SELF-HEALING PAVEMENTS: A REVOLUTION IN PAVEMENT MATERIALS

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Introduction

self-healing can be defined as the ability of material to heal damages automatically and autonomously that is without any external intervention

BUT

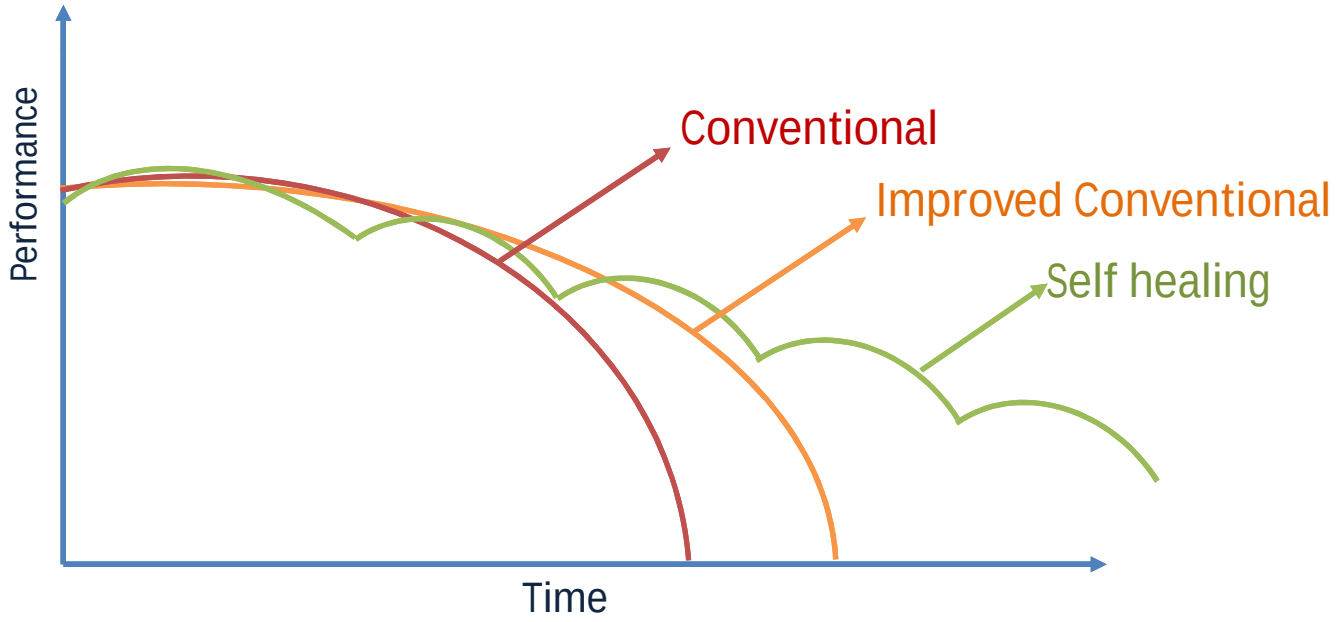
Incorporation of self-healing properties in manmade materials very often cannot perform self-healing action without an external trigger

HERE

self-healing refers to the recovery of the mechanical strength of the pavements

Introduction

Self-healing aims to reduce the level of damage and to extend or renew the functionality and life of the damaged part. Materials perform as a function of time



