Promoting induction heating asphalt mixes HEALROAD

Part: 1-1 – HEALROAD laboratory research

Part: 1-2 – Full-scale demonstrator

Part: 2 – Onsite visit to duraBASt and HEALROAD demonstration

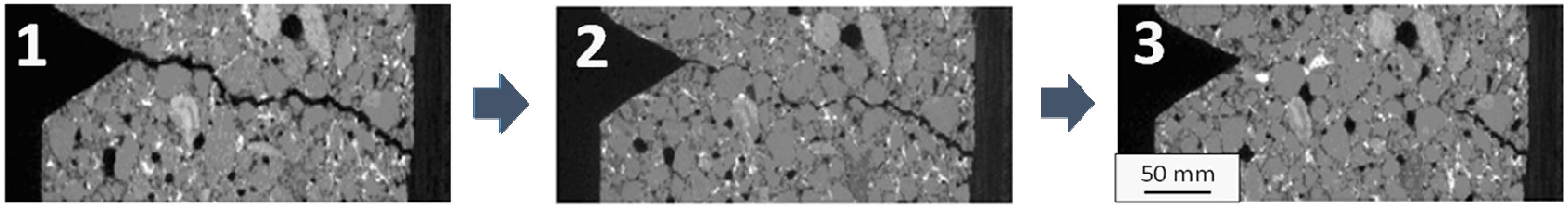
October 26th 2017

Agenda

9:00 – 9:15	**Introduction**
9:15 – 10:00	**HEALROAD laboratory research (mixes and induction energy) -** UC and UoN
10:00 – 10:30	**Full scale demonstrator (asphalt production, construction and accelerated pavement testing) -** SGS, HEIJMANS and BASt
10:30 – 12:00	**Onsite visit to duraBASt facility and HEALROAD demonstration***

Background / Concept of self-healing

- Asphalt mixture is a natural self-healing material. When a crack is open in the road structure, it can close (heal) when enough temperature and time without traffic are provided.
- However, this process requires days for a complete healing, which in practice is impossible due to continual traffic flow.

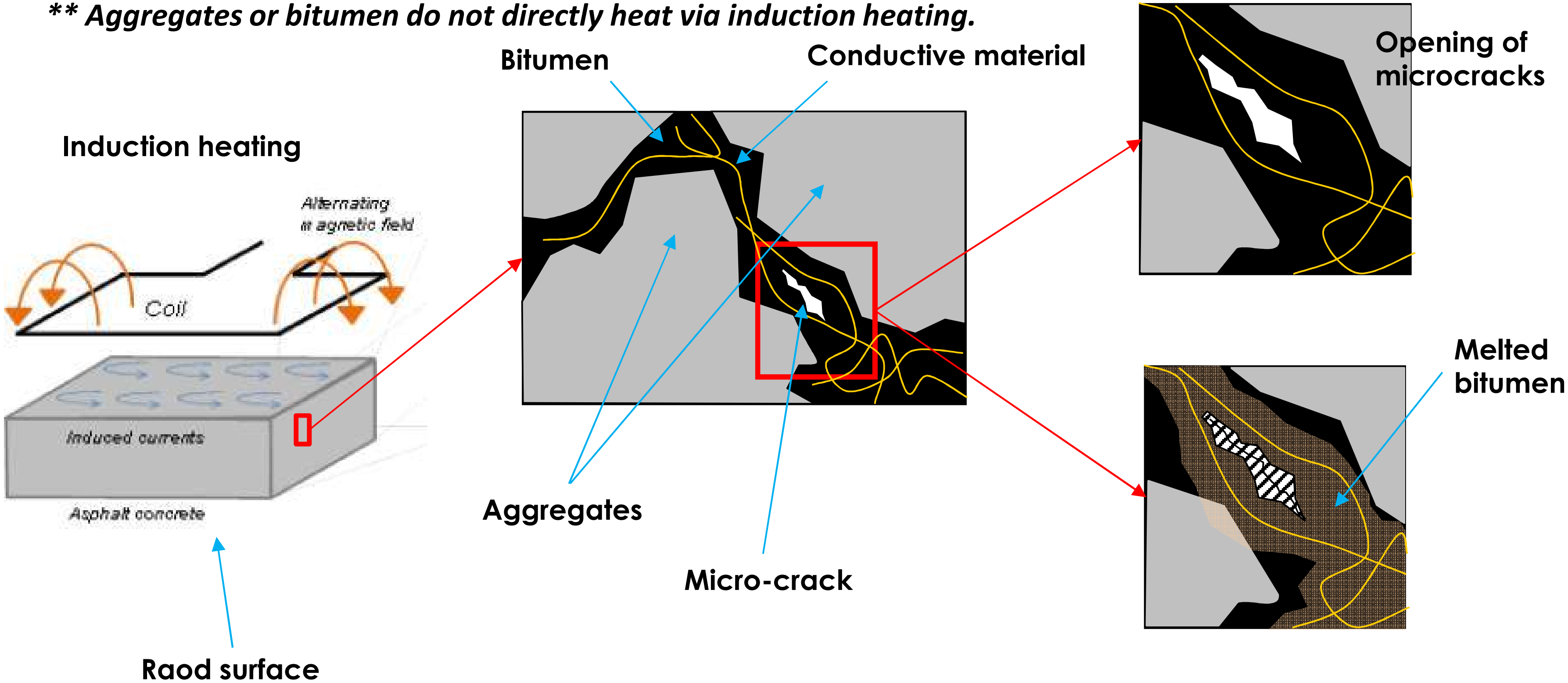


Source: A.García (UoN)

- Self-healing of asphalt mixes can be accelerated by means of induction heating, a technique used to increase the temperature of electrically conductive and magnetic susceptible materials.

Background / Concept of self-healing

***** Aggregates or bitumen do not directly heat via induction heating.***



HEALROAD: **Problems addressed**

- Temperature at which optimal self-healing is obtained.
- When to apply self-healing?
- Quantification of service life extention
- Adequate use of the induction healing device (parameters).
- Impact of aging in healing performance
- Quantification of the energy needed.
- Solve the clusters when upscaling.

Main goal of HEALROAD

- *The overall objective of the project is the **further development** and the **technical, economic and environmental validation** of healable asphalt mixes via induction heating to **overcome the technical barriers for the future industrialization** and market uptake.*

Consortium / partners

PROJECT COORDINATOR
UNIVERSIDAD DE CANTABRIA (UC)

EUROPEAN UNION ROAD FEDERATION (ERF)

UNIVERSITY OF NOTTINGHAM (UoN)

HEIJMANS INFRA B.V. (HEIJMANS)

BUNDESANSTALT FÜR STRAẞENWESEN (BAST)

SGS INTRON B.V. (SGS)

Scientific & Technical Objectives

1. **Understand** the main **chemical and rheological factors** influencing the movement of bitumen through cracks in order to identify the most suitable bitumen for this application.
2. **Optimize** from the technical, economic and environmental point of view the parameters that most influence the induction heating of the asphalt mixture: **magnetic material and air voids**.
3. **Optimal design of asphalt mixes** from the healing capacity and durability point of view.
4. **Ensure the recyclability** of the HEALROAD mixes by defining the amount of virgin material needed to restore the asphalt mixture properties, including its healing capacity.
5. **Scaling up the production** of HEALROAD mixes in a real asphalt plant.

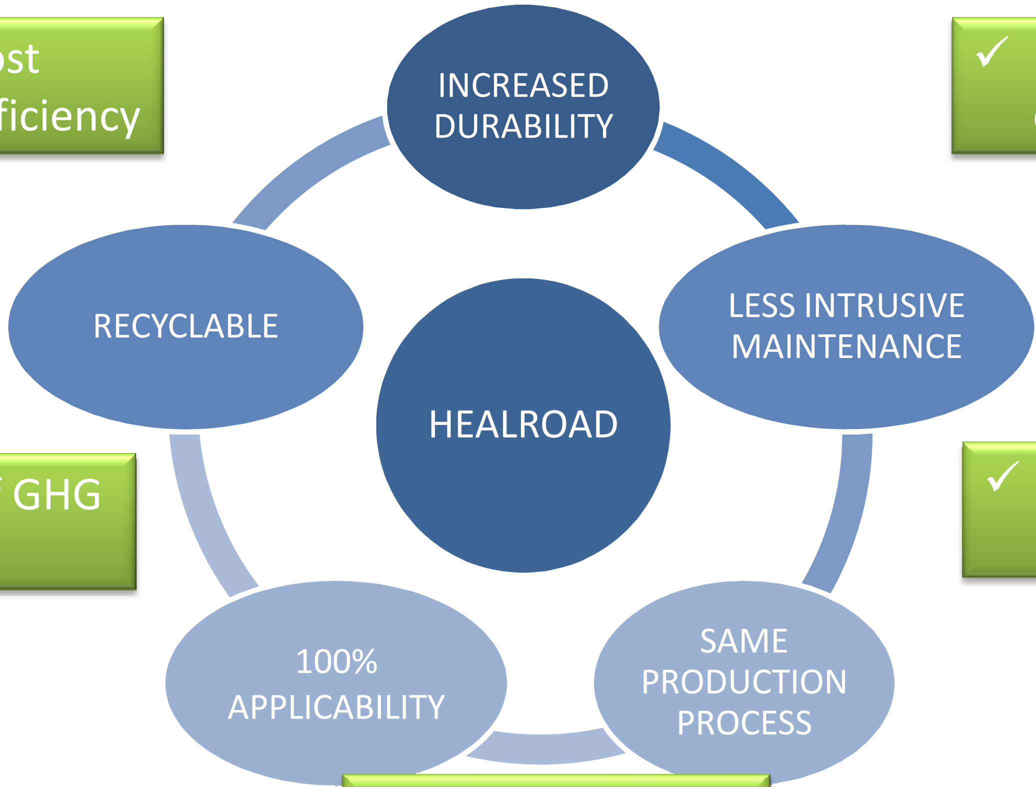
Scientific & Technical Objectives

6. **Demonstration** of the solution proposed:
   - Demonstrating the healing capacity of a real scale test section through and **Accelerated Pavement Testing**.
   - Economic and environmental feasibility through a **LCA and LCC analysis**.

Promoting induction heating asphalt mixes - HEALROAD

Expected **results and Impacts**

- ✓ Cost efficiency
- ✓ Resource efficiency



- ✓ Reduction of GHG emissions
- ✓ Accessibility and reliability
- ✓ Competitiveness

Funders

Infravation

An Infrastructure Innovation Programme

TRANSNATIONAL COLLABORATION OF 11 COUNTRIES
AND THE EC ON ROAD INFRASTRUCTURE INNOVATION

An ERA-NET Plus Call to support development of advanced systems, materials and techniques for road infrastructure under seven defined challenges

Rijkswaterstaat
Ministry of Infrastructure and the Environment

Federal Ministry of Transport and Digital Infrastructure

Road Directorate

Statens vegvesen

TRAFIKVERKET

VEGAGERÐIN

Centro para el Desarrollo Tecnológico Industrial

ANAS

NETIVEI ISRAEL

FEHRL

TÜVRheinland®
Precisely Right.

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

An ERA-NET Plus with funding from the European Union under grant agreement no 618109.

Promoting induction heating asphalt mixes HEALROAD

Part: 1-1 – HEALROAD laboratory research

October 26th 2017

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HEAL ROAD

Induction heating technique to increase road durability and reduce maintenance costs and disruptions.

