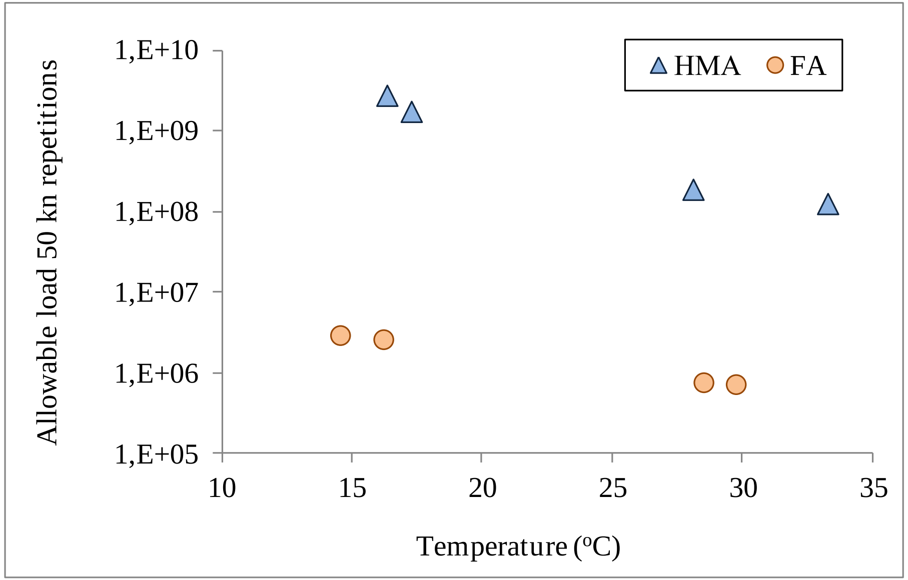
Data analysis (fatigue characteristics)





$N_{FA}=a*\varepsilon_{r2}^{\,b}$ (4) $N_{HMA}=c_1*\varepsilon_{r1}^{\,c2}$ (5)

Allowable load repetitions: N_{HMA} >> N_{FA}.

The differences were more pronounced at mild temperatures (N_{HMA} / N_{FA} = 939 to 667). At high temperatures: N_{HMA} / N_{FA} = 247 to 173.

FA layer is more susceptible to fatigue cracking than the HMA overlay.

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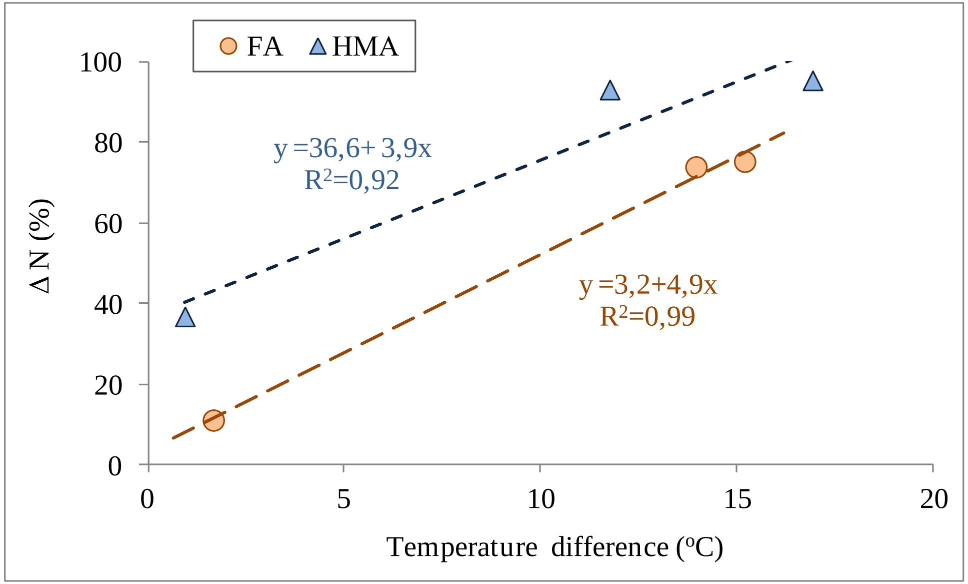
Data analysis (fatigue characteristics)

Load repetitions differences vs. temperature difference



Percentage difference of the load repetitions from the related ones calculated at lower temperatures (Δ N) with respect to the temperature difference

At higher temperatures, the allowable load repetitions (N_{HMA}) were approximately 94% reduced in comparison with the relative ones at mild temperatures, while the reduction of the allowable load repetitions (N_{FA}) was approximately 75%.

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Conclusions

- FA recycled material was less sensitive to temperature changes in comparison to the HMA. This can be attributed to the lower asphalt content of the FA material.
- The tensile strains at the bottom of the FA layer were less sensitive to temperature changes.
- The allowable load repetitions of the HMA were much higher, than FA material. The differences were more pronounced at mild temperatures.
- The HMA overlay and the FA layer sustain significantly more damage from traffic loads at high temperatures. This effect was more pronounced regarding the damage of the of the HMA overlay.

The latest should be taken into account during the pavement design for application in mild to high temperature climate conditions in order to ensure the sustainability of the CIR pavement.

Moreover, in order to contribute towards the influence of the pavement temperature variation and consequently towards the sustainability of the FA technique, continuous field monitoring and related analysis is needed.

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THANK YOU FOR YOUR ATTENTION!

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