Behavior of Material with Time

Background

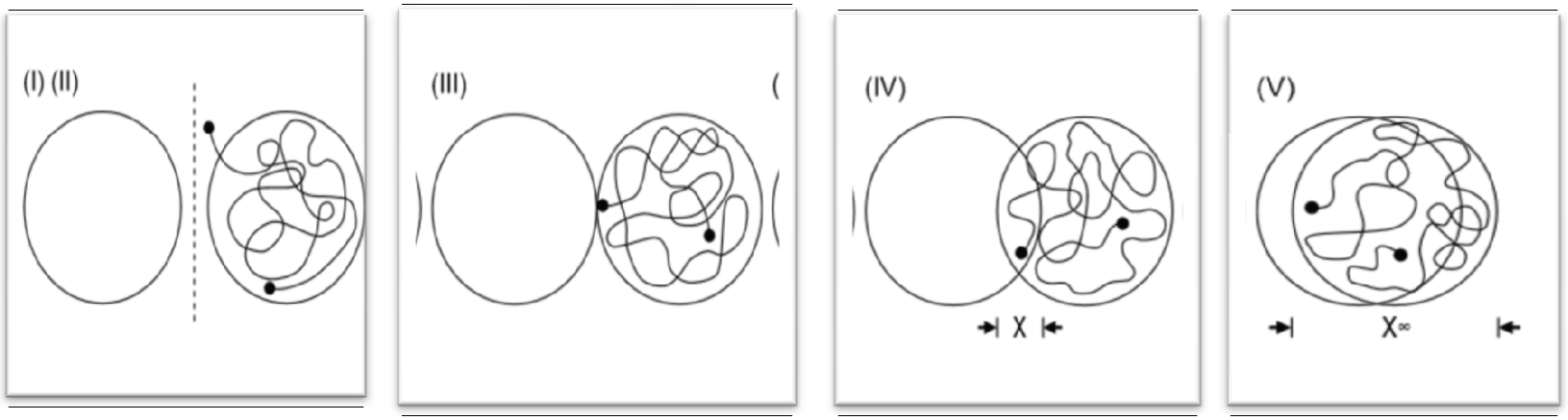
Self-healing is an intrinsic property of bituminous roads

BUT

It’s a slow process at ambient temperature &
Requires rest period

Background

Healing is due to the wetting and inter diffusion of materials between two faces of the micro cracks, so that original properties of material can be regained



(I) Rearrangement,
(II) Approach

(III) Wetting

(IV) Diffusion

(V) Randomization

Factors Influencing the Self-Healing of Bituminous Pavements

Loading Condition	1. Intensity of Loading 2. Duration of loading 3. Temperature & time of loading 4. Rest period
Bitumen Properties	1. Bitumen type 2. Chemical composition 3. Viscoelastic properties 4. surface free energy 5. Ageing 6. Diffusion 7. Modifiers
Bituminous mixture composition	1. Bitumen content 2. Aggregate structure 3. Gradation 4. Thickness

Possibilities of self-healing systems for bituminous mixtures

Technology	Theory	Advantage	Disadvantages
Rejuvenation by Microcapsule	Healing agent (reclamite, paxole) and rejuvenator (Sunflower oil, byproduct of wast e cooking oil)	Good strength recovery	Works only once
Hollow glass fibers	Healing agent and catalyst	Good strength recovery	Works only once
Nanoparticles	Nano effect Nanoclays (organo clay modified binders), Nano rubbers	Prevent crack growth	Distribution
Using polymers	Reversible chemical reaction	Multi time healing	High healing temperature
Induction heating	Wetting and Diffusion	Multi time healing	Aging
Microwave heating	Wetting and Diffusion	Multi time healing	Aging

Essential conditions for self-healing agents to be included into asphalt pavement design

- ❑ Good compatibility with bitumen
- ❑ High temperature stability
- ❑ Ability to survive mixing and construction conditions
- ❑ Capable of continuous/multi-time healing

Familiar Self Healing Techniques

- ❑ Microcapsulation (Rejuvenation)
- ❑ Induction heating technology
- ❑ Nano Particles

Microcapsulation

Rejuvenation : Asphalt rejuvenation is the process of restoring original properties that have been deteriorating since the moment new asphalt was laid down.

Asphalt consists of Asphaltenes + Maltenes

Irreversible

oils + resins

During service period Oils → Resins → Asphaltenes

Which results in higher viscosity and age hardening

Microcapsulation

The property of viscoelasticity of bitumen can be recovered or restored by two ways

1. By adding bitumen with high penetration value
2. By adding Rejuvenating agent

BUT

How to add the rejuvenating agent ??

