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EXPERIMENTAL STUDIES ON HEALING OF ASPHALT MIXTURES

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ABSTRACT

Healing occurs in asphalt mixtures due to the internal structure change which can be due to several mechanisms. To quantify healing of asphalt mixtures in the laboratory, cyclic triaxial tests were carried out on sand asphalt samples. The samples were tested at constant load with rest periods introduced between successive loading cycles to observe the deformation response. A set of loading and rest cycles were applied and the recovery of deformation in the subsequent loading cycles after a rest period of one hour was chosen as a parameter to characterise the healing of sand asphalt mixtures.

Key Words: Asphalt mixtures, Healing, Rest period, Sand asphalt

1. INTRODUCTION

The fatigue life of asphalt concrete pavements is normally predicted by conducting experiments in the laboratory on the fatigue behaviour of asphalt mixtures. However, the laboratory fatigue tests have limited capability in predicting the fatigue life in the field to a reasonable accuracy. This difference between laboratory fatigue prediction and field fatigue life is due to the loading differences between the laboratory and the field conditions. Continuous cycles of loading at constant load or deformation amplitude generally applied in the laboratory tests do not realistically simulate the compound loading conditions to which a pavement material is subjected under actual traffic conditions. One of the major differences between laboratory and field loading is the existence of rest periods. The rest period may be between each loading cycle or after some loading and rest cycles over a certain period of time. During the rest period, relaxation of stresses due to viscoelastic nature of asphalt mixtures and healing takes place. While relaxation of stresses is a well understood phenomenon in viscoelastic material, healing that too for asphalt mixtures is quite complex, yet to be unraveled.

Healing occurs in asphalt mixtures due to the internal structure change. It is hypothesized in the literature that the internal structure change can be due to several mechanisms such as closure of microcracks and macrocracks, coalescence of air voids, steric hardening of asphalt etc. Healing for asphalt mixtures is defined in the literature as "the partial recovery of mechanical properties upon resting"[4], "beneficial internal structure change"[3], etc. To understand the actual field behaviour of asphalt concrete pavements and to predict its service conditions to a reasonable accuracy, it is imperative that one understands the mechanism of healing that is at play during rest periods.

2. REVIEW OF LITERATURE

The healing of asphalt mixtures was observed and quantified by very few researchers through laboratory studies using uniaxial tensile tests[1], Izod impact tests[2], bend tests[1], impact resonance tests[5], etc. Bazin and Saunier[1] first quantified healing of asphalt concrete. They tested beam samples both in uniaxial tensile and bend tests. In the tensile tests, beam specimens were stretched along the longest dimension and the tensile strength and strain at break were measured. The broken samples were put in contact and samples were placed vertically resting on smallest base. After different rest periods and temperatures during rest, the samples were stretched again to determine the tensile strength and strain at break. The amount of healing was evaluated based on the healing index in both uniaxial tensile and bend tests.

Kim[2] observed and evaluated healing based on Izod impact tests. Charpy specimens were fractured before and following rest periods and the fractured faces were observed for visual evidence of healing using scanning electron microscope. An identical fractured surface as the control following a rest period was used to define the total healing of the material.

Daniel and Kim[5] evaluated the changes in the stiffness of two asphalt concrete mixtures due to temperature, fatigue damage growth, and healing during rest periods using the impact resonance method. They reported a decrease in dynamic modulus of elasticity with the increase of temperature and due to microcrack damage growth in the specimen due to fatigue. A gain in flexural stiffness was observed and was attributed to closure of microcracks or healing during the rest period and the amount of healing or stiffness gain increased when specimens were subjected to a higher temperature during the rest period.

Kim et al.[6] studied the effect of fatigue fracture and fracture healing during controlled-strain, dynamic mechanical analysis testing. The mechanical response during dynamic mechanical analysis testing was monitored using three different damage indicators: change in dynamic modulus, change in pseudo stiffness, and change in dissipated strain energy. They reported that healing during several rest periods introduced at equal levels of damage increased the fatigue life.

The review of literature on fatigue and healing of asphalt mixtures was reported by Venkaiah Chowdary and Rengaraju[7].