Breixo Gómez Meijide

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Type of bitumen

Fundamental analysis

	Bitumen type				
	P49	**S46**	**S70**	**T44**	**T73**
Surface tension [$mJ \cdot m^{-2}$]	25.5	24.5	24.7	23.2	24.5
Density at 25 ° C [$kg \cdot m^{-3}$]	1025	1034	1020	1026	1020
Volumetric thermal expansion coefficient [10^{-4} K^{-1}]	6.12	6.64	6.69	6.14	6.30
Viscosity at 100 ° C [Pa s]	3.93	2.87	2.00	3.90	2.36
Saturate content [%]	4.9 ±02	4.7 ±0.2	5.3 ±0.2	4.9 ±0.2	4.1 ±0.2
Aromatic content [%]	41.8 ±1.4	43.2 ±1.5	43.3 ±1.8	43.3 1.8	51.1 ±2.1
Resin content [%]	35.6 ±1.3	35.9 ±1.3	37.7 ±2.0	36.1 ±1.5	33.1 1.6
Asphaltene content [%]	15.8 ±0.4	15.8 ±0.6	13.7 ±0.3	15.5 ±0.6	11.0 ±0.4
Wax content [%]	0.5	1.7	3.6	2.2	0.9
MMHC [-]	2.203	2.214	2.197	2.203	2.203

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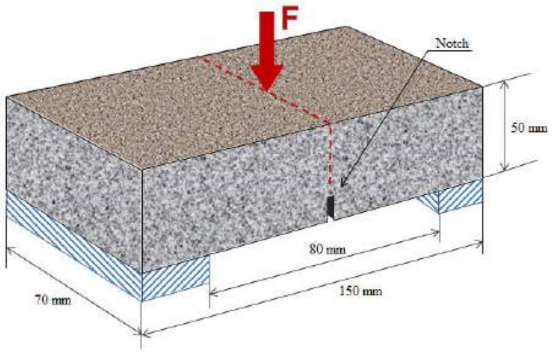
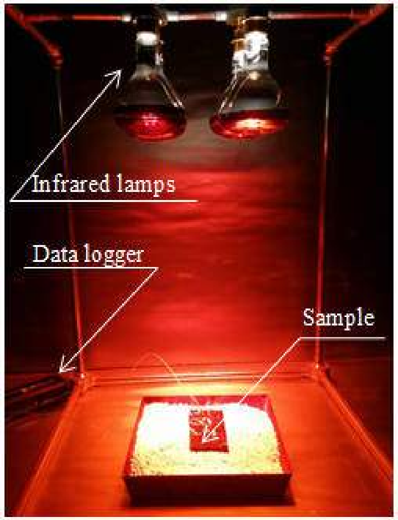
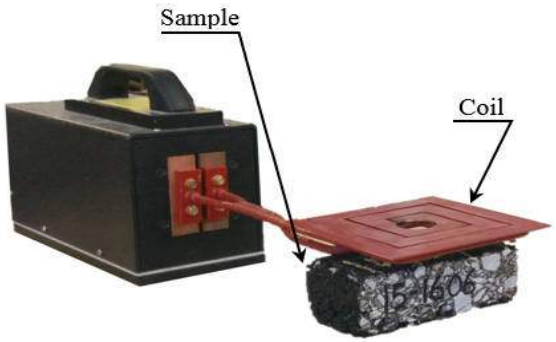
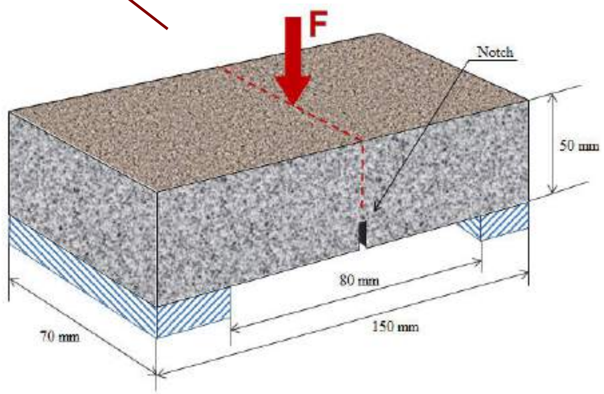
Fundamental analysis



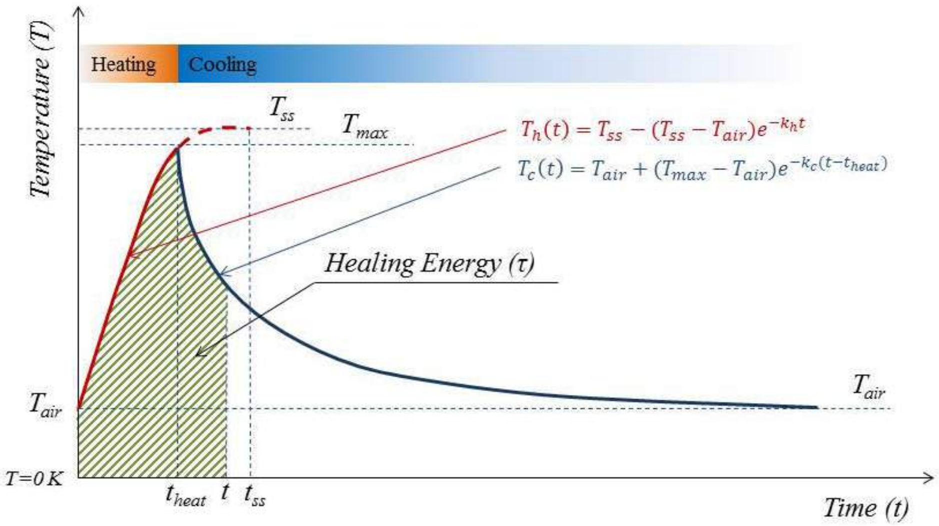
$$\frac{F_f}{F_i} = HR(\%)$$







Fundamental analysis

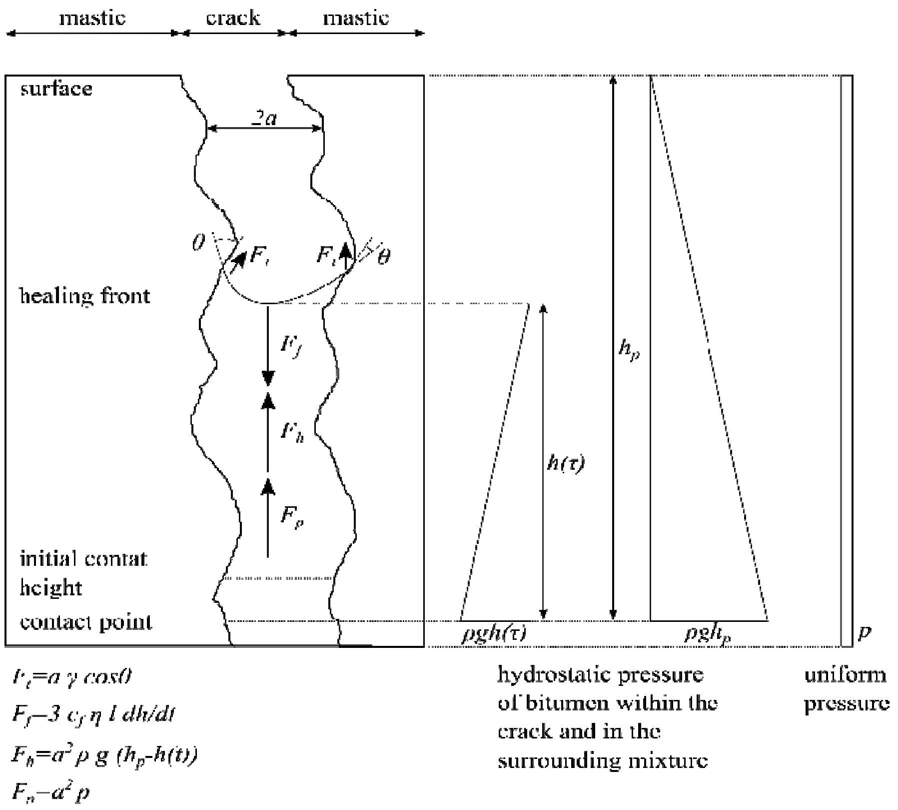


$$\tau(t) = \tau_h(t_{heat}) + \tau_c(\Delta t)$$

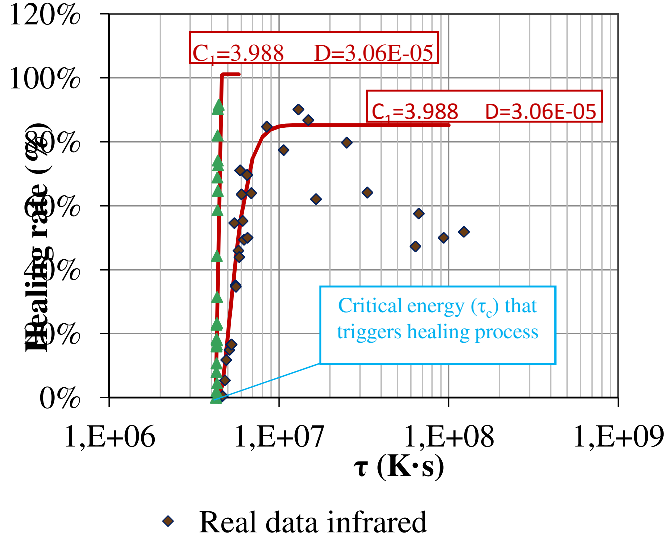
$$\tau_h(t) = T_{ss} \cdot t + \frac{T_{ss} - T_{air}}{k_h}\left(e^{-k_h t} - 1\right) \qquad ; \; t < t_{heat}$$

$$\tau_c(t) = T_{air} \cdot (t - t_{heat}) + \frac{T_{max} - T_{air}}{k_c}\left(1 - e^{-k_c(t - t_{heat})}\right) \qquad ; \; t > t_{heat}$$

Fundamental analysis



$$S(\tau) = \frac{C_1}{F_0} \cdot e^{-D\tau}\left(-1 + e^{\frac{D\tau}{2}}\right)^2$$



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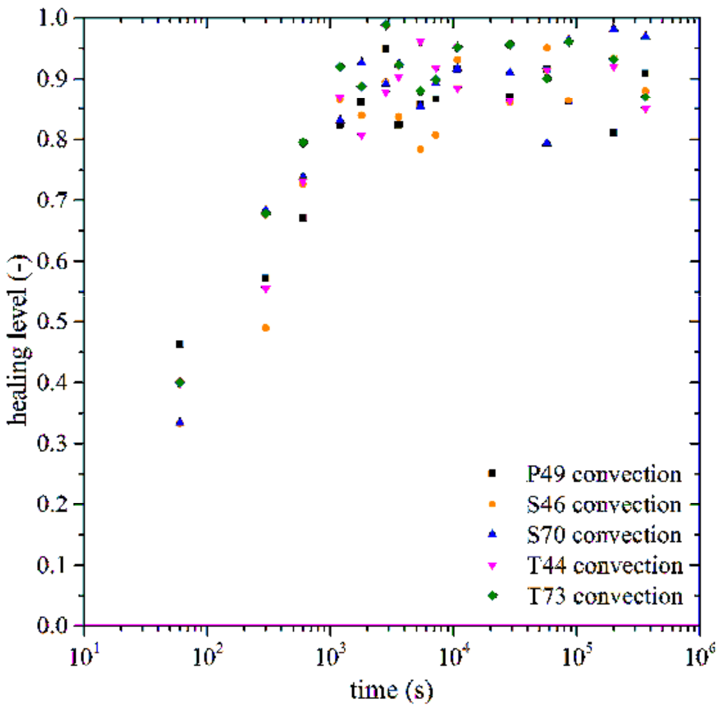
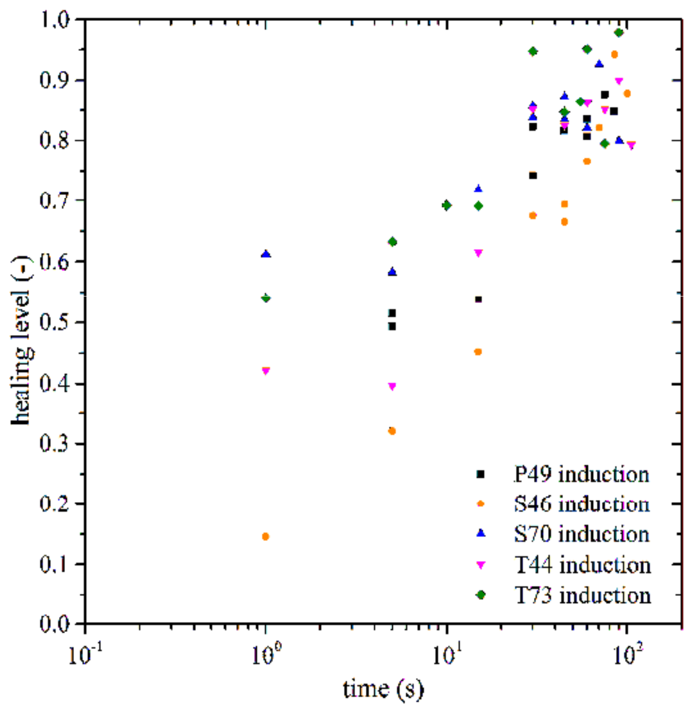
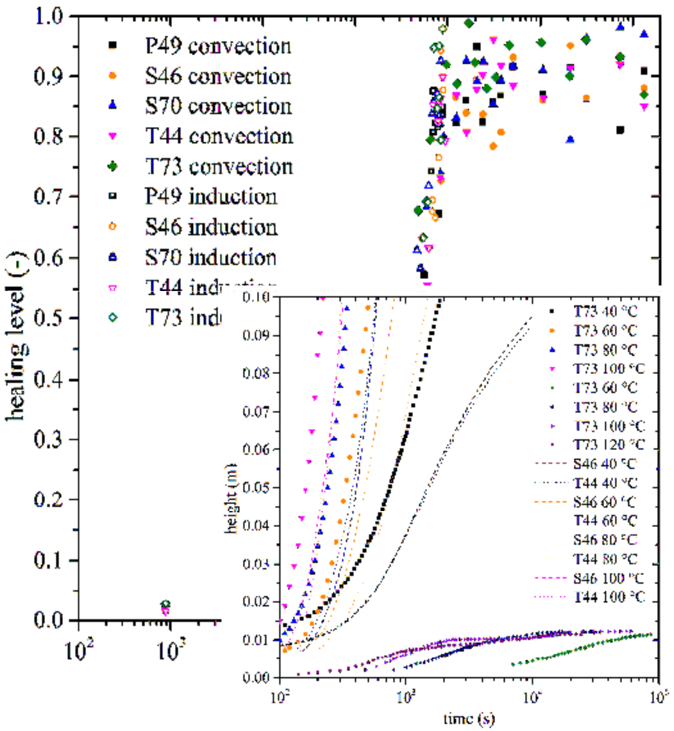
Type of bitumen





