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Evaluation of Self Healing Porous Asphalt for Road Construction

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ABSTRACT

This paper is summarizes the main results of experimental research on the induction healing of porous asphalt with steel wool fibres. Self healing Technology is new field within material engineering and is changing the way of material behave. The aging of asphalt under weather and traffic associated with the formation of micro cracks on surface layer of pavement by adding a conductive material in asphalt production, such as steel fibres, the possibilities arises of heating up the mortar of the asphalt by an induction device. A short " heat shot" through the steel fibre causes melting of bituminous binder and because of that, hairline or micro cracks on the pavement surface are close or healed. The asphalt mixture will reset and start a new life. This technique also can be used as additional way of storm water management. The past few studies suggestsed that, porous asphalt pavement intended to be used for parking lots, storm water management, peak flow reduction & noise reduction. Study includes sample making of various proportion of asphalt, aggregates & steel fibre.

Keywords: Ravelling, Induction Heating, Porous Asphalt, Noise Reduction.

I. INTRODUCTION

Porous asphalt shows excellent performance in both noise reduction and water drainage. Although porous asphalt has these great qualities, its service life is much shorter (sometimes only half) compared to dense graded asphalt roads. Ravelling, which is the loss of aggregate particles from the surface layer, is the main damage mechanism of porous asphalt surface wearing courses. In this research, an induction healing approach (namely, activating the healing process of asphalt concrete through induction heating) was developed to enhance the durability of the porous asphalt roads. Steel fibers are added to a porous asphalt mixture to make it electrically conductive and suitable for induction heating. When micro cracks are expected to occur in the asphalt mastic of the pavement, the temperature of the mastic can be increased locally by induction heating of the steel fibers so that porous asphalt concrete can repair itself and close the cracks through the high temperature healing of the bitumen (diffusion and flow). The closure of micro cracks will prevent the formation of macro cracks. In such a way, ravelling can be avoided or delayed in the end. To make asphalt mastic and porous asphalt concrete electrically conductive and suitable for induction heating, steel wool fibers were incorporated into them. The electrical conductivity and induction heating speed of asphalt mastic and porous asphalt concrete were first studied in this research. Asphalt mastic and porous asphalt concrete with steel fibers can be heated with induction energy. There is an optimal volume content of steel fiber in asphalt mastic or porous asphalt concrete to obtain the highest induction heating speed. However, porous asphalt concrete does not need to be fully conductive for induction heating. Every single steel wool is a heating unit. Nonconductive samples with steel fiber can still be heated with induction heating, but at a low heating speed. The diameter, length and content of steel wool fiber are important for the conductivity and heating speed of asphalt concrete matrix. It is proven that induction heating does not cause extra ageing to bitumen. The steel wool was optimized to obtain the best particle loss resistance in porous asphalt concrete. 8% steel wool was considered as the optimal content. The healing potential of porous asphalt concrete with steel wool fibre was also evaluated in this research with beam sample. The optimal induction heating temperature is 85 ºC for porous asphalt concrete to obtain the best healing rate. These are some objectives

1) To make self healing porous asphalt to be used for road construction.
2) Increase drainage properties of pavement.
3) To prevent raveling of top pavement.
4) Reduction in generation of micro cracks.
5) To minimize the maintenance cost and increase the life span of roads

II. MATERIAL & SAMPLE PREPRATION

The raw materials used in this research to make mastic beams are bitumen, aggregates & steel fibre.

A. BITUMEN

The bitumen used of penetration grade bitumen of 70/100. The crushed sand has an average density of 2.67 g/cm3. The bitumen was obtained from Indian oil corporation limited (IOCL) and the properties of bitumen are

Table 1

Binder grade	Penetration	Softening point	Specific gravity
70/100	89d mm	45.8 °C	1.03 g/cm3

B. COARSE AGGREGATE

Aggregate used for preparation of mastic beam are passing through 12.5mm and retained on 10mm IS sieve. The specific gravity of aggregates are 2.67.