3. EXPERIMENTAL INVESTIGATIONS

3.1 Materials

Fine river sand passing through 4.75 mm Indian Standard sieve with gradation as shown in Figure 1 was mixed with 8 percent asphalt to prepare the Marshall samples of 100 mm diameter and 70 mm height. 60/70 grade straight run asphalt was used as the binder throughout the experiments. Sand and asphalt was heated together to get the desired sand asphalt mix and was transferred to a standard Marshall mould. Marshall sample was prepared by following the relevant ASTM standards[8] by applying 75 blows on either side of the hot mix using a 4.5 kg hammer with a free fall of 457 mm. The compacted specimens are cooled to room temperature in the moulds and then removed from the moulds using a specimen extractor. The physical properties of asphalt, sand and asphalt mix found through laboratory tests are shown in Table 1.
Specimens of 35 mm diameter and 70 mm height as shown in Figure 2 were cored from the Marshall Samples prepared with 8 percent air voids using a coring machine. The cored samples were allowed to cure for 24 hours at room temperature before the test to ensure the relaxation of residual stresses developed during coring.

3.2 Testing Method

To characterize healing of asphalt mixtures in the laboratory, repeated triaxial tests were carried out on sand asphalt mixtures in confined and unconfined mode. In reality, an asphalt concrete pavement is confined in all directions as shown in Figure 3 and the cyclic loading simulates the load application due to the vehicular movement. In order to verify the healing of asphalt mixtures without any lateral confinement, tests were also carried out in unconfined mode. All the tests were conducted in load controlled mode using a cyclic triaxial testing machine.

The cored specimen from the Marshall sample was covered with a rubber membrane to prevent the entry of water during confinement. The specimen was placed inside the triaxial test cell and was made water tight. Water was pumped into the cell to fill the cell completely without any air bubbles. Compressed air was pumped into the triaxial cell by rotating lateral pressure valve to provide confinement pressure. The specimen was tested at constant load with rest periods introduced between successive loading cycles to observe the deformation response. The test matrix is shown in Table 2. Continuous data throughout the loading and rest periods was gathered through a data acquisition system attached to a computer.

Repeated load and rest period of same duration was applied for certain number of cycles as shown in Figure 4. The material was allowed to rest for one hour and the same loading and rest cycles of equal duration were applied again to observe the deformation response. The deformation of the material with time during loading and rest periods was measured. Two samples were tested for each condition and the repeatability was found to be 4.7 percent. The deformation of the material after one hour rest period was chosen as the parameter to characterise the healing of sand asphalt mixtures. The influence of different test variables such as magnitude of confinement, magnitude of the load applied, etc., on the healing parameter was investigated.

3.3 RESULTS AND DISCUSSION

Large number of triaxial test specimens were tested to characterise healing of sand asphalt mixtures and only a few results have been discussed here. Triaxial test specimens were tested in both confined and unconfined mode. The deformation vs time plot for specimen tested in confined mode with a lateral pressure of 0.75 kg/cm^2 and vertical pressure of 4.875 kg/cm^2 (lateral to vertical stress ratio of 1:6.5) are shown in Figure 5. The sample was tested for 50 consecutive loading and unloading cycles of 10 seconds each. A rest period of one hour was introduced before the 51st loading and rest cycle. The deformation vs time curve in the 52nd cycle is very much below that of the 50th cycle curve. The decrease of deformation shows that the specimen healed with a rest period of one hour introduced after 50th cycle. This follows the similar trend as reported in the literature that "pressure on the surface of a damaged sample improves healing of asphalt mixtures" [1].

The deformation vs time plot for specimen tested in unconfined mode is shown in Figure 6. The sample was tested for 5 consecutive loading and unloading cycles of 14 seconds each. A rest period of one hour was introduced before the 6th loading and rest cycle. The deformation vs time curve in the 7th cycle was found to be above the 5th cycle curve. This shows that the specimen is getting damaged even with a rest period of one hour introduced after 5th cycle in unconfined mode. Thus it is necessary to confine the triaxial test specimen in order to observe healing.