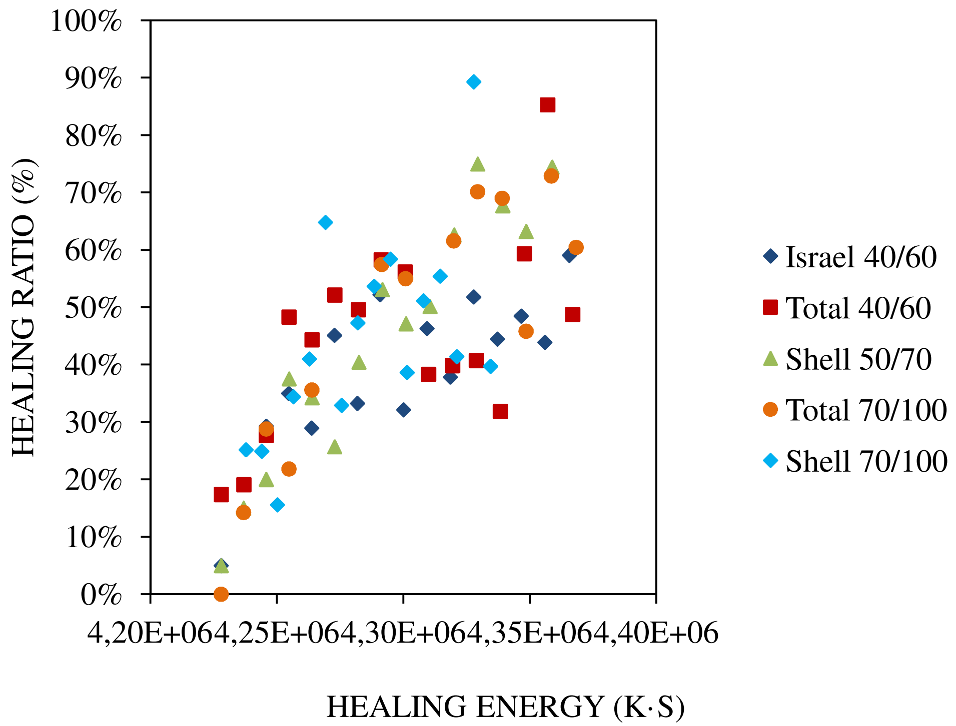
Type of bitumen



- Penetration grade
- Viscosity
- Density
- Thermal expansion
- Fractional distribution (SARA)
- Attenuated Total Reflection Fourier Transformed Infrared Spectroscopy
- Capillary tests

No significant correlation with any of these factors for the studied types of bitumen

Type of bitumen



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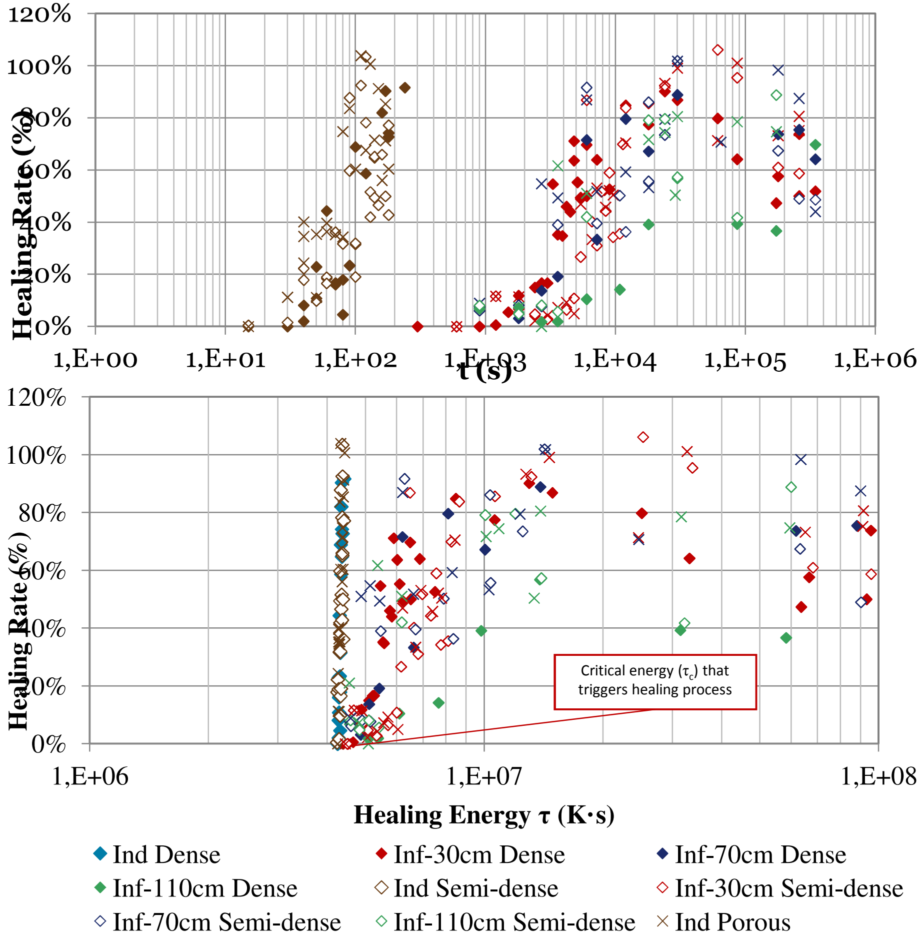
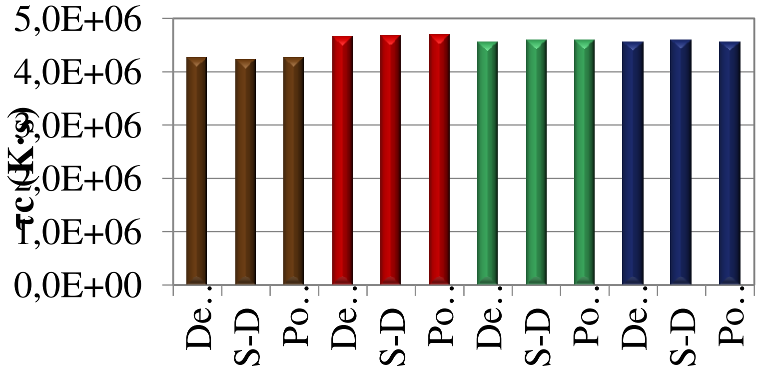
Heating method

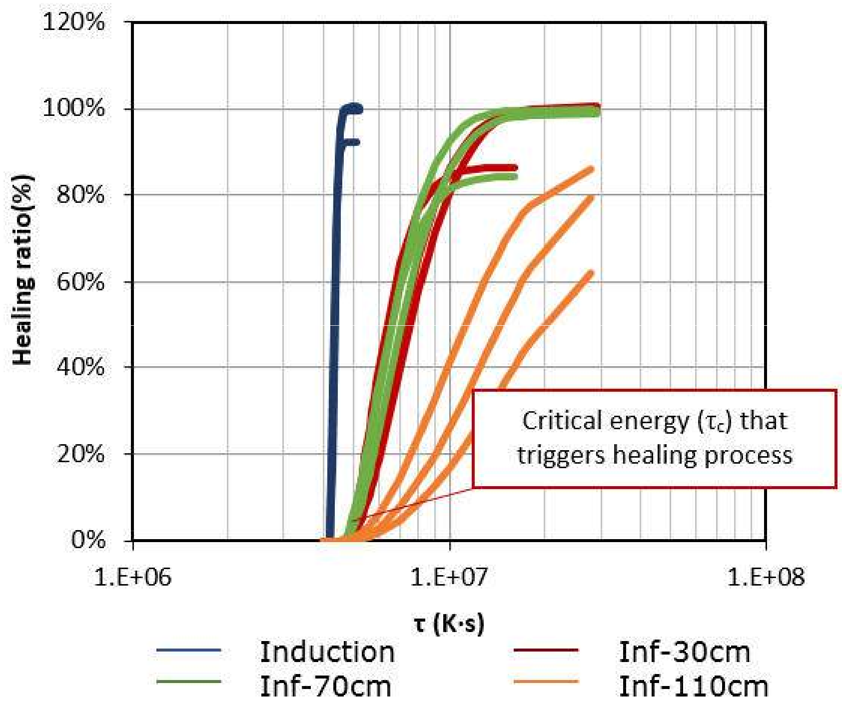
Heating method





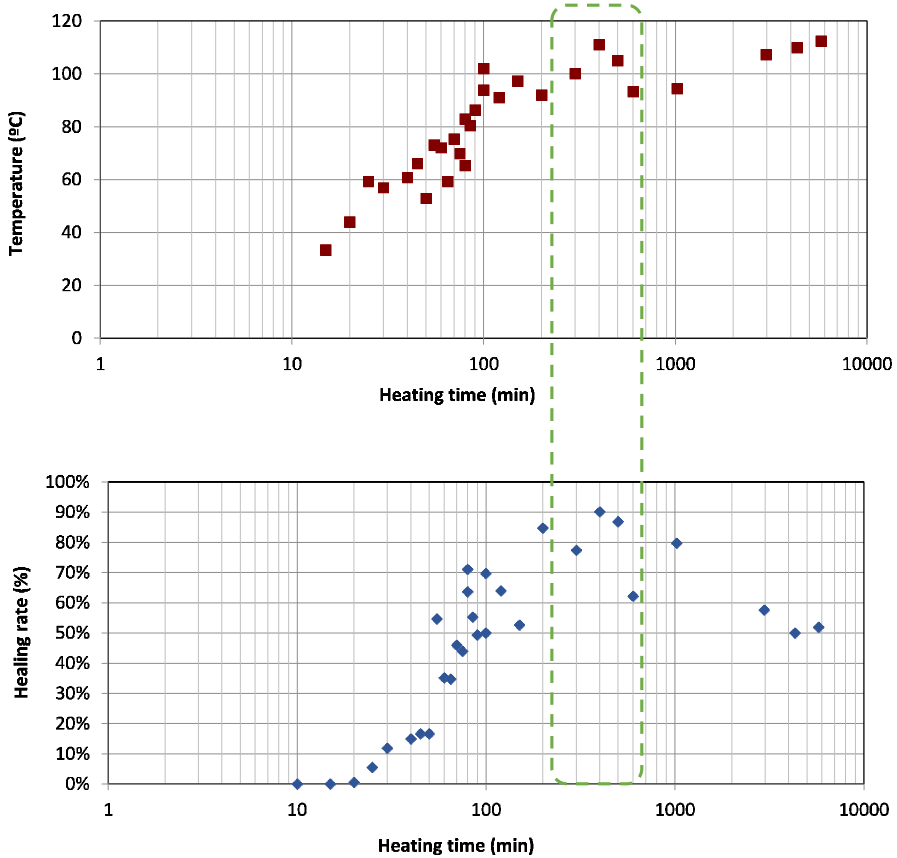
Induction method faster and more energy efficient

Heating method



There is a minimum temperature required for an effective and efficient healing

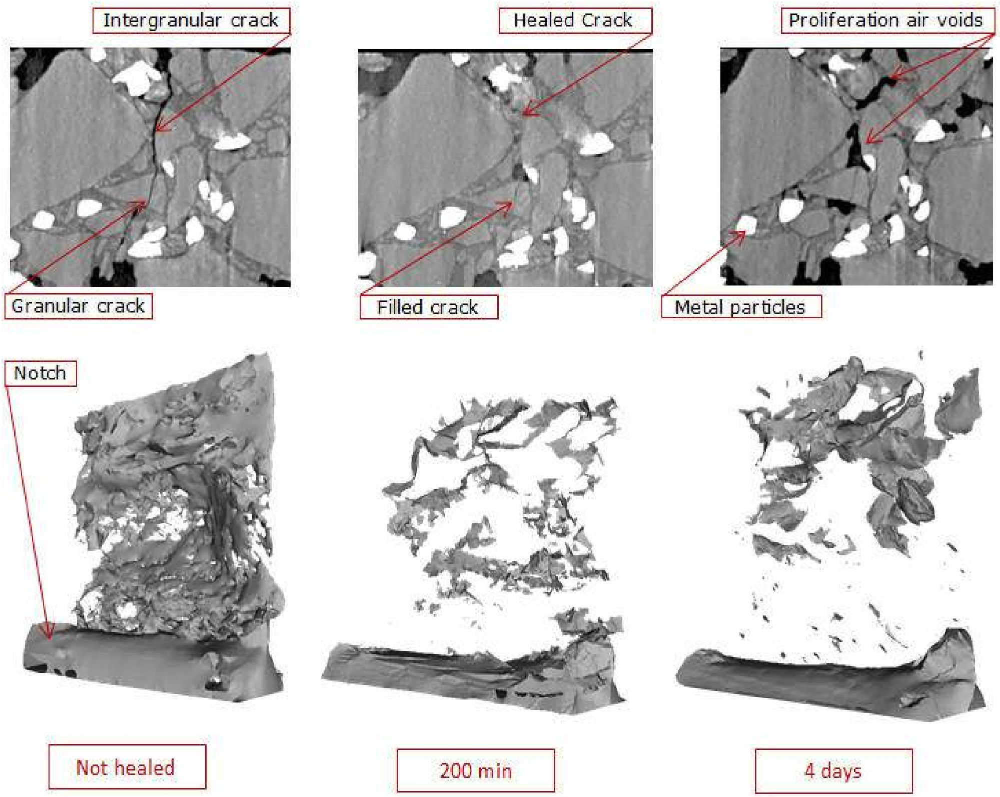
Heating method



Steady-state temperature

Decreasing healing

Heating method



There is an optimum heating time

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Types of conductive particles