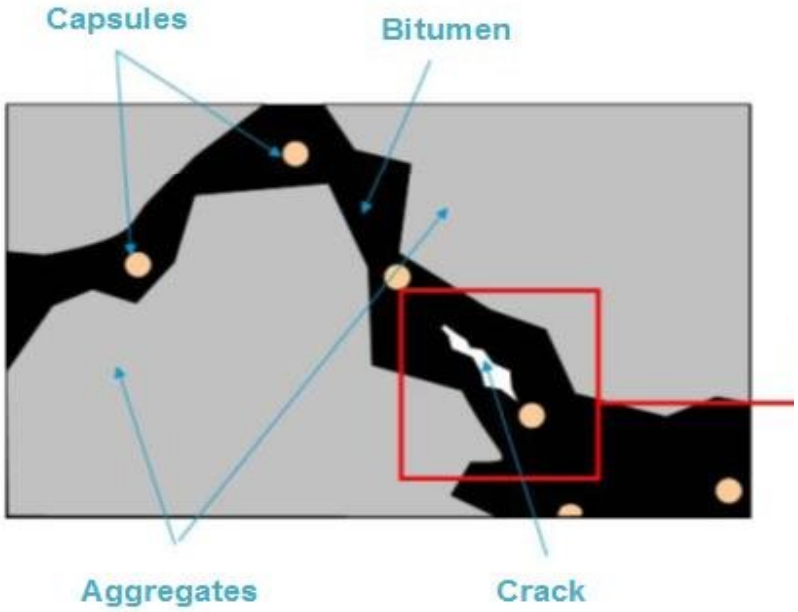
Microcapsulation

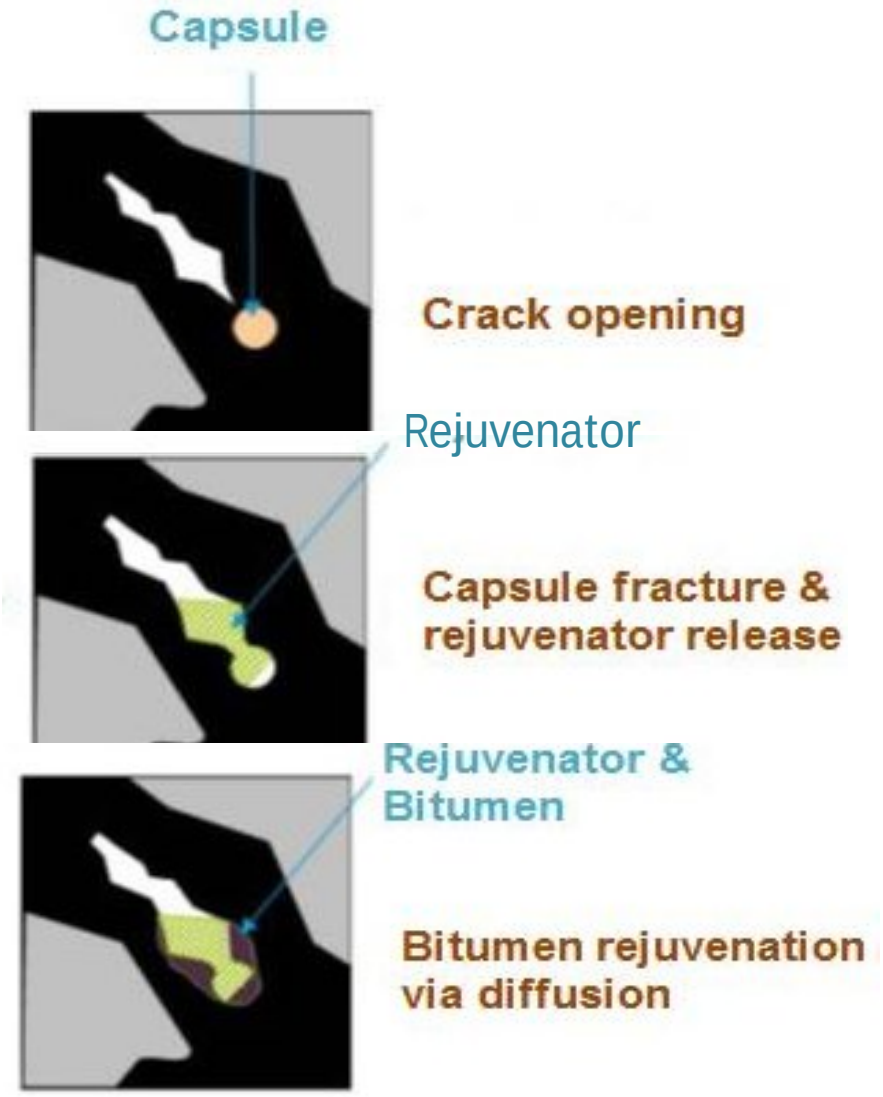
Simply applying rejuvenator to the surface of the pavement means that rejuvenator penetrates only top few mm of the pavement.