In order to observe the effect of magnitude of confinement pressure on healing of sand asphalt mixtures, tests were carried out by varying the lateral pressure. The deformation vs time plot for specimen tested in confined mode with a lateral pressure of 0.6 kg/cm^2 and vertical pressure of 3.9 kg/cm^2 (lateral to vertical stress ratio of 1:6.5) are shown in Figure 7. The sample was tested for 50 consecutive loading and unloading cycles of 10 seconds each. A rest period of one hour was introduced before the 51st loading and rest cycle. The deformation vs time curve in the 52nd cycle is slightly below that of the 50th cycle curve. The decrease of deformation shows that the specimen healed with a rest period of one hour introduced after 50th cycle and also with the influence of a lateral pressure of 0.6 kg/cm^2 acting during the rest period. With the same lateral to vertical pressure ratio of 1:6.5, the decrease of lateral pressure from 0.75 kg/cm^2 as shown in Figure 5 to a lateral pressure of 0.6 kg/cm^2 as shown in Figure 7 shows that the decrease of lateral pressure reduces deformation recovery or healing of sand asphalt mixtures.

The deformation vs time plot for specimen tested in confined mode with a lateral pressure of 0.5 kg/cm^2 and vertical pressure of 4.5 kg/cm^2 are shown in Figure 8. The sample was tested for 15 consecutive loading and unloading cycles of 14 seconds each. A rest period of one hour was introduced before the 16th loading and rest cycle. The deformation vs time curve in the 17th cycle coincided with that of the 15th cycle curve. This shows that the specimen has not accumulated any damage and it healed with a rest period of one hour introduced after 15th cycle and also with reduced lateral pressure acting continuously during the rest period.

4. CONCLUSIONS

The experimental investigations and the results obtained have adequately proved the healing or beneficial deformation recovery of sand asphalt mixtures with rest periods. The amount of healing was observed to be dependent on the lateral pressure applied on the specimen in the triaxial test and also on the magnitude of the lateral pressure. Thus a triaxial test setup is best suited to study the healing of sand asphalt mixtures in the laboratory.

It was observed from the experimental studies that with repeated loadings, the damage accumulates and even a rest period of one hour increases the deformation in unconfined mode. With confinement of the triaxial specimen during loadings and rest period, the healing or deformation recovery increased which is due to the beneficial internal structure change occurring in the asphalt mixtures during a rest period with lateral pressure acting continuously. The amount of healing or deformation recovery increased with increase in lateral pressure for the same lateral to vertical pressure ratio.

Further studies will be carried out to study the effect of different test variables such as air voids in the mix, specimen loading period, asphalt grade, etc on healing of sand asphalt mixtures.

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6. REFERENCES

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TABLES

Table 1 Properties of asphalt, sand and sand asphalt mix

S.No.	Property	Value
1	Penetration @ 25°C, 5 sec, 100 g, 1/10 mm	67
2	Softening point of asphalt, °C	41
3	Ductility of asphalt @ 27°C, cm	102
4	Specific gravity of asphalt	1.01
5	Specific gravity of sand	2.56
6	Specific gravity of sand asphalt mix at 8% air voids	2.10
7	Specific gravity of sand asphalt mix at 10% air voids	2.06

Table 2 The test matrix

S.No.	Variable	Value
1	Vertical pressure (σ_1)	3.0, 3.9, 4.5, 4.875 kg/cm^2
2	Lateral pressure (σ_3)	0.0, 0.5, 0.6, 0.75 kg/cm^2
3	Rate of Loading	1/14, 1/10 cycles per second