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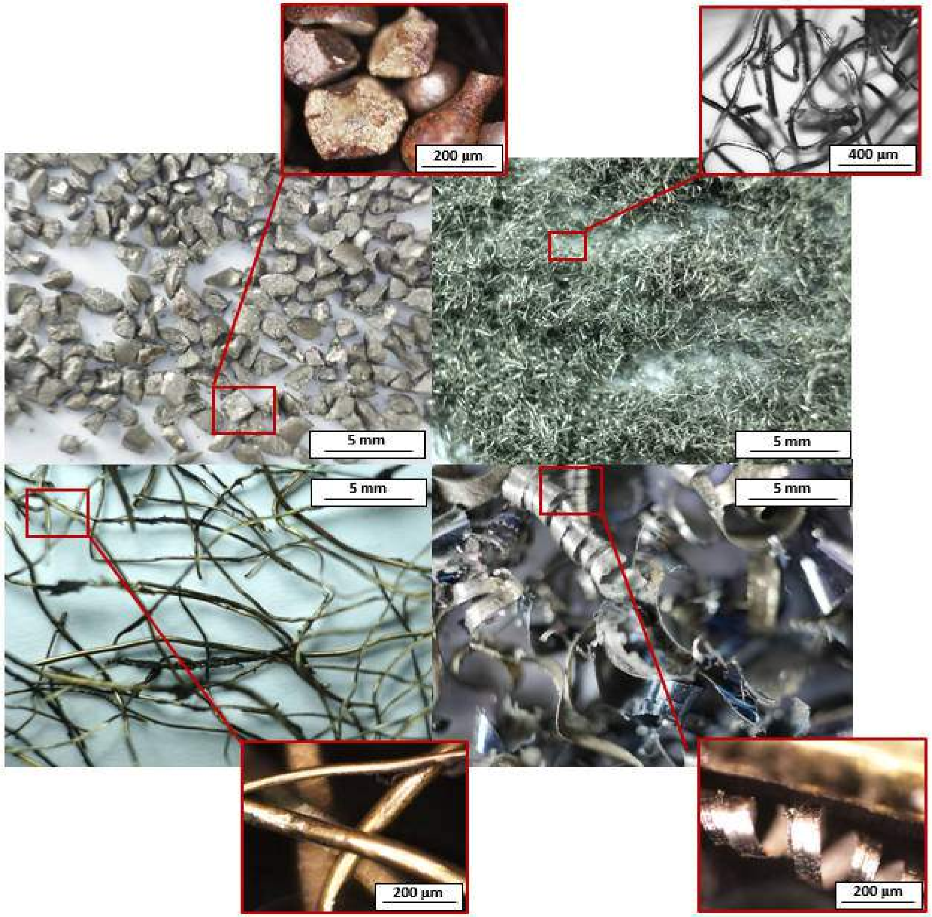
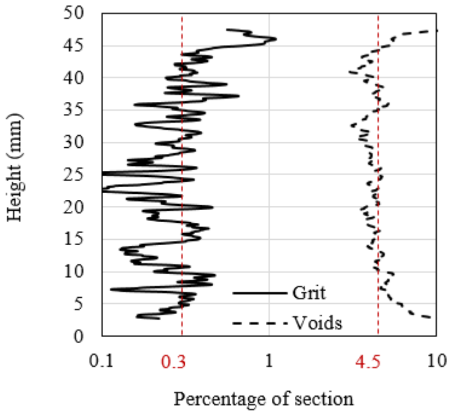
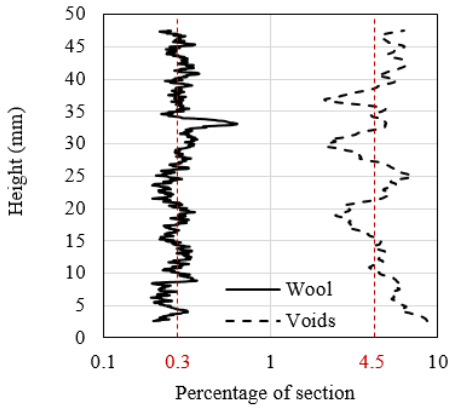
Type of conductive particles

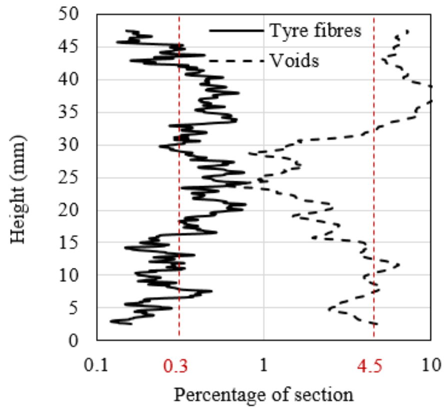


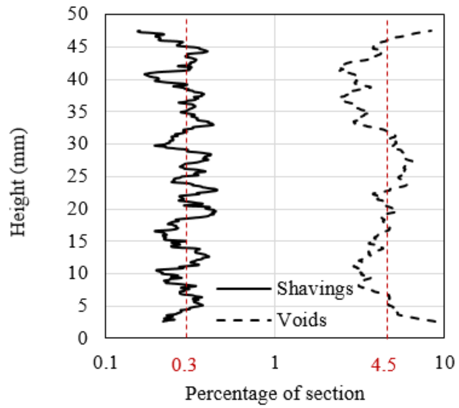
Reductions in economic and environmental impact through the use of metal waste

Type of conductive particles









Grit

Wool

Tyre

Shavings

Type of conductive particles

		Type of fibre			
		Grit	Wool	Tyre	Shavings
Volumetric properties	- Density	▲	▲	▲	▲
	- Air voids	●	●	●	●
	- Homogeneity of mix	●	●	▼	●
Mechanical properties	- Indirect tensile strength	▲▲	▲	▲	▲
	- Resistance to water damage	▼▼	▼	●	●
	- Stiffness modulus	▲	▲	▲	▲
	- Particle loss resistance	▼	●	▼	●
	- Skid resistance	▲▲	▲	▲▲▲	▲▲
Healing properties	- Induction heating capacity	▲▲	▲▲	▲▲▲	▲
	- Self-healing properties	▲▲▲	▲▲	▲▲*	▲

▲Increase ▼Decrease ● No significant effect (x1 – Slight effect; x2 –Moderate effect; x3 – Strong effect)
*Due to test configuration, results in real roads are expected to be better that those observed in the present investigation

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Aging and RAP content

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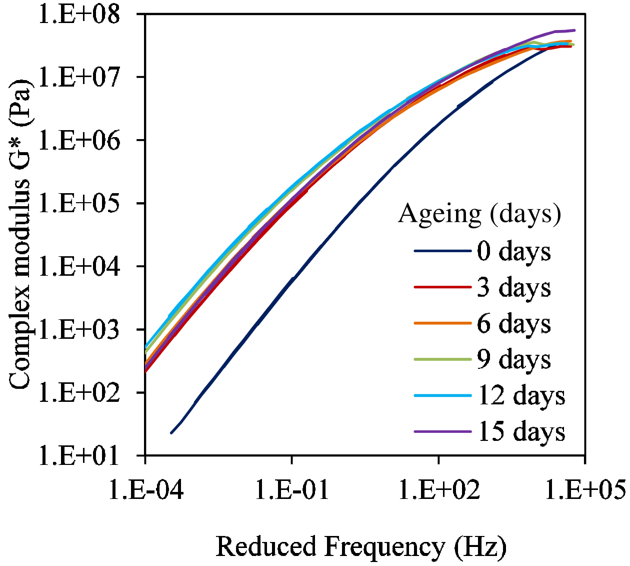
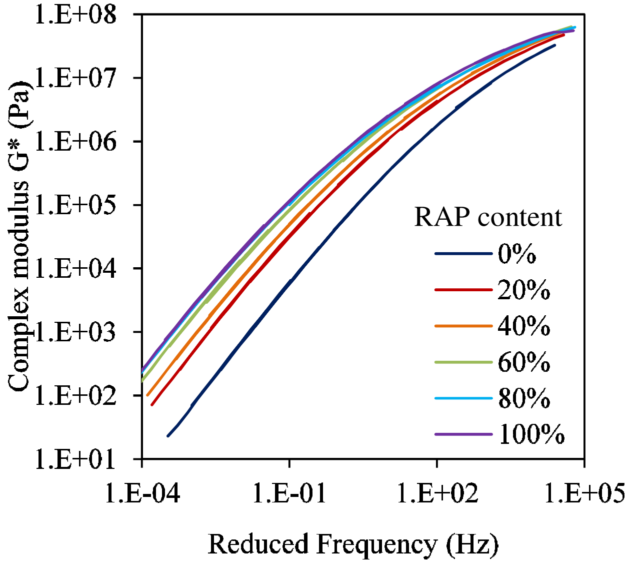
Aging and RAP content

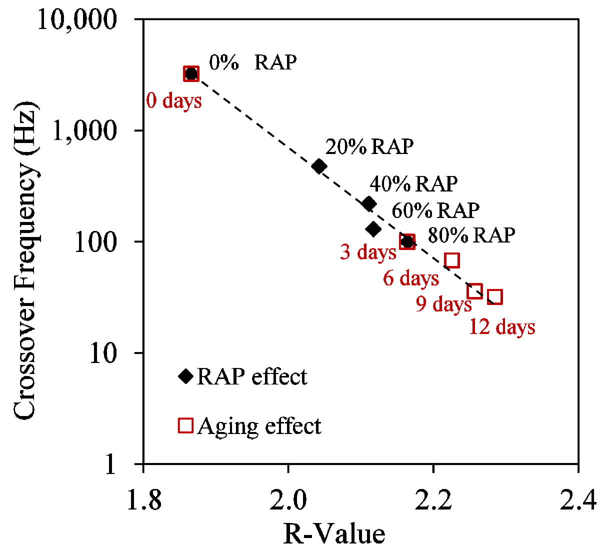
Mix	RAP content in mix (%)	Ageing after compaction (days)	
1	0	0	New road (control)
2	0	3	Effect of ageing process during the service life of the road
3	0	6	
4	0	9	
5	0	12	
6	0	15	
7	20	0	Effect of mixing aged material (RAP) with new material for a new road
8	40	0	
9	60	0	
10	80	0	
11	100	0	