Solution – embed microcapsule containing the rejuvenator, throughout the bituminous matrix.

Microcapsulation

Concept





Microcapsulation

The limitation of this approach is that it works **only once**

Nevertheless the self-healing using microcapsules in early stages of result, further research is required in this field to finalize the parameters such as optimizing the quantity of capsules to be mixed, dosage of rejuvenators etc.

Hope the potential of self-healing using microcapsules will be demonstrated in the coming years

Induction Heating

During service period, bitumen will start degrading and loses the property of adhesion will aggregate minerals which results in propagation of cracks

At present there are no methods to close a crack especially when it is in developing stage.

Once the cracks becomes visible crack sealants or resurfacing techniques are used to close the crack, by that time maximum loss will be occurred and overall maintenance cost will also become high

Induction Heating

It is also proven that healing rate increases with the increase in temperature during this rest periods.

When you heat it, bitumen (1) expands and (2) it reduces its viscosity.

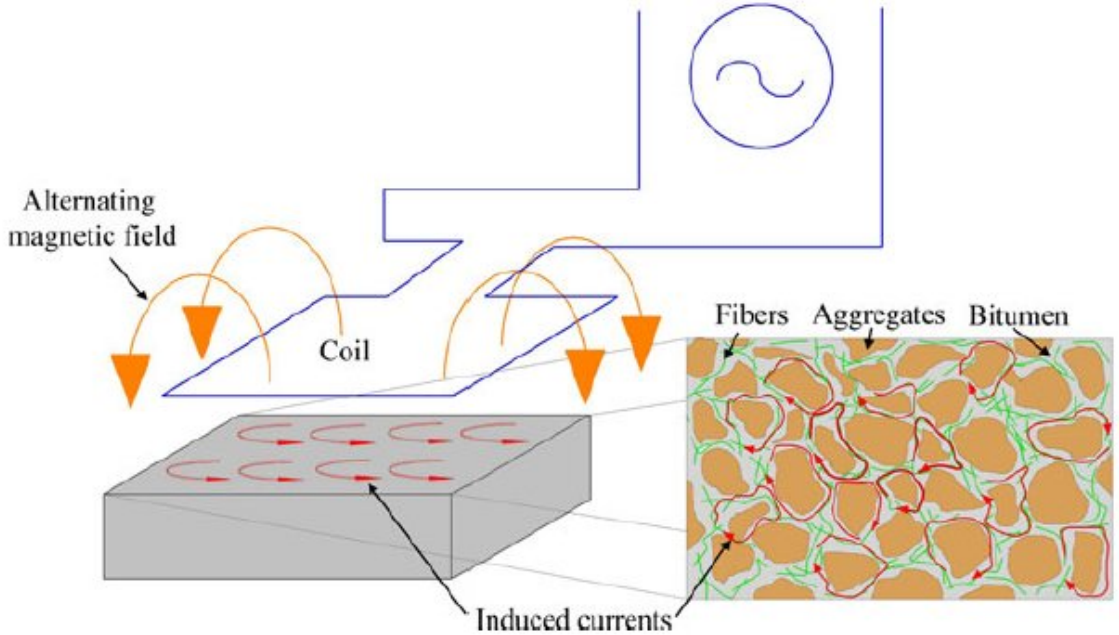
As bitumen has a reduced viscosity, it can flow better into the cracks. Bitumen drains into the cracks following the Darcy law. Pressure, gravity and surface tension are the main forces affecting it.

BUT

How to heat the bitumen uniformly through out the thickness of pavement ?

Induction Heating

The induction process operates by sending an alternating current through the coil and generating an alternating electromagnetic field. When the conductive bitumen specimen is placed under the coil, the electromagnetic field induces currents flowing along the conductive loops formed by the steel fibers