C. STEEL FIBER

Steel fibre are brought from market and no treatment was needed for steel fiber. The size of steel wool should be 1mm and should be mixed in pieces of more than 100. The steel wool fibre used for making mastic beam & its properties are:

Table 2

Length of fibre	Diameter	Tensile strength	Density	Material type
30-60mm	0.45 to 1.00mm	750-1300Mpa	7.9g/cm3	Low carbon drawn round wire

The beams, were sawn from porous asphalt slabs. The dimension of these beams is 400 mm × 50 mm × 50 mm. The beams will be used to determine the healing effect of different percentage of steel wool fibre with asphalt mix.

PREPRATION OF MASTIC BEAM

The procedure for making mastic beam:

1. Select of mould size 400mm*50mm*50mm
2. Select the aggregates passed through 12.5mm & retained on 10mm IS sieve.
3. Heat the aggregates to remove the water content of aggregate and make it surface dry.
4. The bitumen required is obtained from 4.5% of total weight of aggregates. Heat the bitumen and pour the required bitumen into the mixing bowl.
5. Add the required steel fibre. The steel wool is added in different proportions such as 4%, 8% & 12% of the volume of bitumen. Add the required steel fibre.
6. Mixed bitumen & steel fibre in the mixing bowl then add the heated aggregates into the mixing bowl and mixed it thoroughly.

7. Blend the mixture at high speed until the steel fibres are dispersed quite well (for 15 minutes).
8. After mixing, the mould are casted by filling the mixed into the moulds and compacted.

III. RESULT & DSCRIPTION

A. Test description

Healing of asphalt mastic beams was characterized by testing the fracture resistance recovery of beam samples after fracture. The test procedure is first, two mastic beams were frozen at -20 ºC and broken in three point bending test (as shown in Figure 1). This temperature was chosen to avoid permanent deformation and to create a brittle fracture in the sample. Then, both pieces were put together in the same mould where they were originally made and induction-heated for few minutes. Finally, the samples were frozen to -20 ºC and broken again by means of three point bending test. This process was repeated until the beams did not resist any more loads.

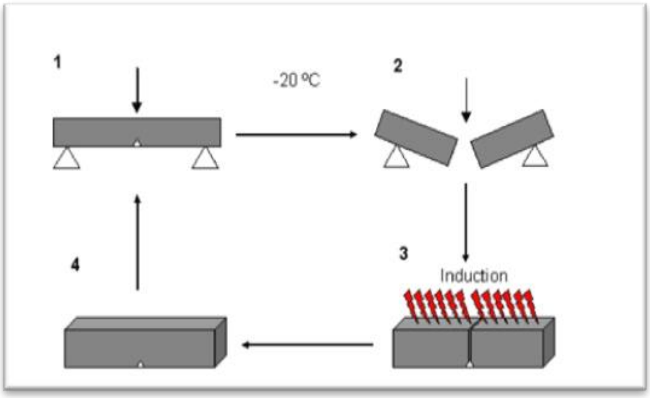

Figure 1. Three Point Bending Test

B. Test result

To study how induction heating influences the healing rate of the fractured beams, the fractured beams were induction-heated to different temperatures (30-50-70-85-100 °C), respectively, and then the corresponding fracture resistance of the heated beams was tested after cooling.

The evolution of the bending strength of asphalt mastic samples through successive damage-healing cycles. This process was repeated until the accumulated damage in the material was too high to continue the healing process. The strength recovery of the samples after the first healing is about 85% of the original value. In the successive cycles, it becomes stable at about 70% of the original value. The strength recovery is not complete for two reasons. The crack represents a weak point and the sample suffers some kind of structural damage due to the induction heating.

It could be seen that cracks disappeared because of the flow of bitumen during the induction heating process. It could also be observed that the volume of the mastic increased through the cycles, maybe because the heating was excessive and the air voids in the mixture suffered an expansion.