Aging and RAP content

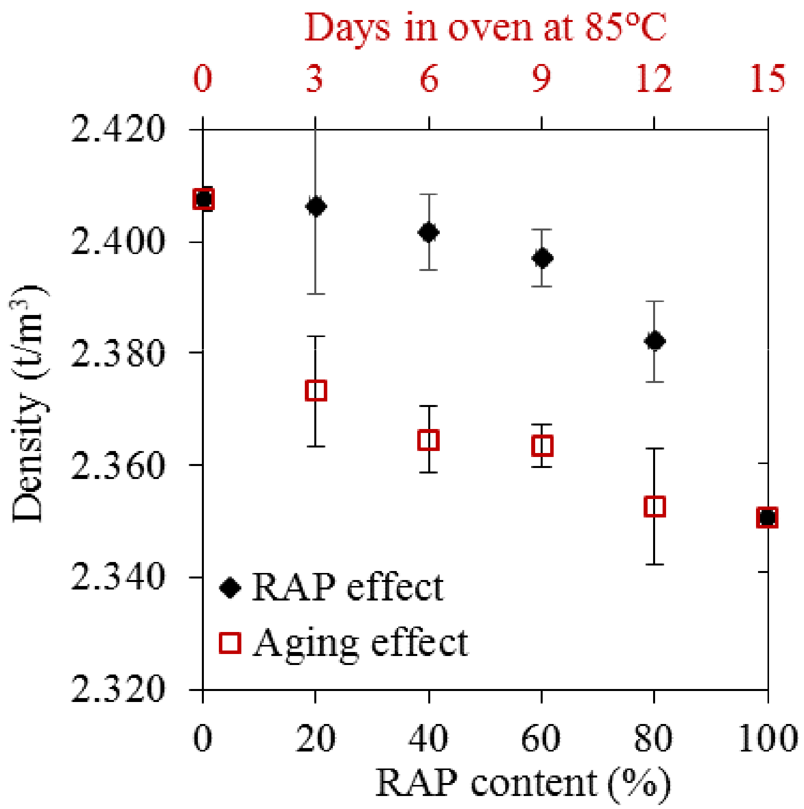


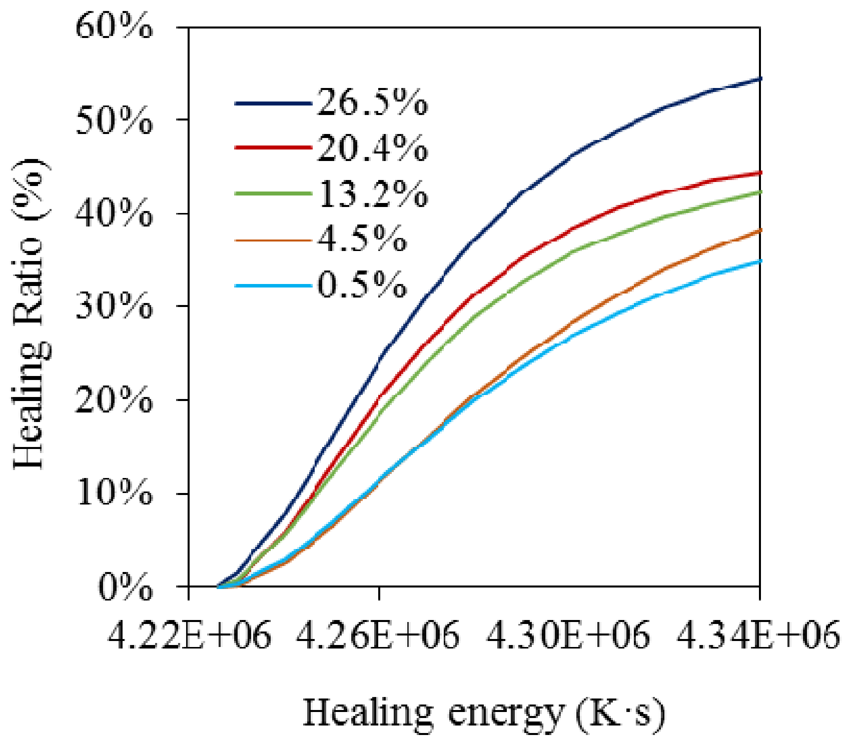


Great effect first days

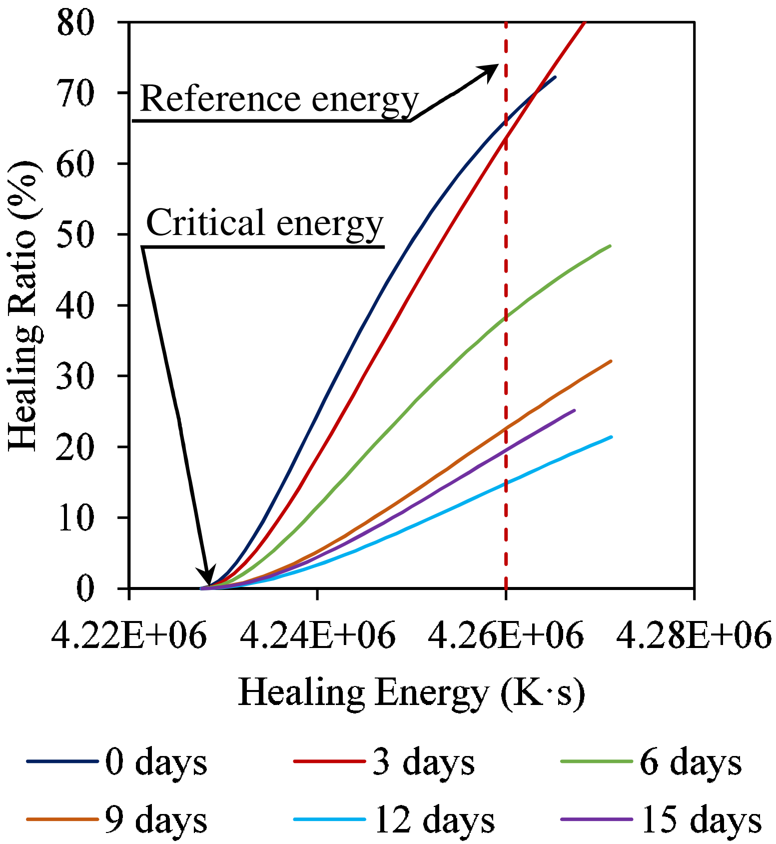


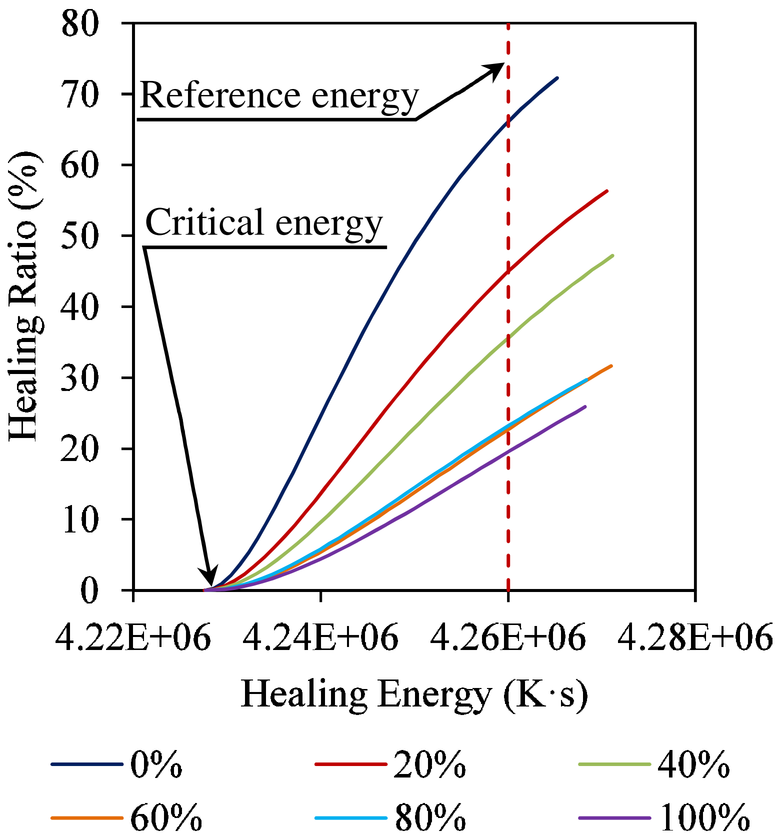
Aging and RAP content



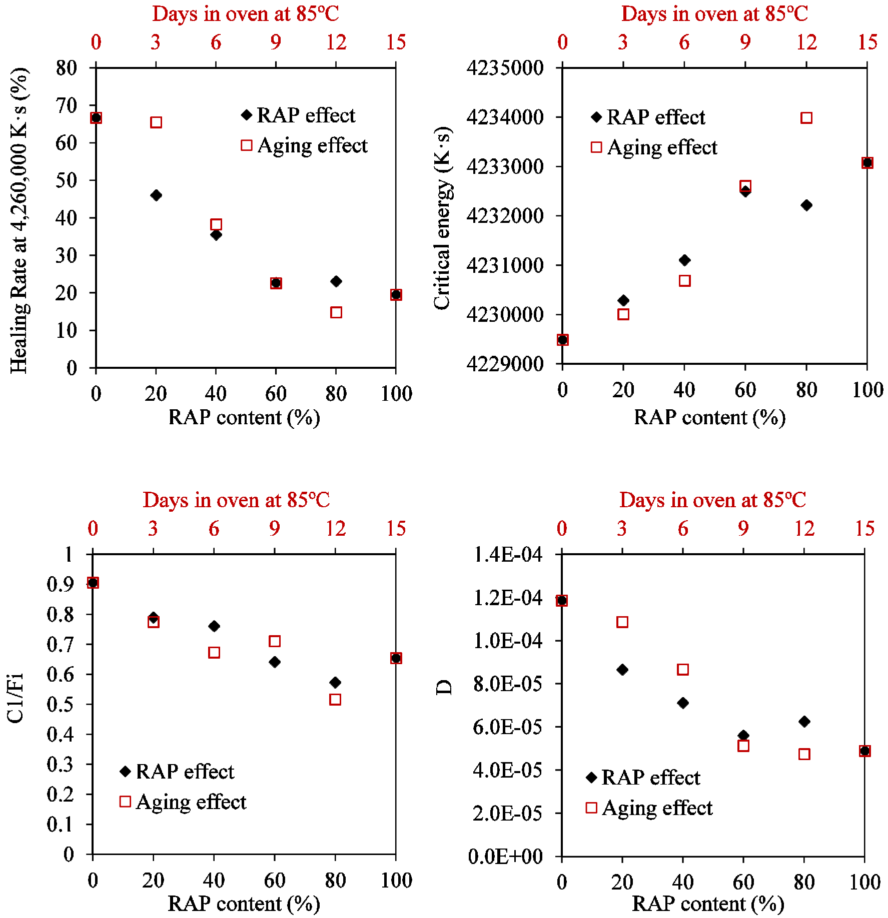


Aging and RAP content





Aging and RAP content



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Fatigue life

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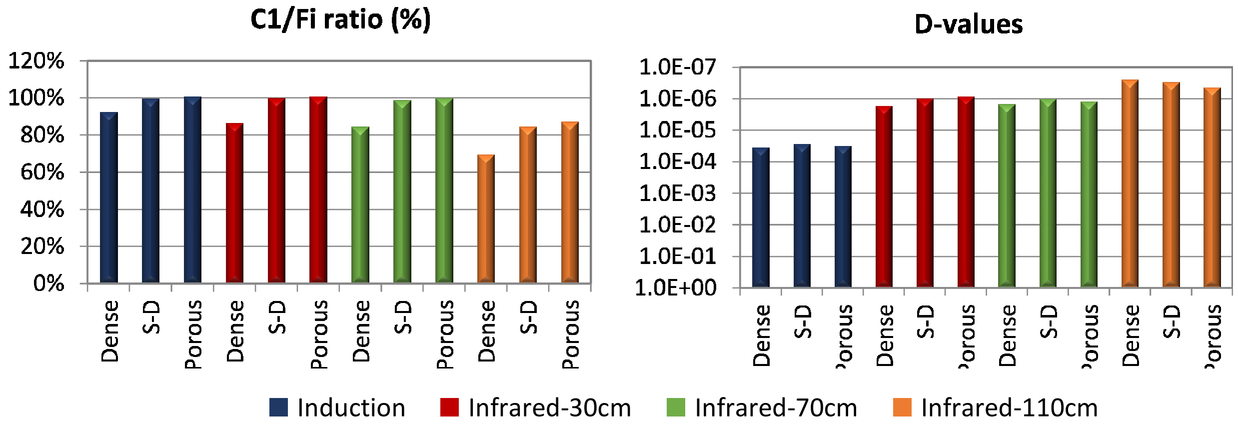
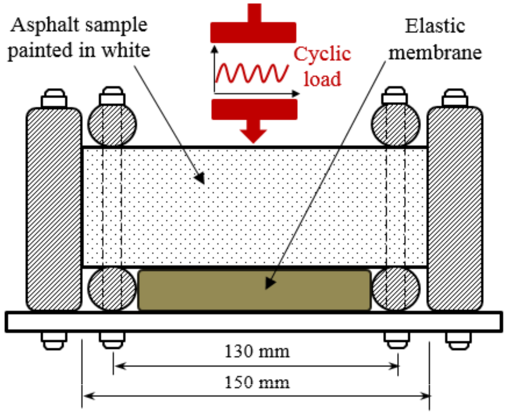
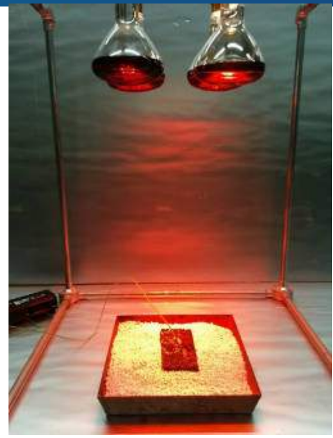
Fatigue life

