ASPHALT MASTIC SELF HEALING

García A.[1,2], Schlangen E.[2] and van de Ven M[3]

[1]Empa Swiss Federal Laboratories for Materials Testing & Research, CH-8600, Duebendorf, Switzerland
Email: alvarogarcia007@hotmail.com

[2]Delft University of Technology, Faculty of Civil Engineering and Geosciences, Micromechanics Laboratory (MICROLAB), Stevinweg 1,2628 CN Delft, The Netherlands
Email: H.E.J.G.Schlangen@tudelft.nl

[3]Delft University of Technology, Faculty of Civil Engineering and Geosciences, Road and Railway Engineering, Stevinweg 1,2628 CN Delft, The Netherlands
Email: M.F.C.vandeVen@tudelft.nl

Keywords: Self-healing asphalt, Activation energy, CT Scan, Capillarity.

ABSTRACT

Better knowledge of the self-healing rates of asphalt concrete would aid in planning the times for pavements reparation and maintenance. Although asphalt healing has a great importance in the performance of asphalt mixtures, limited work has been done to fully understand the mechanisms that control healing in asphalt binders. It is well known that healing depends on the surface energy of the material (wetting, to put both faces of the crack in complete contact) and in the interdiffusion and randomization capacity of the molecules from one face to the other [1]. The problem is that, in a fresh open crack in a real pavement or in the laboratory, it is improbable that its faces match perfectly. There will always be empty spaces in between, some times so wide that wetting cannot take place. In spite of this, healing continue happening: in the field, visible cracks observed in winter time can disappear in summer time. Even under fatigue tests, cracks in the mastic and debonding from the aggregates will happen. At that moment, these cracks are full of air, but if a rest period is allowed and enough energy is given to the system (the test sample is at an appropriate temperature), they disappear, even if their faces are not in contact.

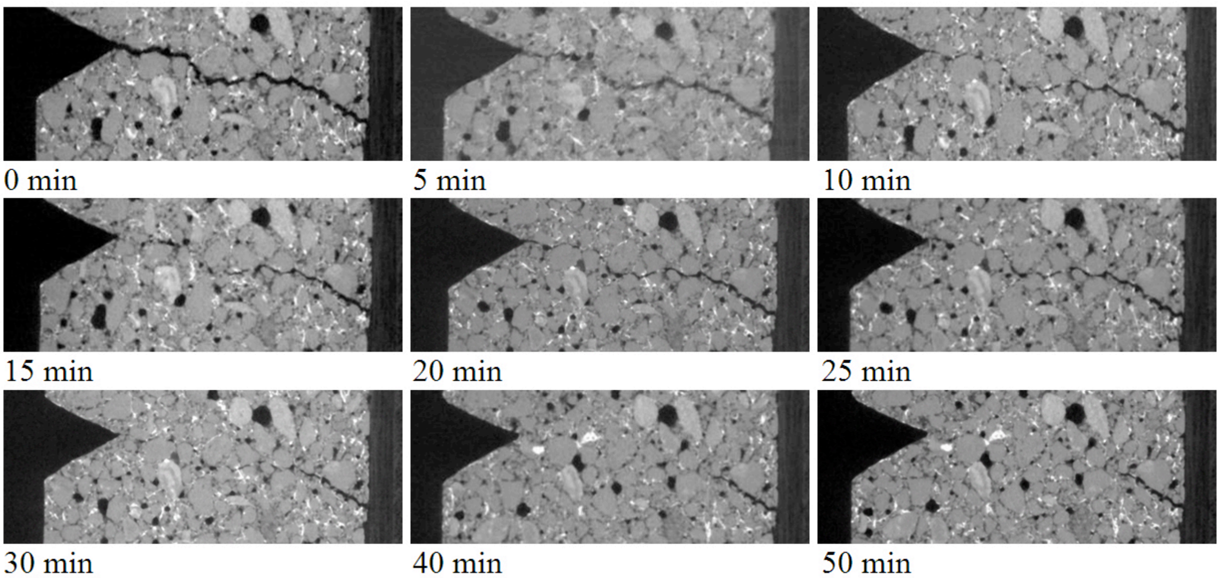

Figure 1: CT-Scan images of one section of the beam through the healing.

The objective of this research is to check if there is an extra mechanism, which influences healing to the point of closing big cracks whose faces are not in contact. It can be observed that asphalt mastic beams, broken in two halves, can be fully repaired by heating the material, even when the crack is visible to the naked eye (Figure 1). The hypothesis the author followed is that this happened because above certain temperature, bitumen starts behaving as a Newtonian fluid: When the two bodies of a broken mastic beam are put in contact through the original crack, there will be contact points and empty spaces. If the binder behaves as a Newtonian fluid, a pressure difference will appear in the contact points, which will be the driving force for a capillary flow of the binder, that will serve to close the cracks.

The main forces that act in the crack are: (1) the surface tension, $2\pi r\gamma\cos(\theta)$, where r is the crack width; γ the surface tension of the liquid and θ the contact angle in the wetting front. This value is not constant, but will vary with the velocity of the front and with the different materials in the composite. To simplify this research, it has been assumed constant in the calculations. (2) The viscosity of the liquid, $8\pi\eta h(t)(dh(t)/dt)$, where η is de viscosity of the liquid and $h(t)$ is the height of the liquid within the capillary at a time t. Although, as the diameter of the crack studied is rather small, the author expect the effect of the inertia term to be minor. For this reason, this term has been neglected.

Additionally, the effect of gravity as well as the hydrostatic pressure in the point where the binder is flowing into the crack have been considered: $\rho g h_p - \rho g h(t)$, where $\rho g h_p$ is the positive hydrostatic pressure, being ρ the density of the binder and h_p the distance from the beam surface to the bottom of the healed zone and $\rho g h(t)$ the weight of the healed crack. Finally, in order to take into account possible sources of energy dissipation during healing, a dissipation parameter β can be introduced. It would be variable with time for an individual contact point, but constant and equal to H when the whole beam is being considered. The equation obtained by balancing these forces is:

$$2\pi r\left(\gamma - \beta\frac{dh(t)}{dt}\right) = \rho g\left(h(t) - h_p\right) \qquad (1)$$

And the analytical solution for Eq. (1) is given by

$$h(t) = \left(h_p + \frac{2\gamma\pi r}{\rho g}\right)\left(1 - e^{-\frac{\rho g t}{2\beta\pi r}}\right) \qquad (2)$$

Which represents the evolution of a healed zone with time, starting from a contact point in a crack.

From this formula, it can be observed that gravity has a great effect in the healing: cracks buried dept in the specimen will heal faster than cracks in the surface. Also, healing rates will be influenced by the bitumen viscosity: They will be increased when it is reduced.

As a conclusion, self-healing of asphalt mastic happens when two faces of a crack are in contact. It is not necessary that all the points of both faces are in contact, only with some points healing will happen. In the beginning, diffusion of molecules in the contact points will take place. Immediately after this, capillary phenomena will start from these contact points and it will extend through the crack. Healing is faster in cracks buried deep in the specimen. And this capillary process will happen even if asphalt mastic is not under compression.

REFERENCES

[1] Little DN, Bhasin A, Exploring mechanisms of healing in asphalt mixtures and quantifying its impact. Self Healing Materials an Alternative Approach to 20 Centuries of Materials Science, Springer Series in Materials Science 2007; 100: 205-218.