Induction Heating

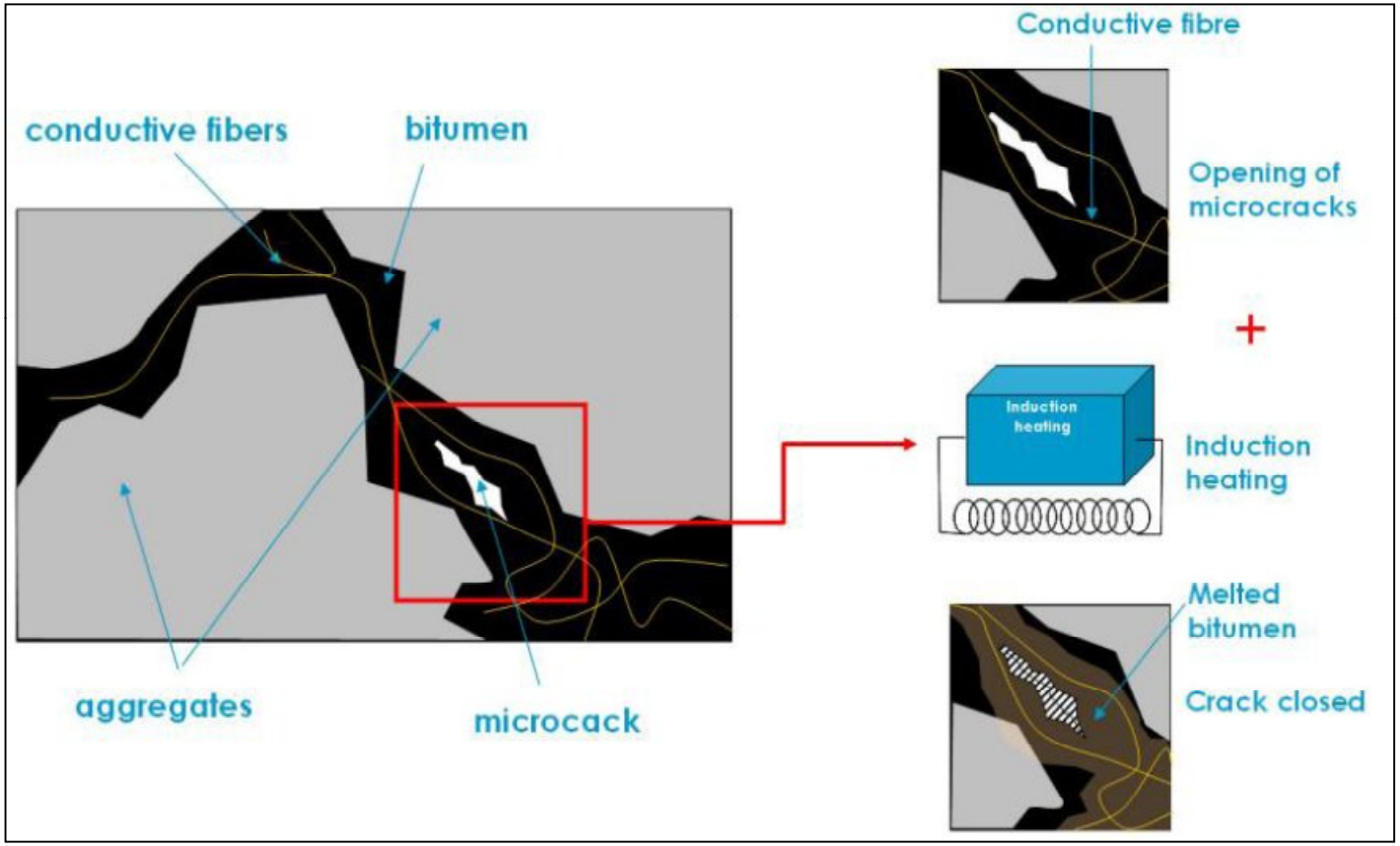
Is bituminous mix conductive ?

NO

To make the Bituminous mix conductive, a small amount of conductive materials like steel fibers, graphite etc. is added.