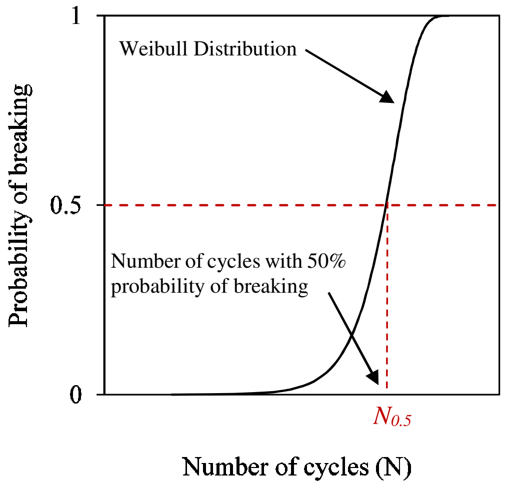


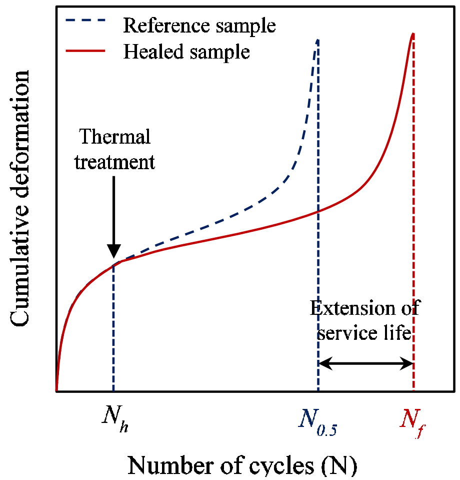
Fatigue life





Size (mm)	(%) Passing	(%) Passing	(%) Passing	(%) Passing	(%) Passing
31.5	100	100	100	100	100
20	99.1	99.1	99.1	99.1	99.1
16	91.3	91.2	91.2	95.5	91
14	83.3	82.9	82.9	88.1	78.2
10	62	58.8	58.8	53.4	27.6
8	54.1	48.7	48.7	36.3	17.9
6.3	47.8	40.7	40.7	23.1	13.5
4	34.3	29.5	29.5	17.8	11.4
2.8	28.7	25	25	16.6	10.6
2	23.7	20.8	20.8	14	9
1	17	15	15	10.2	6.7
0.5	12.9	11.3	11.3	7.9	5.2
0.25	10.2	9.1	9.1	6.3	4.3
0.125	8.1	7.2	7.2	5.1	3.5
0.063	6.5	5.7	5.7	4.1	2.9
Bitumen *	[illegible]	[illegible]	[illegible]	[illegible]	2.7%
Air voids	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]





$$HI = \frac{N_f - N_{0.5}}{N_{0.5}}$$

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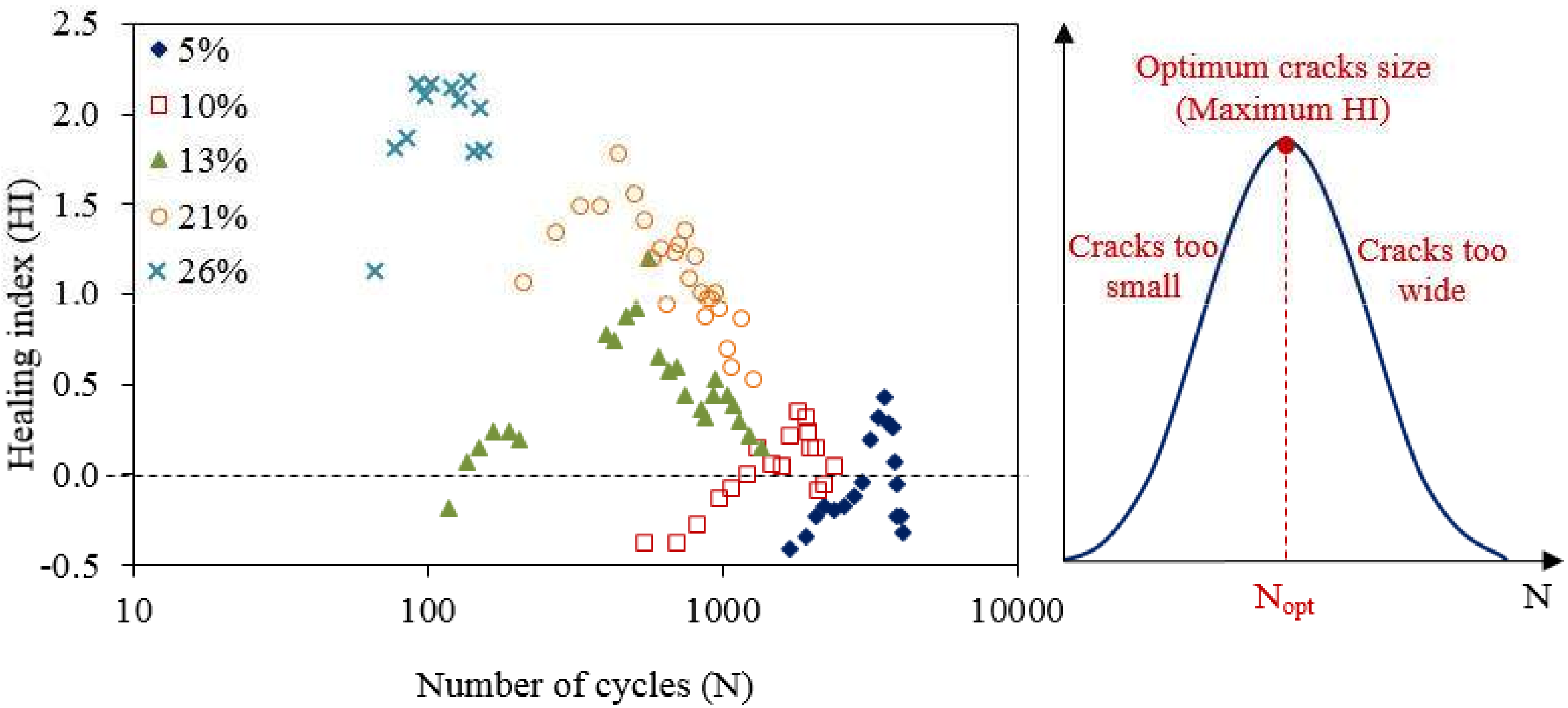
Fatigue life



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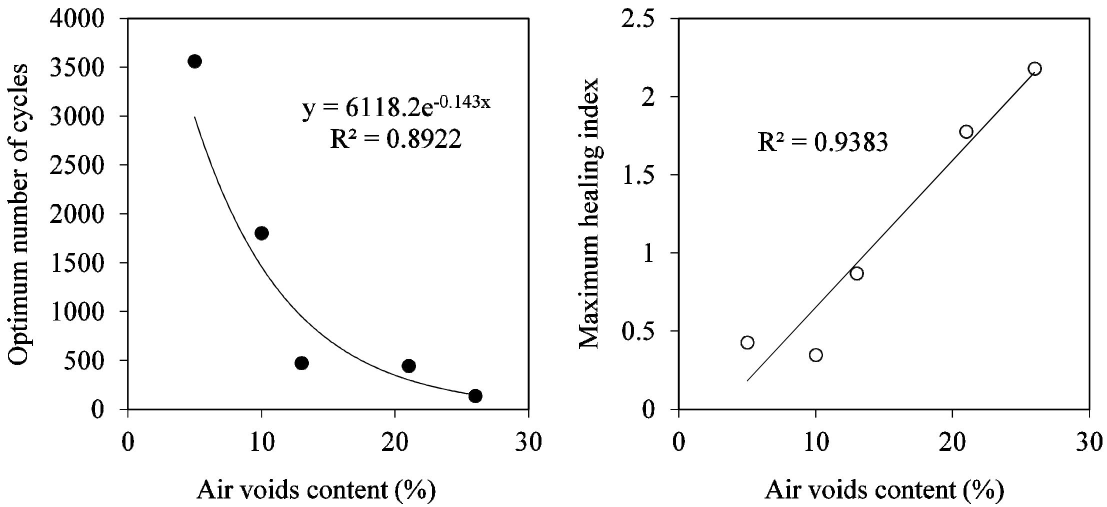
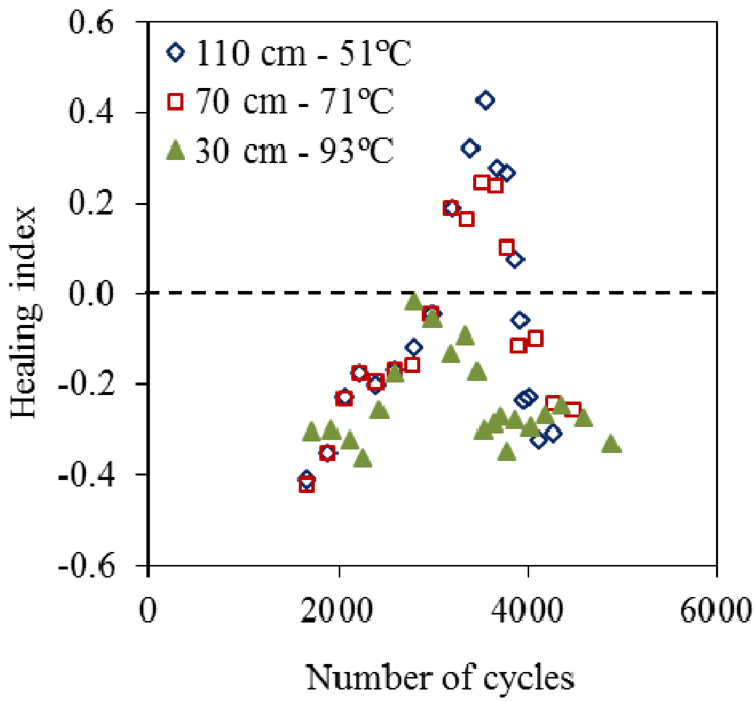
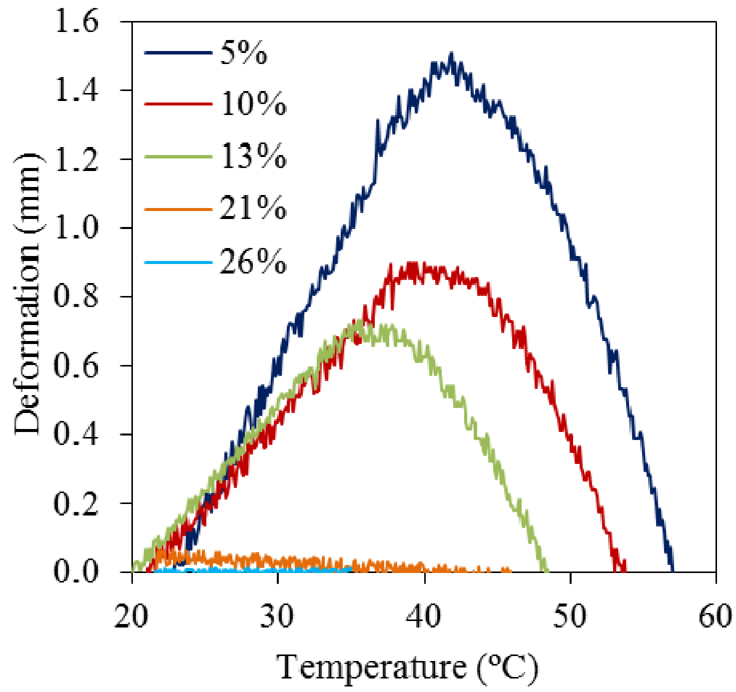
Fatigue life



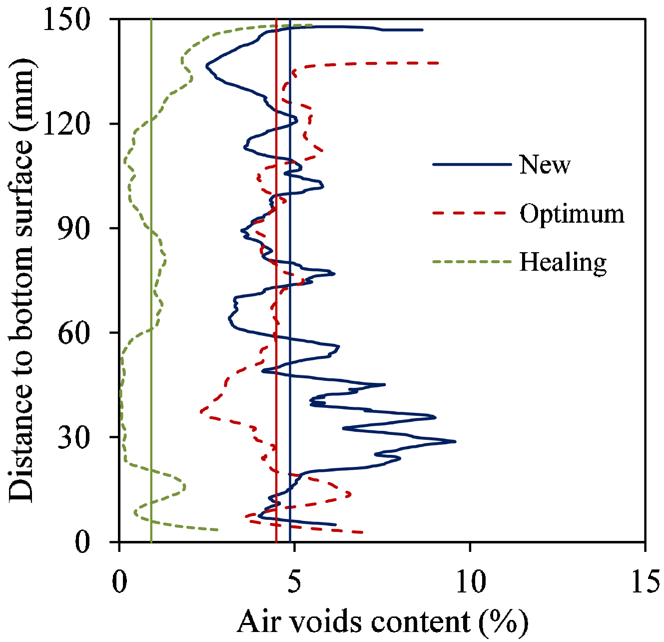
Air void content	Fatigue life without thermal heating ($N_{0.5}$)	Longest fatigue life with thermal treatment	Increase
5%	21160	30218	42.8%
10%	11440	15419	34.8%
13%	2120	4657	119.7%
21%	1200	3333	177.8%
26%	227	721	217%

