Use of Compartmented Sodium-Alginate Fibres as a Healing Agent Delivery System for Asphalt Pavements

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Motivation

- **Preservation of the EU road network**

The European Commission: "*Transport infrastructure influences both economic growth and social cohesion. A region cannot be competitive without an efficient transport network*." (Vita and Marolda, 2008)

- **Length of road network:**
  - Global 16.3 mil. km
  - **EU 5 mil. km**
  - USA 4,4mil. km,
  - China 3,1 mil. km

- **Maintenance Expenditure (€)**
  - EU annual expenditure 20billion

Road Failure Prevention Methods

1. **Increased Inspection and Maintenance** – inspection and maintenance at regular intervals.

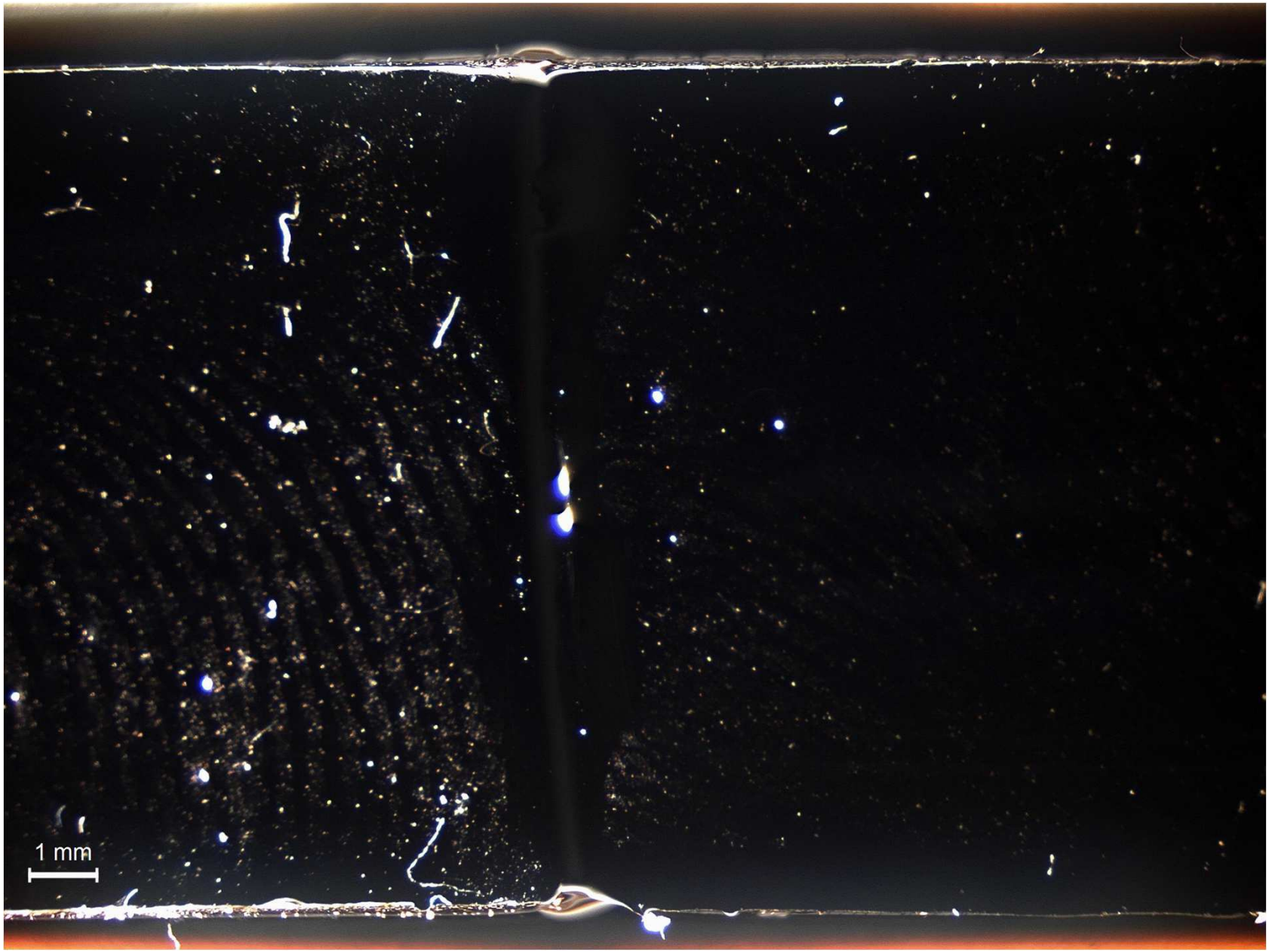
2. **Design standards** – enhance asphalt pavement performance, to increase its durability and improve its load carrying capability.

3. **New technology** – Self Healing Technology for Asphalt Pavements.

Types of Self Healing Technology for Asphalt Pavements

- **Nanoparticles:**
  - **Nanoclay**
  - **Nanorubber**
- **Induction heating**
- **Rejuvenation**