FIGURES

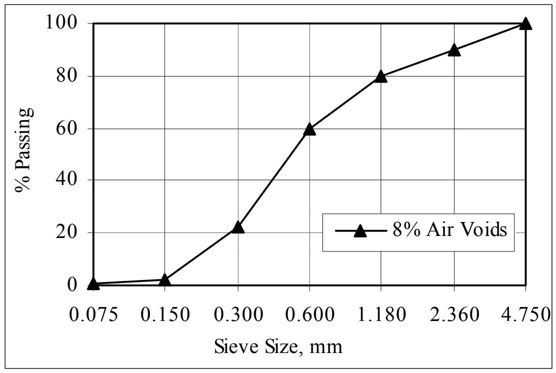

Figure 1 Gradation of sand used for the study

Figure 2 Triaxial test specimen cored from Marshall Sample

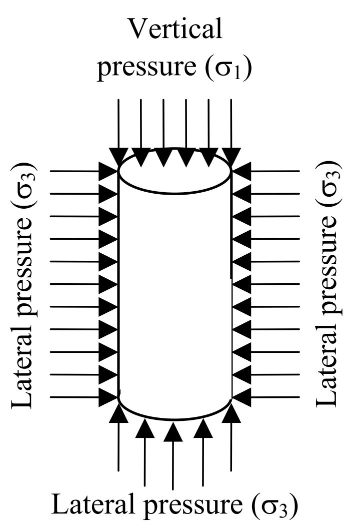

Figure 3 Loading configuration of the triaxial specimen

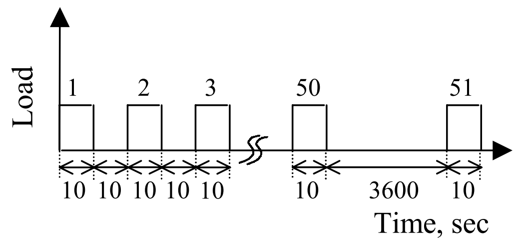

Figure 4. Load controlled cyclic loading and rest periods

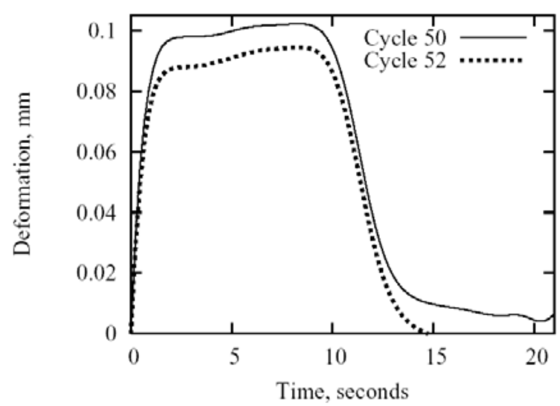

Figure 5. Vertical Pressure = 4.875 kg/cm^2 and Lateral Pressure = 0.75 kg/cm^2

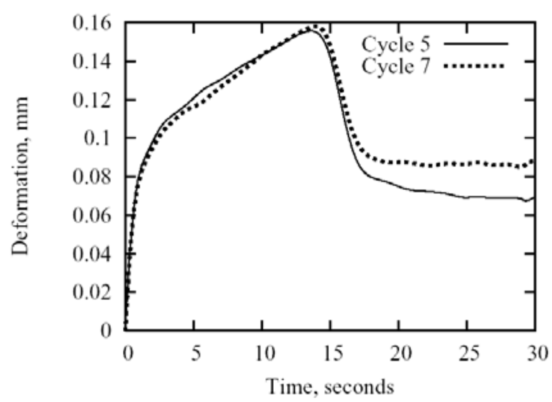

Figure 6 Vertical Pressure = 3.0 kg/cm^2 and Lateral Pressure = 0.0 kg/cm^2

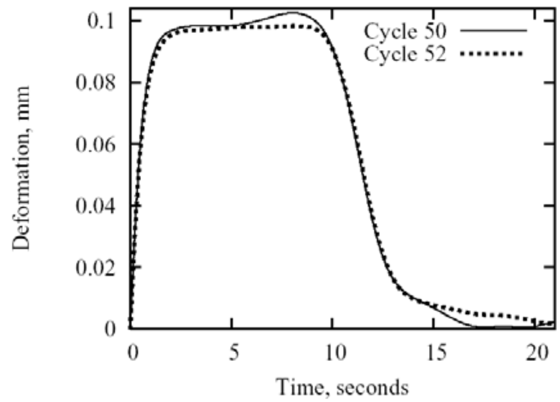

Figure 7 Vertical Pressure = 3.9 kg/cm^2 and Lateral Pressure = 0.6 kg/cm^2

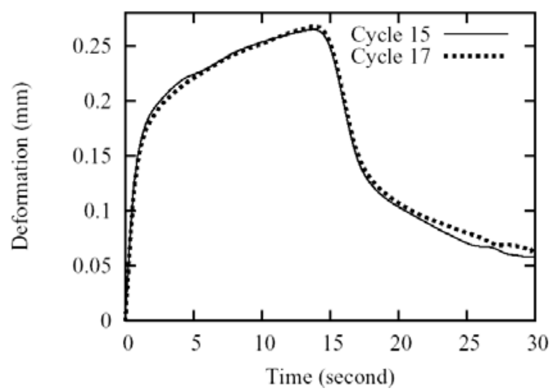

Figure 8 Vertical Pressure = 4.5 kg/cm^2 and Lateral Pressure = 0.5 kg/cm^2