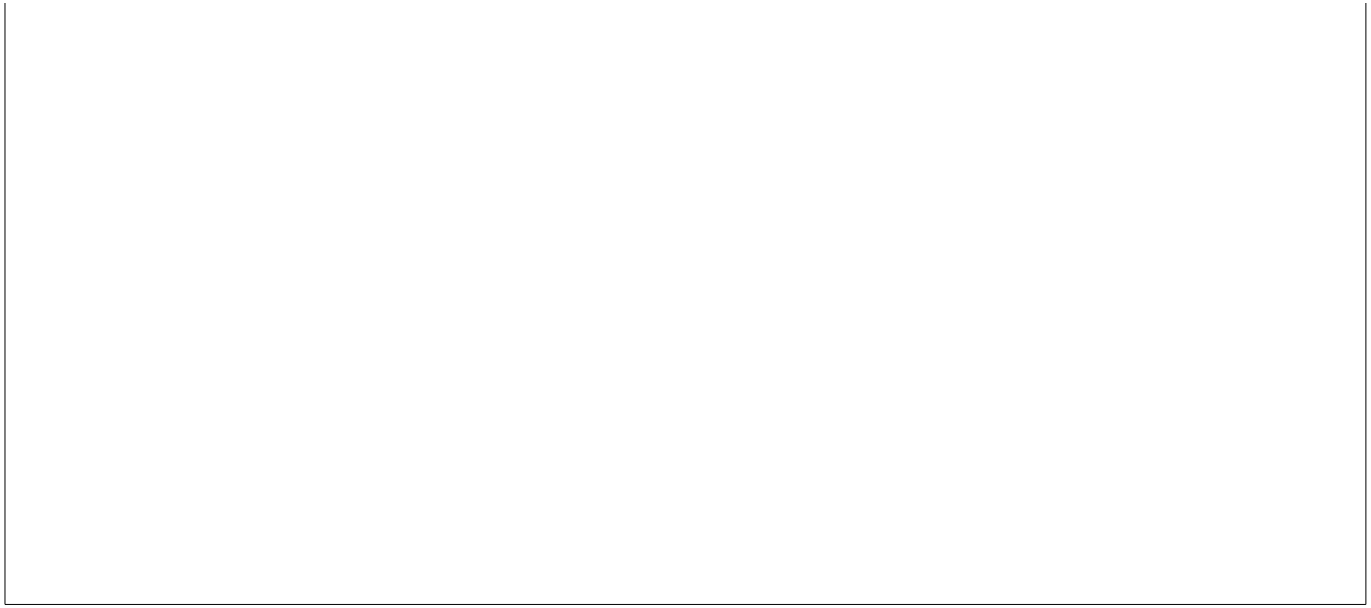
Induction Heating

Concept



Induction Heating

Induction Heating

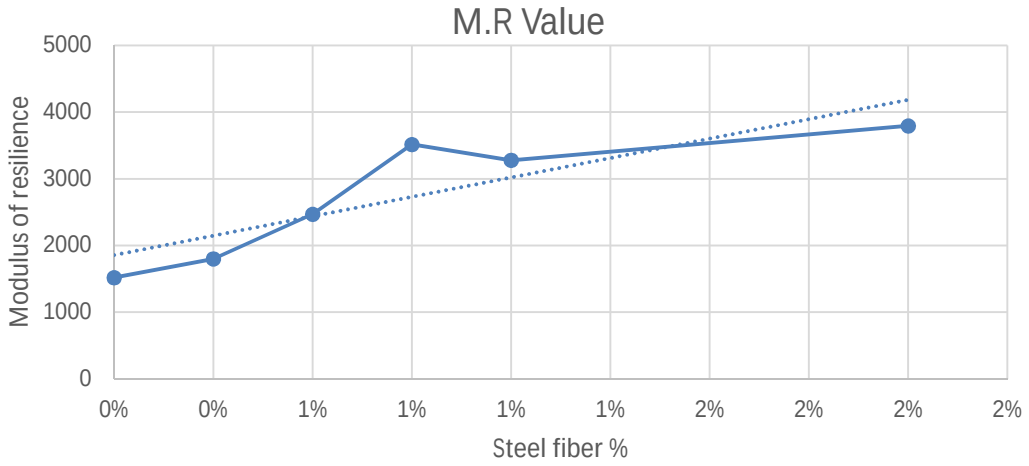


Induction Heating

The steel fibers added to provide conductive property of bituminous mix also have influence on the mechanical and physical properties of the bituminous mix.