Binder Rejuvenation

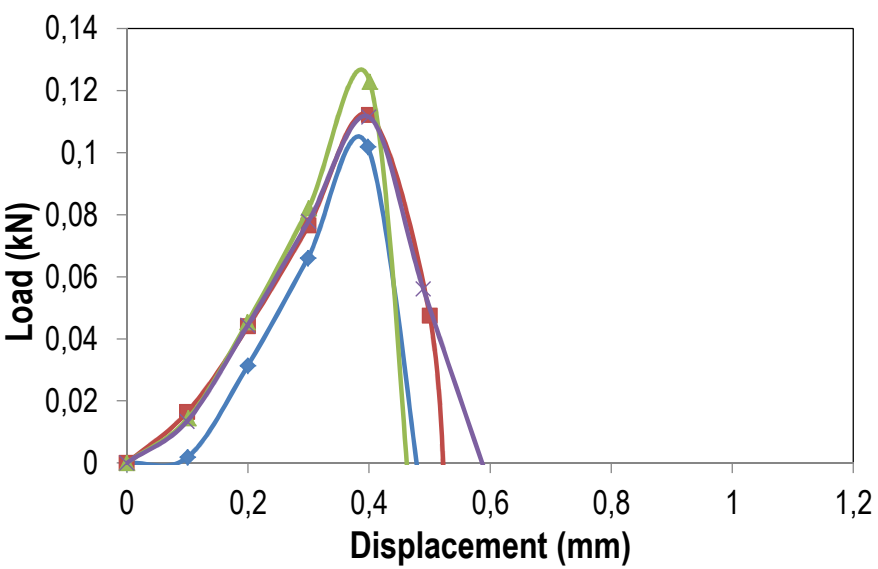


Types of Self Healing Technology for Asphalt Pavements

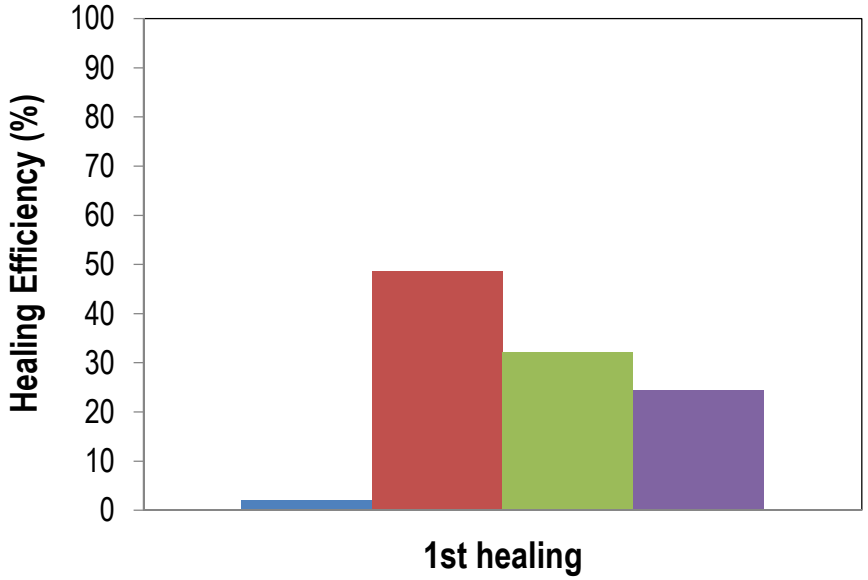
- Nanoparticles:
  - Nanoclay
  - Nanorubber
- Induction heating
- **Rejuvenation**
  - **Rejuvenators types:**
    - Industrially produced rejuvenator, e.g. Latexfalt Modiseal R20,
    - High pen value binder,
    - Organic oils:
      - Vegetable oils,
      - Waste cooking oil.

Binder Rejuvenation

- **Strength recovery – 3PB Test**



Healing
@ 20°C for 3h



Specimen without healing agent

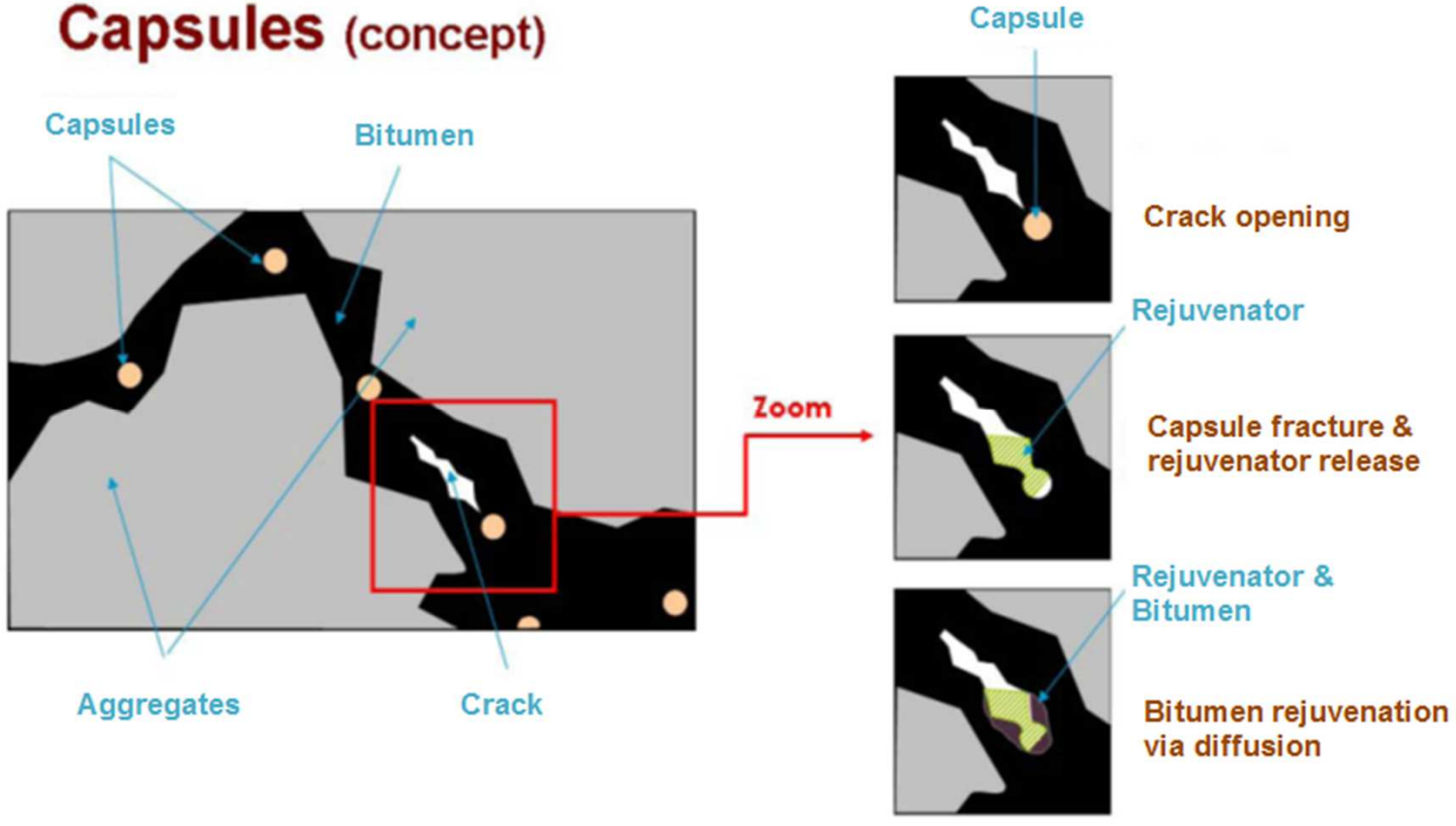
Specimen with rejuvenator (Modiseal R20) as healing agent