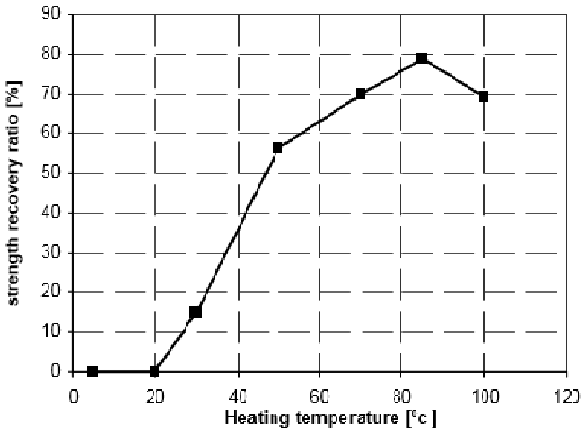

Figure 2. Strength recovery ratios with different induction heating temperatures.

IV. CONCLUSION

The general conclusions with regards to the main goals are as follows

1. Adding steel (wool) fiber to porous asphalt concrete makes it electrically conductive. The electrical resistance of porous asphalt concrete depends on the content, diameter and length of steel fiber. There is an optimal content of steel fiber for porous asphalt concrete to obtain the highest conductivity. Addition of more steel fibers does not increase the conductivity

anymore. Excess steel fibers can make the mixture difficult to mix.

2. Addition of a moderate amount of steel fiber can increase the ravelling resistance and indirect tensile strength of porous asphalt concrete. steel wool fiber proved to be the most efficient to increase the particle loss (ravelling) resistance and strength of porous asphalt concrete. The optimal content of this type steel wool is 8% (by volume of bitumen) to obtain the lowest particle loss value or highest indirect tensile strength. Adding 8% steel wool fibre to porous asphalt concrete increases its resilient stiffness and decreases its temperature dependency, increases its fatigue resistance and water sensitivity.

3. The healing capacity of asphalt mastic and porous asphalt concrete is increased by induction heating. The completely fractured asphalt mastic beams and porous asphalt concrete beams with steel wool cannot heal themselves at low temperatures; but they can be healed many times due to induction heating. The stiffness of fatigue damaged porous asphalt concrete beams recovered more and faster when induction heating is applied on the samples. The fatigue life of porous asphalt concrete beams with steel wool is significantly extended after induction heating. The optimal heating temperature is 85 ºC. Induction heating can be repeated when cracks appear again. Through multiple times induction heating, the fatigue life of a porous asphalt beam can be strongly increased. Induction heating also significantly increases the healing capacity and speed of aged porous asphalt beams. Induction heating should not be applied too early or too late during the service life of pavement.

4. The durability of porous asphalt concrete roads will be improved with induction heating because of the improvements in the healing capacity and in the fatigue resistance.

5. The induction healing capacity of porous asphalt concrete beams was evaluated in bending test on elastic foundation. The fractured beams cannot heal themselves at low temperatures. With induction heating, the beams can be healed up to 78.8%. The optimal heating temperature is 85 ºC. Further heating causes swelling and drainage problems of the binder, which offset the benefits of induction heating. Reheating doesn't decrease the healing ratio of the sample, which means that heating can be repeated when cracks appear again.

V. RECOMMANDATION

1. Optimization of steel fiber (wool) - The diameter and length of steel fiber are very important factors affecting the electrical conductivity and induction heating speed of porous asphalt concrete incorporating steel fibre. Addition of steel fiber should not reduce the air voids content of the mixture, which is very important for the noise reduction, spray and splash functions of a porous asphalt layer.

2. Optimization of mixing technology - To shorten mixing time and save energy consumed in dispersing steel fiber into porous asphalt mixture, the mixing technology needs to be optimized. It is recommended that steel wool is first mixed with bitumen.

3. Optimization of induction generator - To enhance the induction speed, the induction generator should be optimized by changing its frequency and the shape/size of the coil. The porous asphalt trial section should be heated very quickly and locally in the mortar to close the cracks inside without heating the stones. A surface temperature of 85 ºC in the mortar is recommended

4. Modeling of induction healing in porous asphalt concrete - To fully understand the mechanisms involved in induction healing and to predict the induction heating time needed to obtain a full healing recovery of porous asphalt concrete, modeling work can be of great help.

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