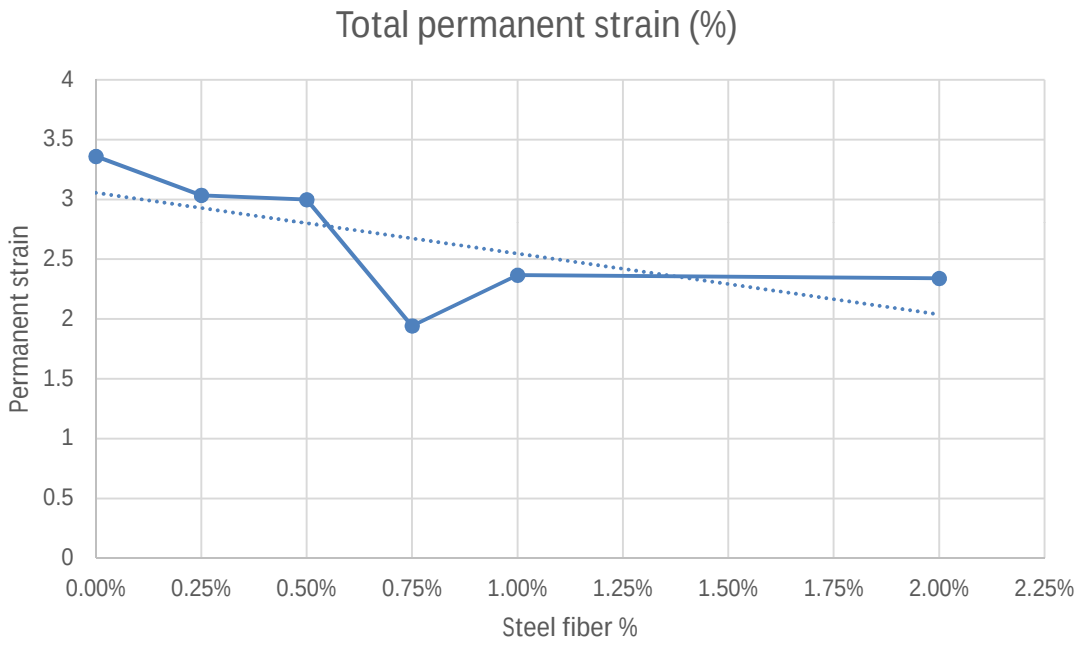
Modulus of resilience test

% steel fibers	*M.R Value (MPa)*
0%	1518
0.25%	1800
0.50%	2469
0.75%	3515
1%	3279
2%	3794



Induction Heating

Dynamic creep test



Induction Heating

Though the self-healing through induction energy is the most progressively used technology compared to other self-healing techniques

Few limitations such as overheating, draining, ageing of bitumen, loss of conductivity due to corrosion of steel fibers.

More studies are required to optimize the temperature, dosage of fibers, duration of heating etc. for better performance and successful application if this technology.

Induction Heating

This is the only self-healing technology which translated to field from laboratory studies when Dutch Nationals Roads Authority along with cooperation from TU Delft, resurfaced a road using induction self-healing bituminous porous mix for a length of 400 m

Nano Materials

Incorporation of Nanoparticles into bituminous pavements enhances the rheological, Thermal properties and ageing of the bitumen.

Additional to that it also have the potential to heal the micro cracks that are developed in the bituminous mix

The different Nano materials which shows self healing characteristics are

- Nano clay
- Nano silica
- Nanorubber

Nano Materials

Through engineering selection of type of nanoparticle and optimum dosage of these particles depending upon the application, very good results in terms of healing capacity will be achieved.

Major limitation of this technique is distribution of nano particles uniformly in the asphalt mix.

Few extension of the studies like multi time healing using nanoparticles, performance of healed pavements need to be demonstrated to gain the global acceptance as a feasible self-healing technology

Economic And Environmental Benefits By Self-healing Pavements

The additional cost involved in self-healing pavements are mainly of additional filler such as Nanoclay or Nanotubes, rejuvenators and conductive fibers for self-healing using Nano particles, Binder healing agent and steel fibers respectively is the 10% more on project cost, which is compensated as the life period of the pavement is almost doubled, negligible maintenance cost and the longevity of the road.

This technology helps in conservation of material resources, since the usual over-design of materials is no longer required. The benefits in terms of reduced energy consumptions and the carbon emissions caused by the maintenance activities will also be completely eliminated if this technology is successfully deployed

Conclusions

Though there are sophisticated and advanced pavement design techniques has evolved from time to time, but the basic ingredients of the bituminous pavements like aggregate, bitumen and filler were not replaced from past five to six decades.

All of them being a non-renewable resources, it requires special attention so that something is also left for future generation.

The development of such areas require interdisciplinary approach to understand the complexity of the technique and will have great future especially for the roads with limited access, areas where maintenance of the pavement causes lot of hindrances/cost/disturbance to traffic flow and this will truly revolutionize the bituminous pavement materials and its design.


SLOW