Specimen with Vegetable Oil as healing agent

Specimen with Waste Cooking Oil as healing agent

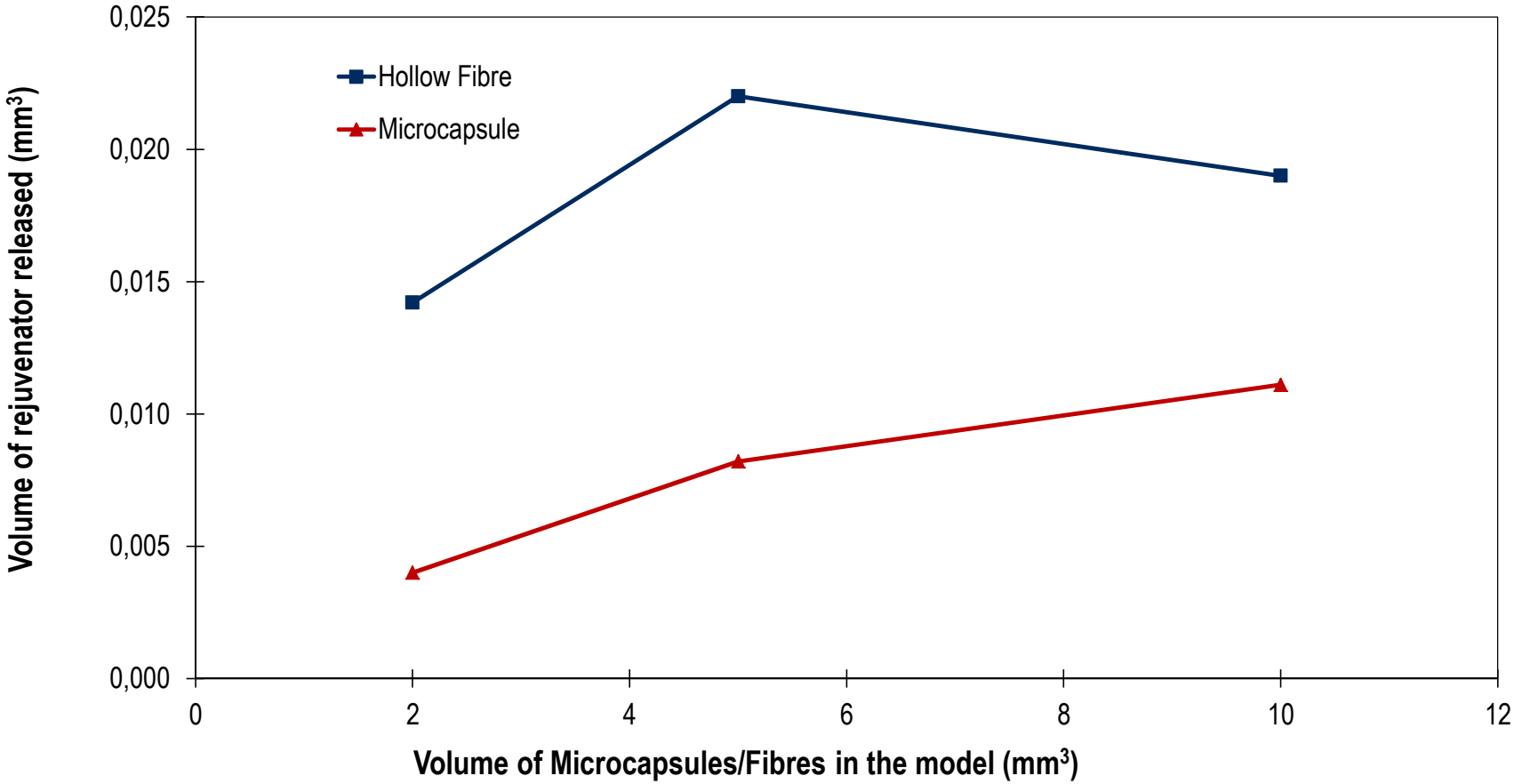
Rejuvenator encapsulation

- **Simply applying rejuvenator to the surface of the pavement means that rejuvenator penetrates only top few mm of the pavement.**
- **Solution – embed microcapsules/hollow fibres, containing the rejuvenator, throughout the asphalt matrix.**
- **How does it work?**