Fatigue life

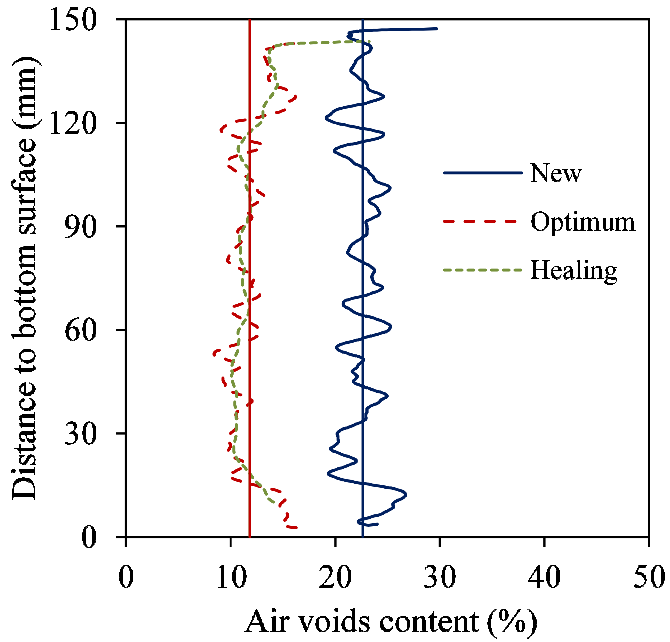




Fatigue life

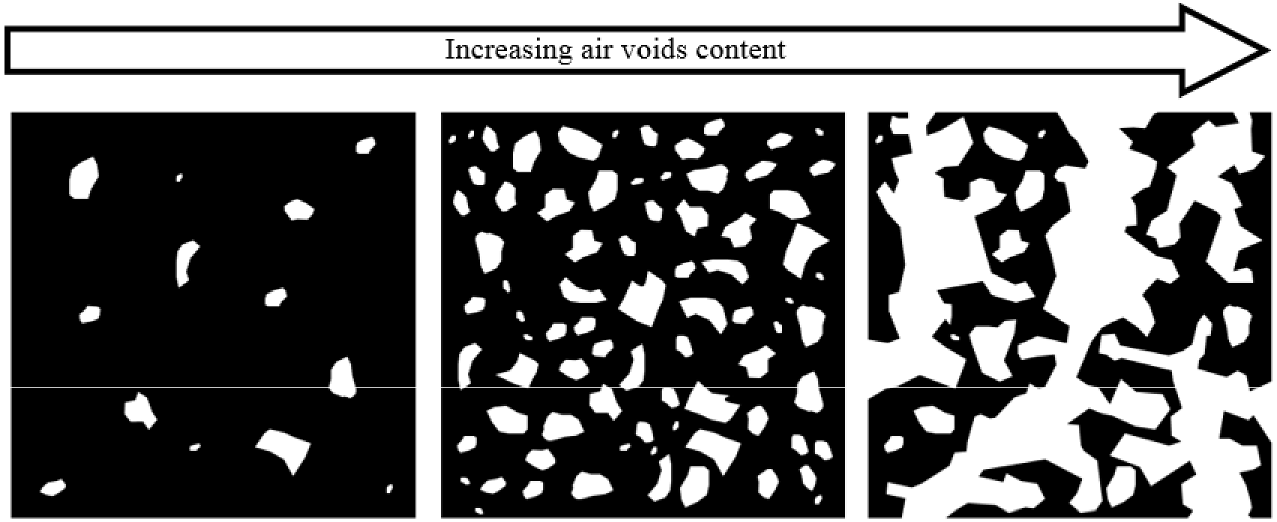


Dense



Porous

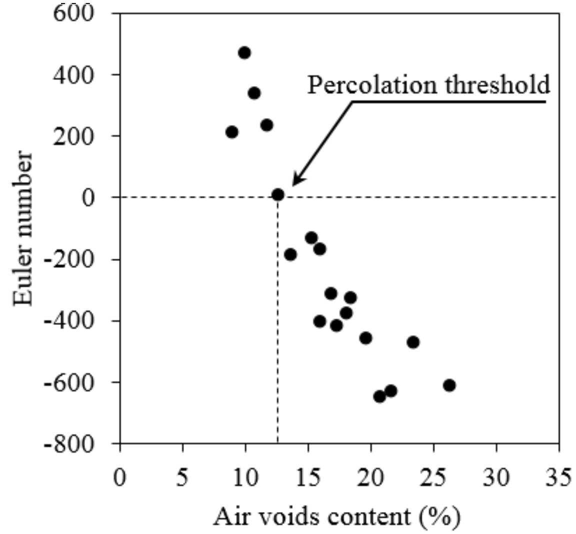
Fatigue life



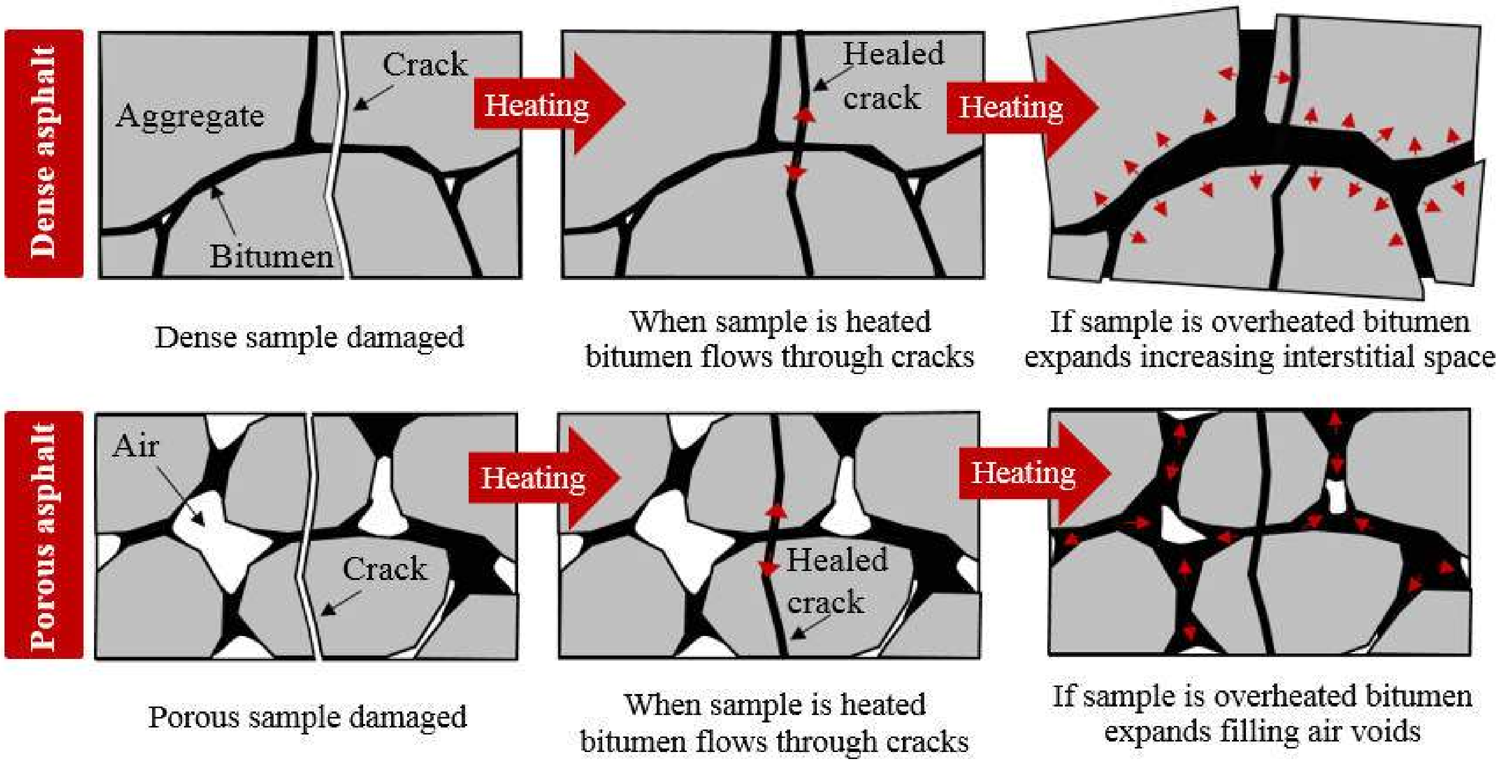
Low air voids content — $\chi >> 0$

Air voids close to percolation — $\chi > 0$

Percolated air voids — $\chi < 0$



Fatigue life



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Thank you

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Promoting induction heating asphalt mixes HEALROAD

Part: 1-2 – Full-scale demonstrator

October 26th 2017

Part 1-2 - **Agenda**

- full-scale Asphalt production (Task 5.1)
- test-section on duraBASt (Task 5.2)
  - construction
  - testing
  - healing
- evaluation process and LCA/LCCA are not presented during this event

Part 1-2 - **Mix design and testing**

1. The Healroad mixtures, developed by Cantabria University UC, are translated by Heijmans to Dutch raw materials
   → volumetric approach / high density of steel particles
   results showed the required Type Test properties
2. Ravelling test at the PA variant: Rotating Surface Abrasion test (RSAT)

Part 1-2 - **Full-scale Asphalt production (Task 5.1)**

- Determining the correct mixing procedure in a asphalt production plant

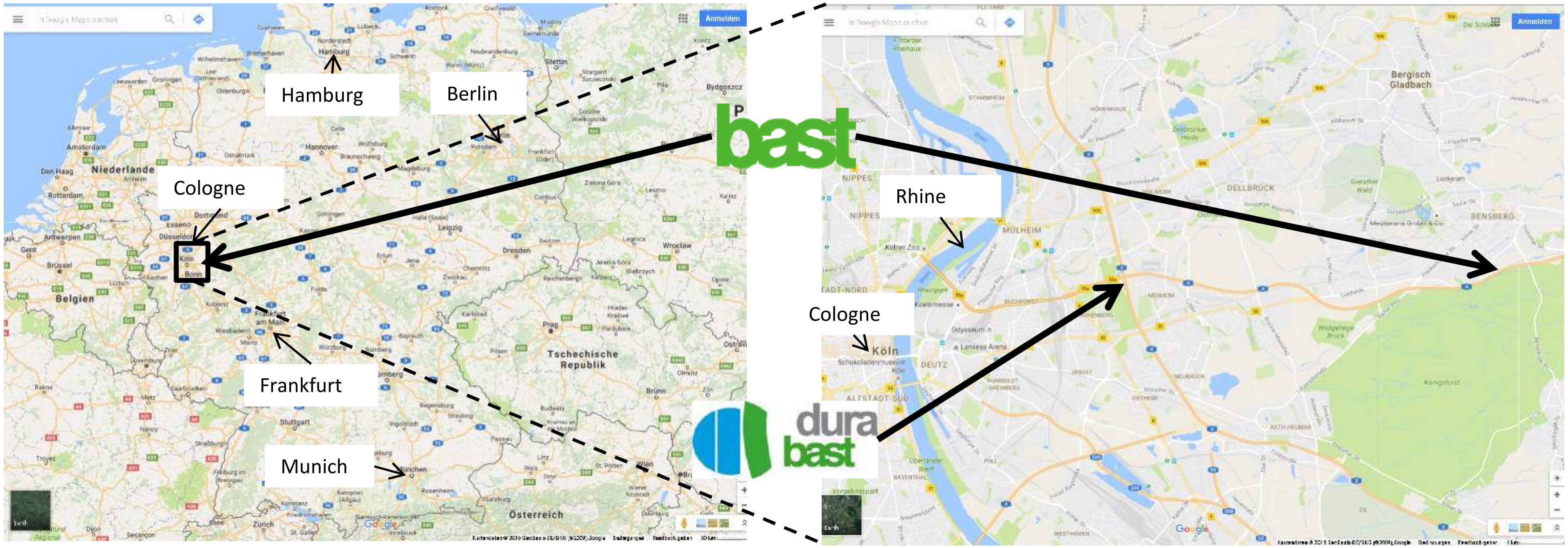
Several mixing-variants, produced in an asphalt plant → mechanical tests

→ No special and exceptional procedures are needed to produce the Healroad mixtures

→ Standard production plant is suitable with the usual way of adding additives

→ Positive factor for the introduction of Healroad mixes in the European asphalt market