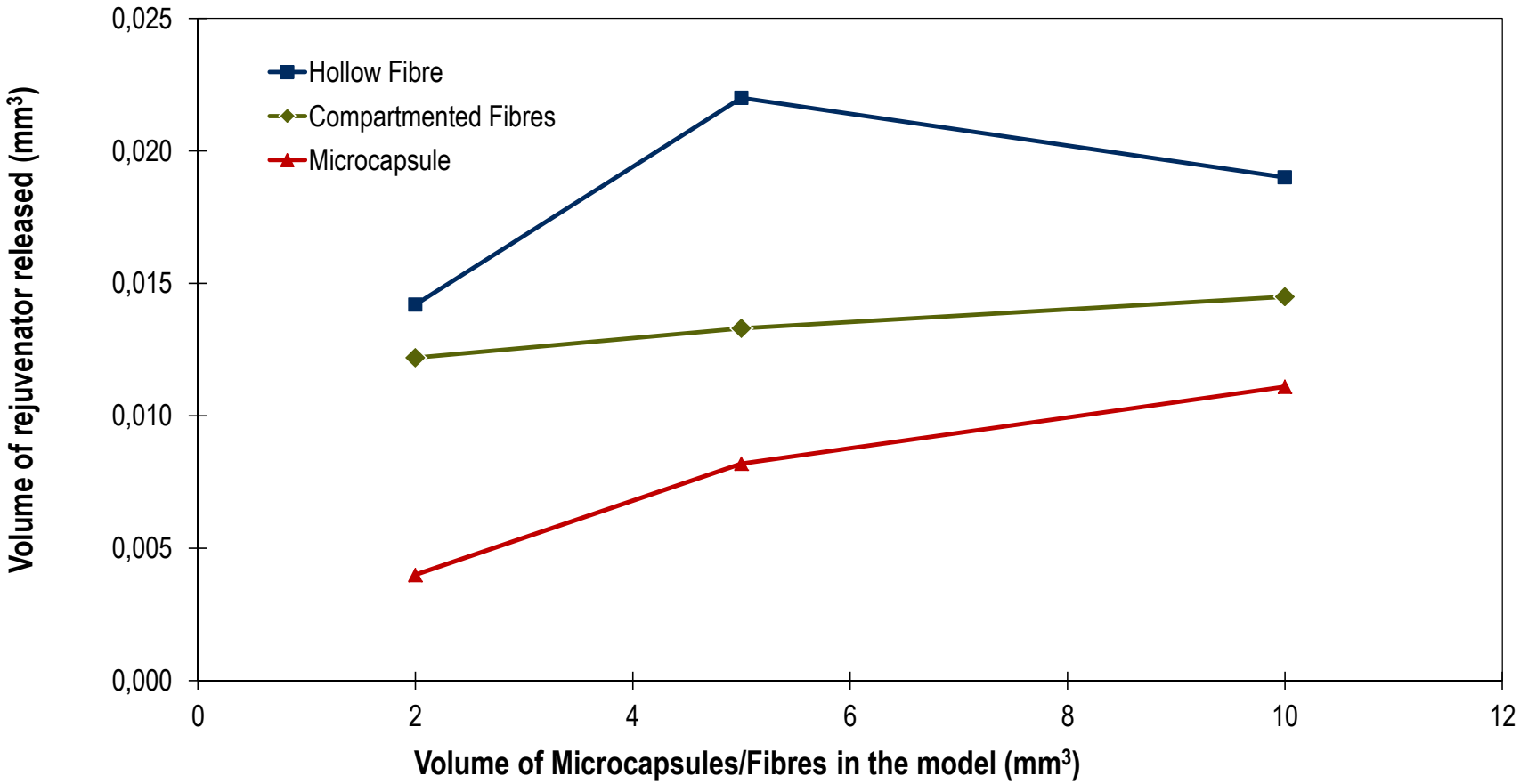
Rejuvenator Encapsulation

- **Fibres vs Microcapsule as rejuvenator encapsulation method:**
  i. Efficient production method – Spinning/Weaving,
  ii. Fibre increases material strength,
  iii. Higher delivery of rejuvenator to the damaged site.



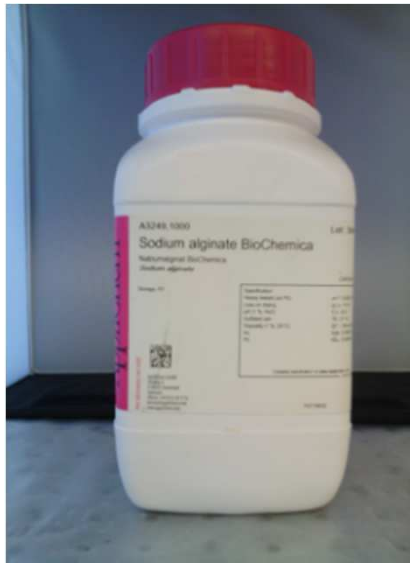
Compartmented Fibres

- **Compartmented fibres – contain healing agent/rejuvenator in pockets throughout the length of the fibre.**
- **Advantages – compartmented fibres allow multiple healing events.**



Sodium Alginate

- **Sodium Alginate is a promising methodology currently being investigated and developed for the production of:**
  - **Microcapsules** - bacteria encapsulation for self healing of concrete, (Palin, et al. 2015),
  - **Compartmented fibres** - encapsulation of healing agents for polymer based composites, (van der Zwaag, et al. 2014).
- **Advantages of Sodium Alginate as Rejuvenator encapsulation material:**
  - **Low cost,**
  - **Organic** – non toxic, low impact on the environment,
  - **Self degrading** – secondary rejuvenator release triggering mechanism.

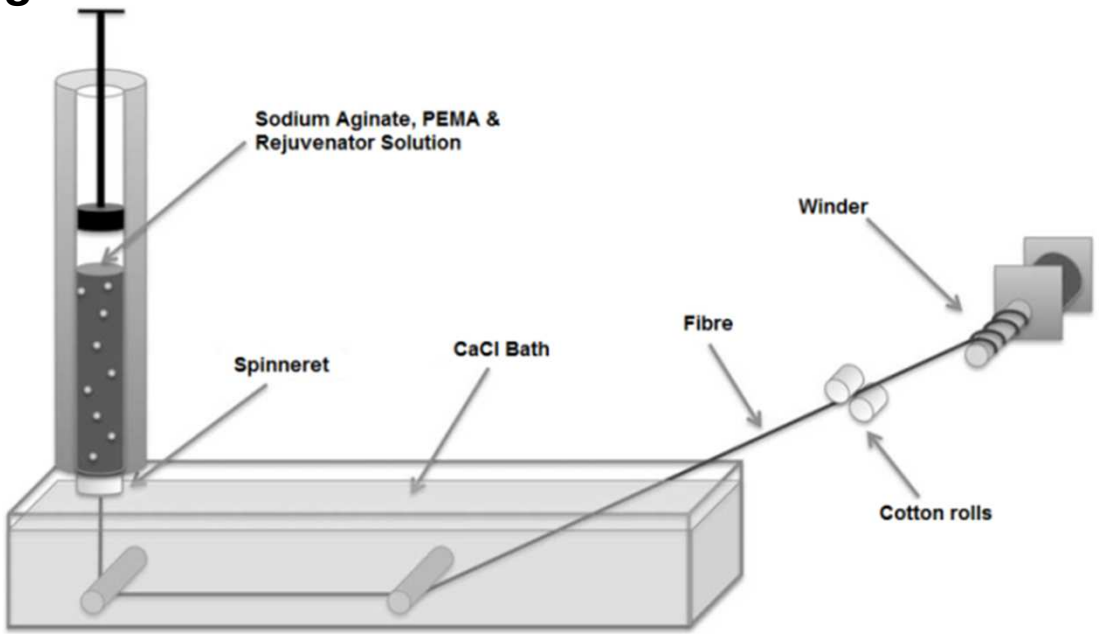


Sodium Alginate Compartmented Fibres – Production Process

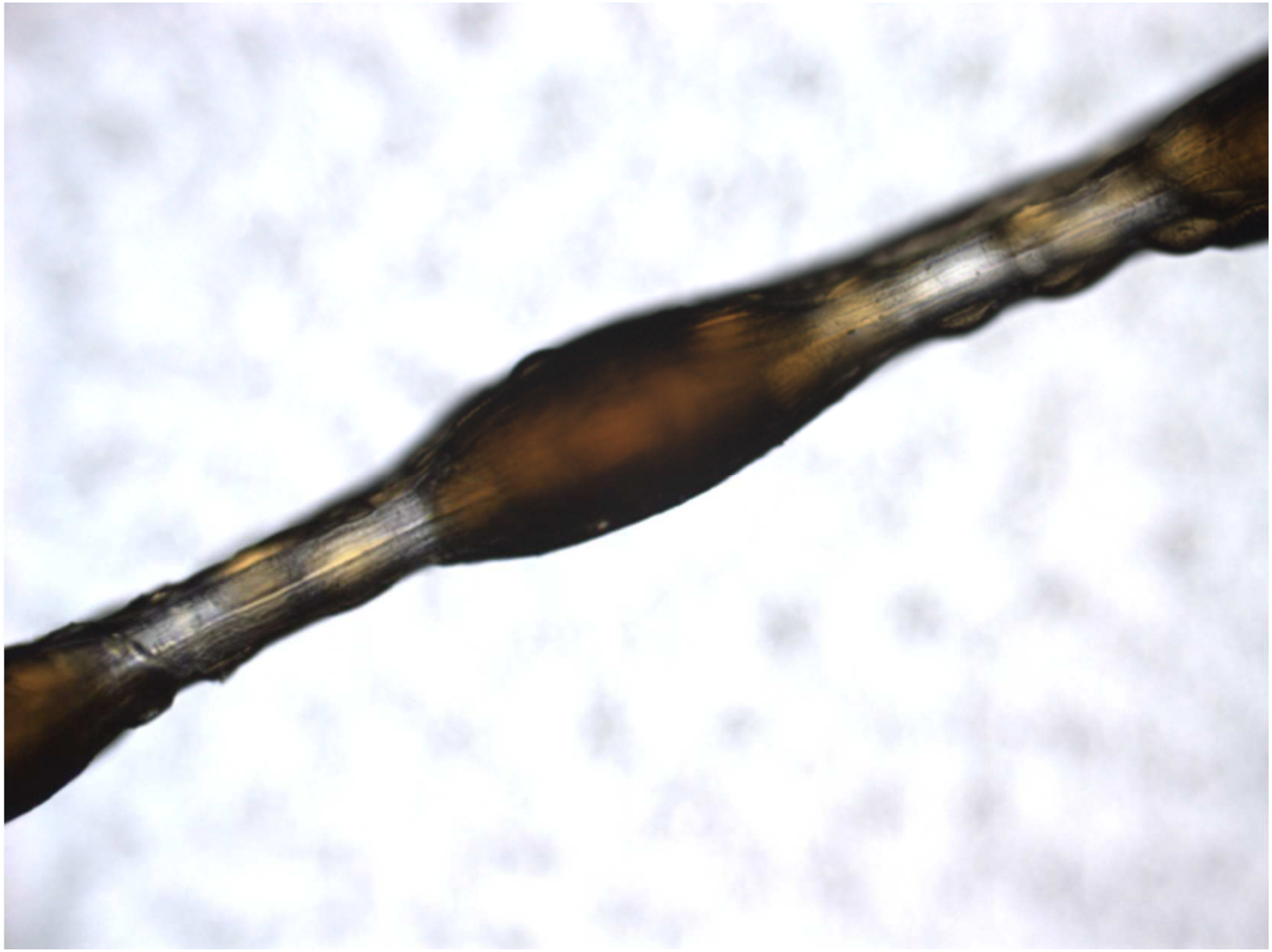
- **Solution:**
  - 6,0 wt% sodium alginate solution in demineralized water,
  - 2,3 wt% PEMA solution in water (ratio PEMA : Alginate = 1:100),
  - Ratio rejuvenator : Alginate = 40:60 in weight%.

  Solution is stirred manually for 20 seconds. The size of the rejuvenator compartments can be controlled by increasing or decreasing mixing speed. The higher the mixing speed the smaller the compartments.