Part 1-2 - **test section** on duraBASt

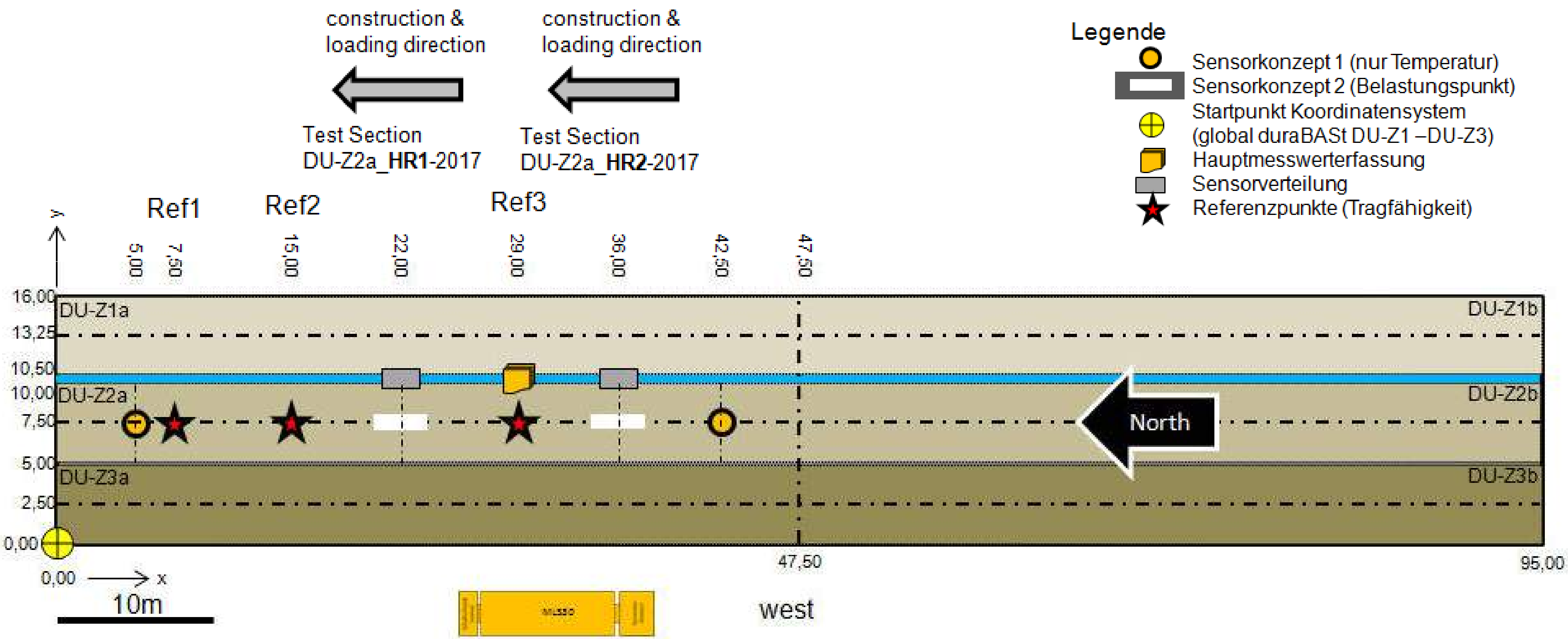


Part 1-2 - **Construction test-section on duraBASt (Task 5.2)**

- Transport to duraBASt, laying and compaction

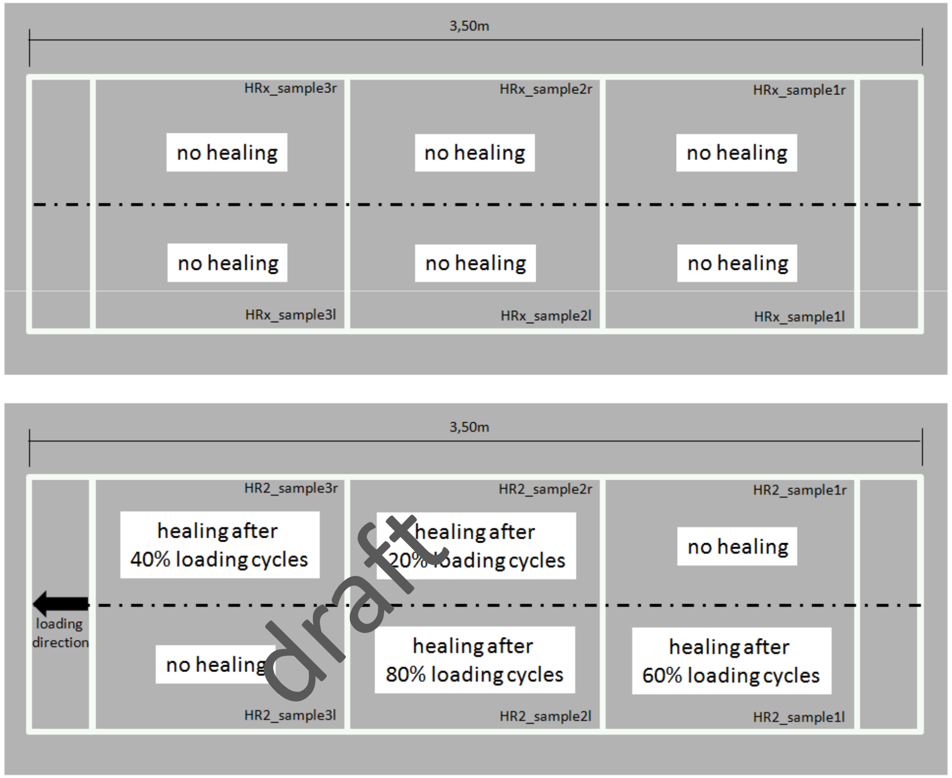
→ Special attention to temperature (no segregation) / compaction in the correct window

Part 1-2 - **test section** on duraBASt



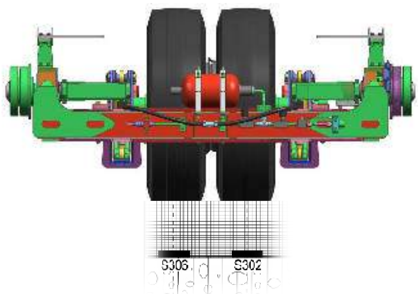
Part 1-2 - **test section** on duraBASt

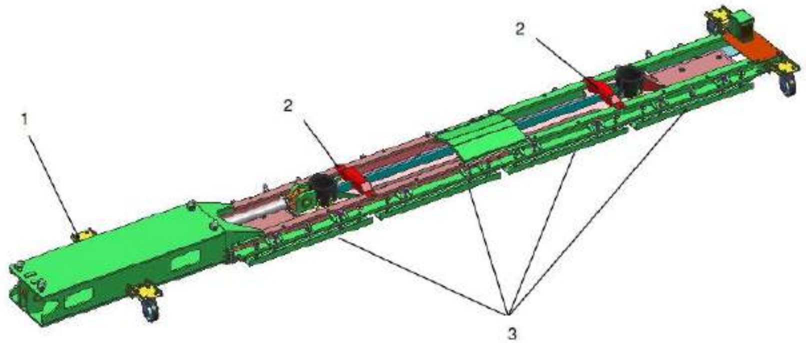
- failure criteria = stone loss
- HEIJMANS laboratory test with RSAT
  - 5 samples – laboratory production
  - 5 samples – duraBASt production
- BASt will use two loading points
  - first loading point = reference track
    - no healing at all six samples
    - surface observation (pictures)
  - second loading point
    - no healing at two samples
    - healing on four samples different moments



Part 1-2 - **test section** on duraBASt

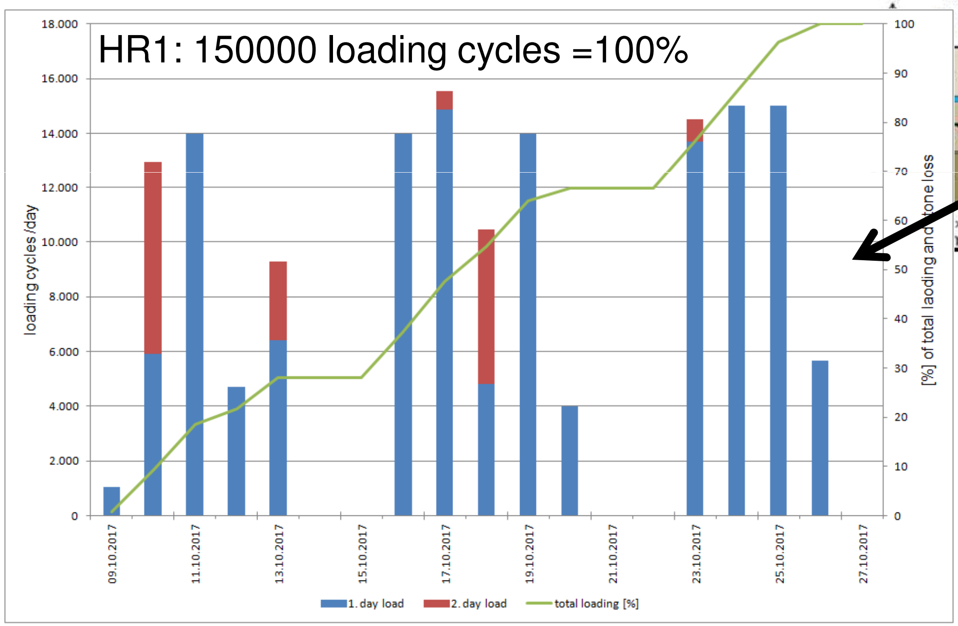
- Accelerated Pavement Testing (APT)
  - Mobile Load Simulator MLS30
    - Super-Single (9.0 bar)
      4 loading wheels in closed chain
    - load = 75 kN
      speed = 7 km/h = 2000 Ü/h
    - lateral unite
      ±350 mm left and right
      (one whole program need approx. 12min)

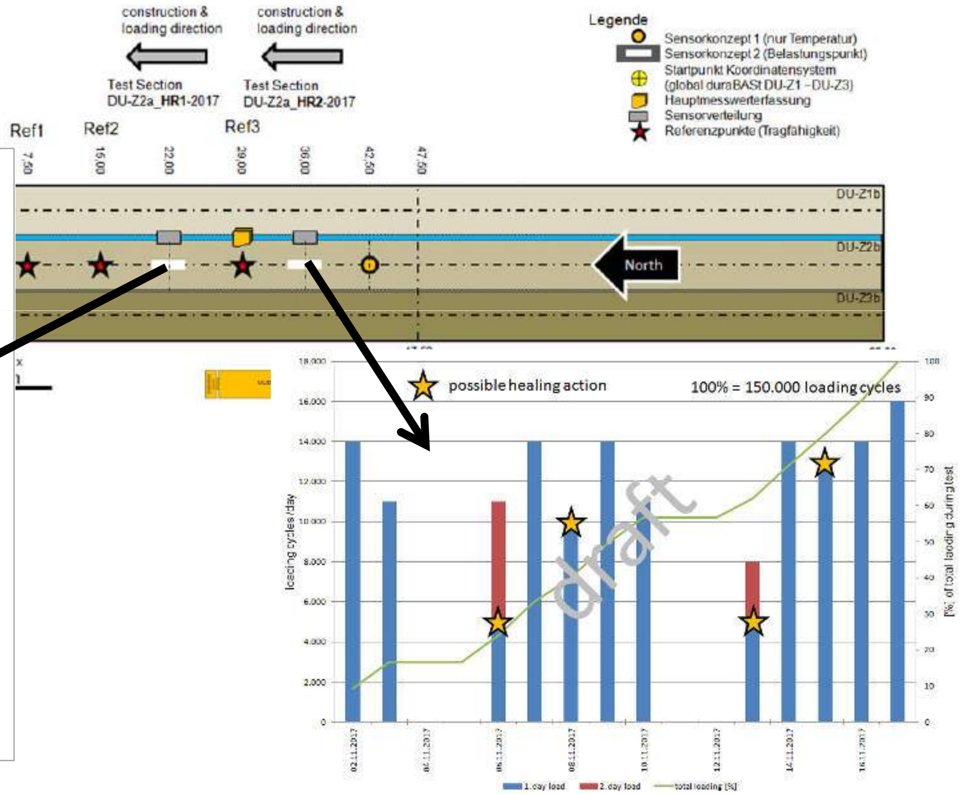




Part 1-2 - **test section** on duraBASt

- loading cycles and healing actions

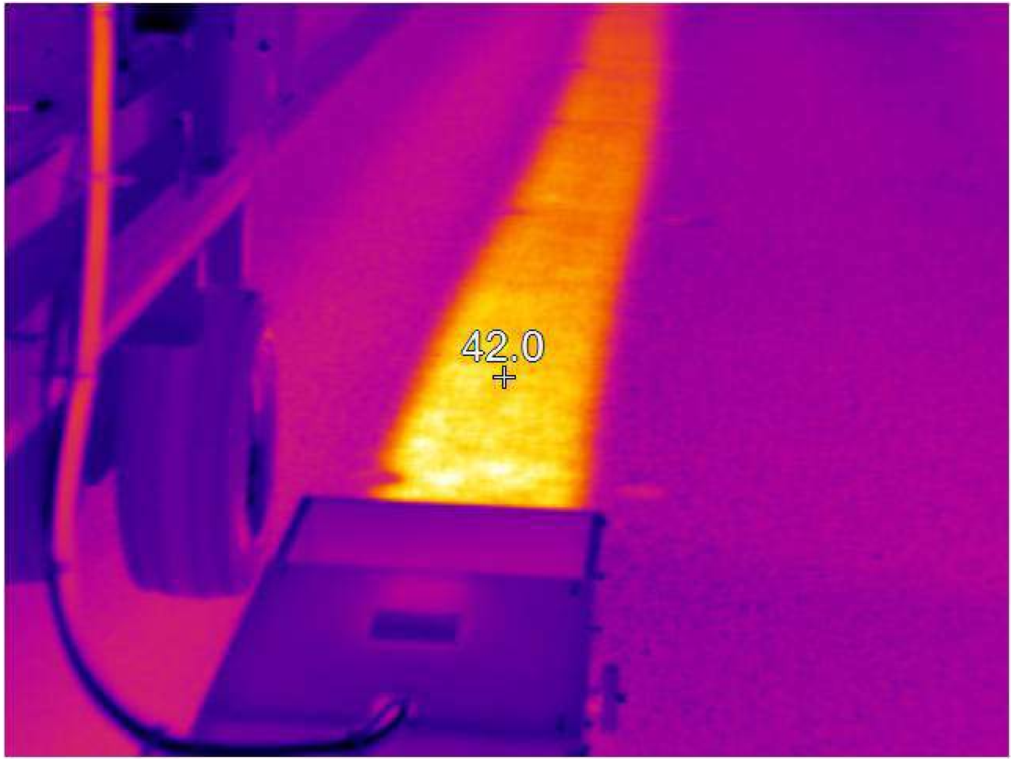




Part 1-2 - **test section** on duraBASt

- Details to Induction machine
  - 1400 Volt
  - 312 kHz
  - 33 Ampere
  - Energy 7-7,5 kW
  - 40 cm Coil (2 pieces)
  - Condensators:
    4 x 0,33 µF

Part 1 - 2 - **test section** on duraBASt



Promoting induction heating asphalt mixes HEALROAD

Part: 2 – Onsite visit to duraBASt and HEALROAD demonstration

October 26th 2017

Part 2 - **Onsite visit** to duraBASt and HEALROAD demonstration

duraBASt – outdoor test area

demonstration, investigation (**U**ntersuchung), **r**eference **a**real

investigation areal
APT (MLS30) and non-destructive test methods