- **Spinning/Weaving Process**

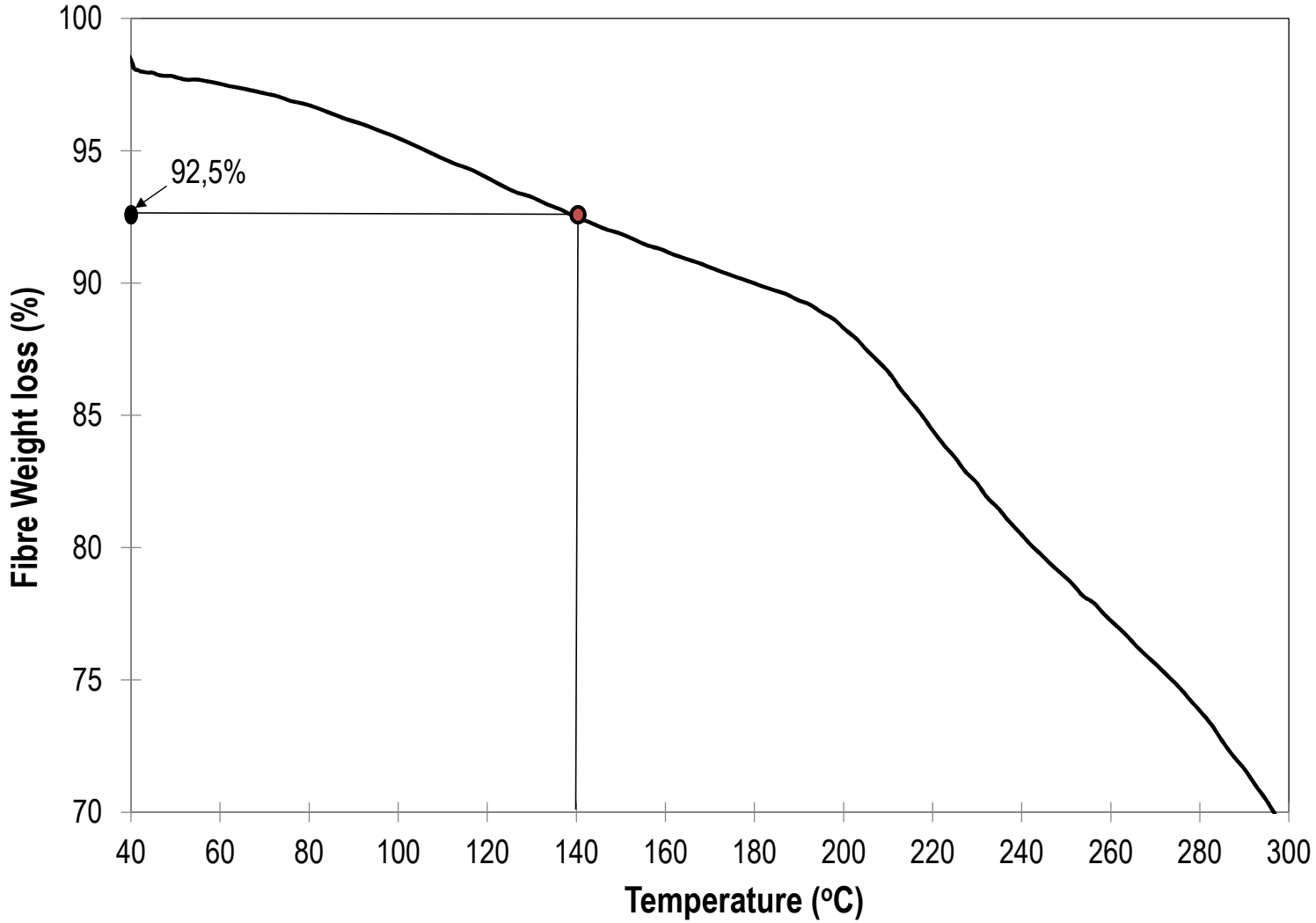


Sodium Alginate Compartmented Fibres Containing Rejuvenator



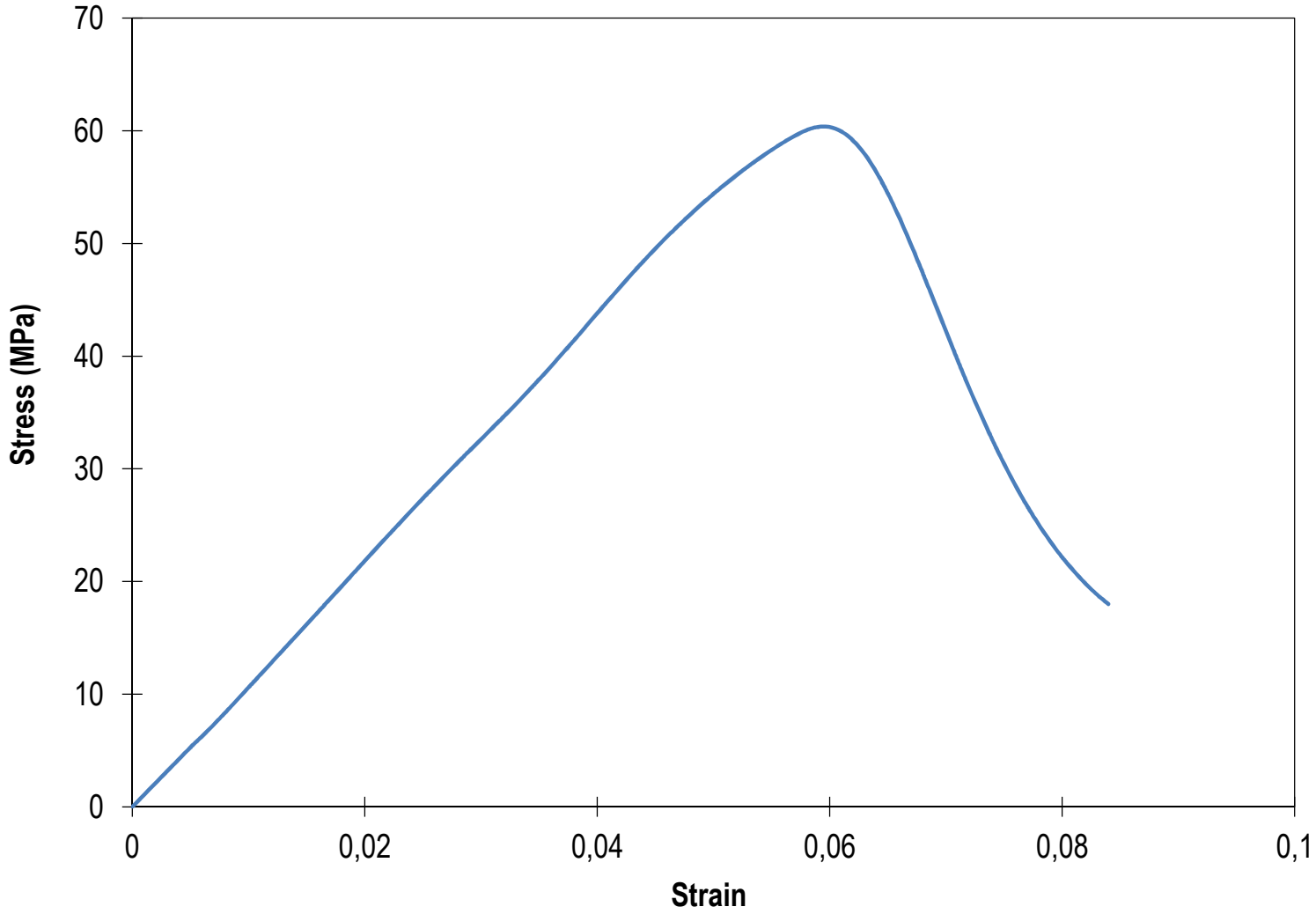
Thermal Properties of Sodium Alginate Fibres Containing Rejuvenator

- **Fibre weight loss at asphalt mixing temperature (140ºC) is 7,5%**



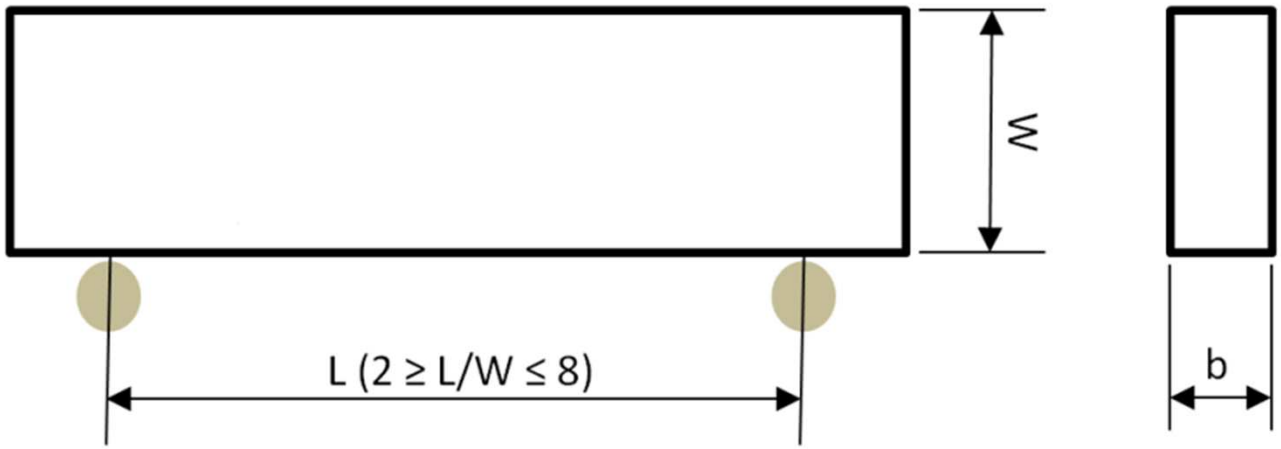
Tensile Strength of Sodium Alginate Fibres Containing Rejuvenator

- **Fibre average diameter = 170µm ⟶ cross sectional area = 0,023mm²**
- **Ultimate Tensile Strength (UTS) = 60,4MPa**



Asphalt Mortar Mix with Fibres

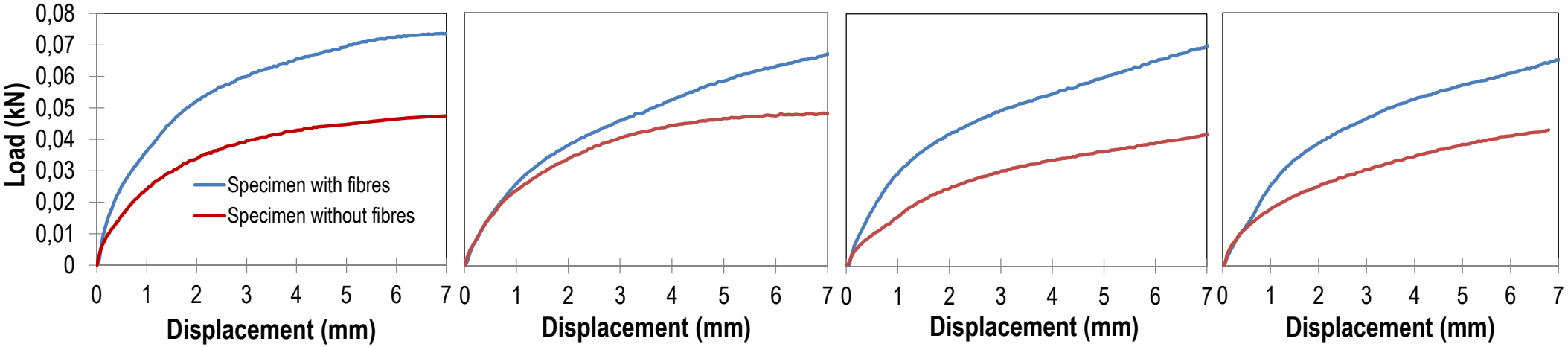
Mix Constituent	Percentage weight in the mix (%)
Sand	49,4
Filler	24,7
Fibres	1,3
Bitumen (70/100 pen)	24,7



Where: L = 120mm, W = 25mm, b = 20mm

Healing Efficiency of Sodium Alginate Fibres Containing Rejuvenator

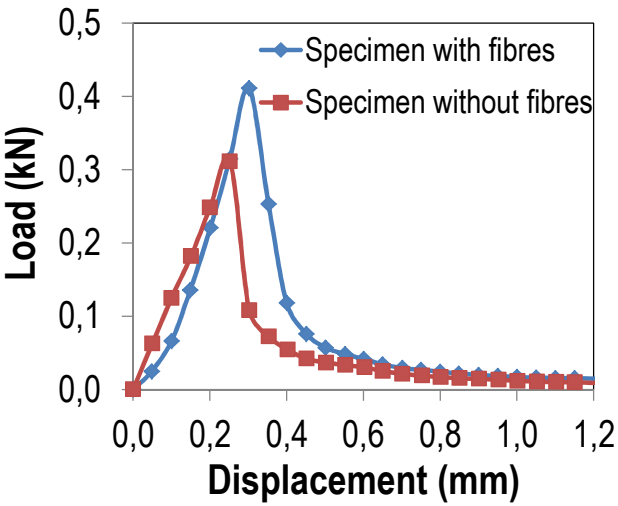
- **Three point bend test:**
  - Loading rate = 0,1mm/s
  - Test temperature = 20^{o}C
- **Healing @ 20 ±3 ^{o}C**
  i. First healing stage 30 minutes after the initial test
  ii. Second healing stage 1 hour after the second test
  iii. Third healing stage 3 hours after the third test
- Test results



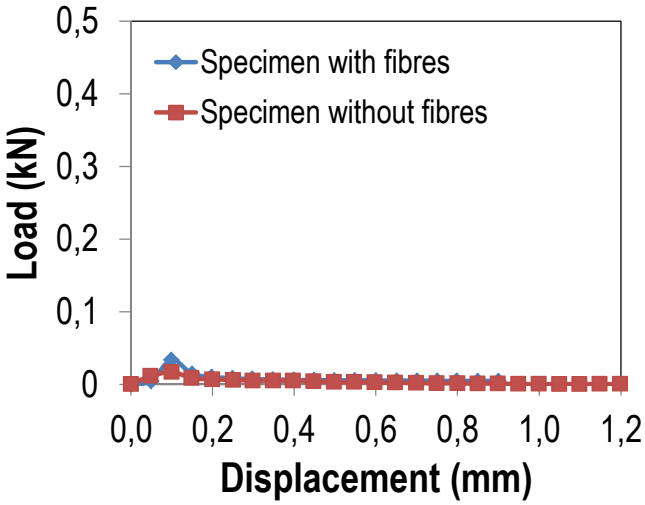
Initial test | Second test – after 1st healing | Third test – after 2nd healing | Fourth test – after 3rd healing

Healing Efficiency of Sodium Alginate Fibres Containing Rejuvenator

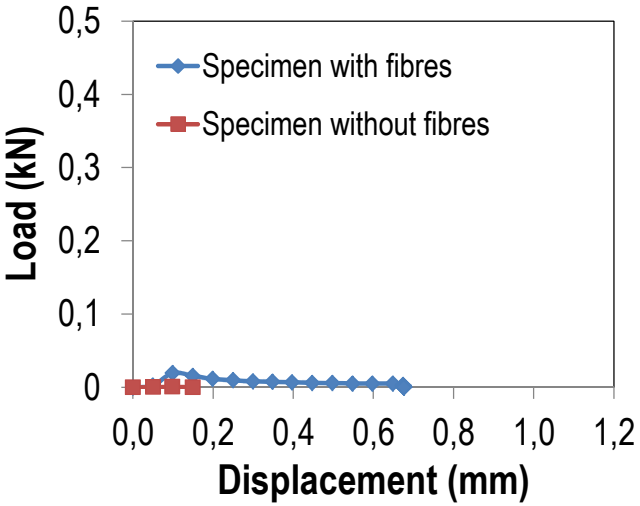
- **Three point bend test:**
  - Loading rate = 0,1mm/s
  - Test temperature = -5 ºC – test specimen conditioning time 3 hours prior to testing
- **Healing @ 20 ±3 ºC**
  i. First healing stage 3 hours after the initial test
  ii. Second healing stage 12 hours after the second test
- Test results



Initial test



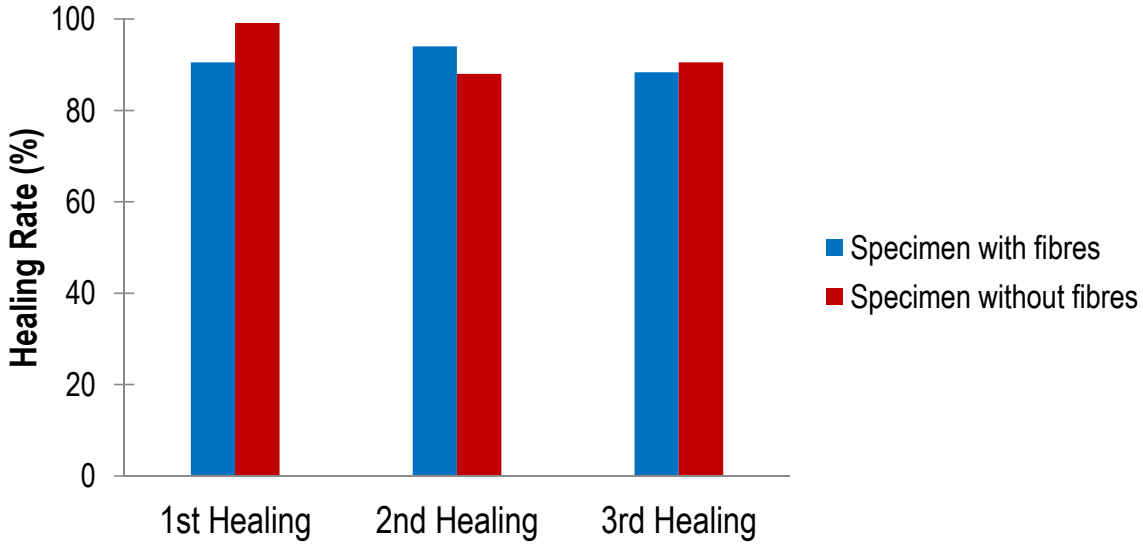
Second test – after 1st healing



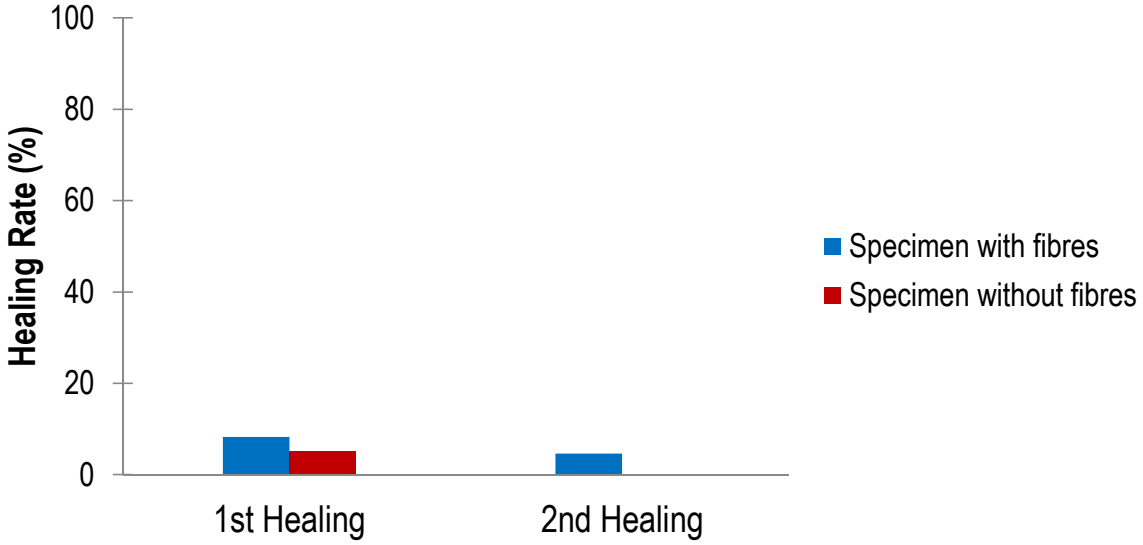
Third test – after 2nd healing

Healing Efficiency of Sodium Alginate Fibres Containing Rejuvenator

- **Test temperature 20°C**



- **Test temperature -5°C**



Conclusions

- **Results demonstrate that rejuvenators can heal bitumen damage.**
- **Sodium Alginate Compartmented Fibres effectively encapsulate bitumen rejuvenator.**
- **Sodium Alginate Compartmented Fibres demonstrated good thermal and mechanical strength.**
- **Fibres increase asphalt mortar strength by up to 36%.**
- **Sodium Alginate Compartmented Fibres encapsulated Rejuvenator (healing system) showed limited healing capacity.**
- **Bitumen rejuvenator encapsulated in Sodium Alginate fibres shows potential for self healing asphalt pavement.**

Acknowledgements

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