THE EFFECT OF RAINFALL ON ROAD SURFACE PERFORMANCE

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ABSTRACT

It has been the experience of all countries throughout the world that our climate is changing. It is predicted that climate change will affect rainfall patterns with increased frequency and intensity. This paper considers the effect of water on the performance of road surfacing materials based on laboratory test analysis.

During a rainfall event, the road is being wet and the water can also fill in the void structure of the road material through joins, cracks and road soulders. A simple laboratory method was developed to assess how different types of asphalt dried out after a rainfall event and found a distinct difference between the more impermeable materials and the more permeable materials used.

Keywords: rainfall, dry out process,climate change

BACKGROUND

There is now overwhelming evidence that the Earth's climate is changing. This has been shown by changes in rainfall pattern, rises in sea level, retreating of glaciers and thinning of arctic sea-ice.

These changes have been also experienced in the Indonesia and throughout the world. The changes are accompanied by serious global risks threatening access to water, food production, health and the environment (Stern Report, 2006).

All aspects of human life are therefore threatened with these changes. Global efforts to tackle climate changes should also be accompanied with regional and national responses. In relation to this, the focus is on temperature and precipitation. IPCC (2007) stated that one of the most important factors relating to climate change was air temperature.

The main objective of this paper was to assess the effect of rainfall on the durability of surfacing materials. Mix durability is a fundamental property and relates to global issues ranging from sustainability and climate change.

For example, if the surface mix can be designed to have a longer life then there will be less spent of its maintenance. Climate change predictions imply that roads will be wetter for longer periods of time therefore increasing the risk of moisture related premature failures.

Therefore, this issue of mix durability is a very important factor that needs to be understood. Although there have been attempts to look at moisture sensitivity few have fully considered the simple effect of rainfall on the surface layers of a road.

The research considered the relatively simple issue of how road surface materials dry out i.e. how long do they remain wet and how repeated rainfall events effect mix stiffness i.e. does a road loose stiffness during prolonged periods of wet weather.

In real-life both conditions will affect the life of the surfacing layer and possibly the structure underneath.

LITERATURE REVIEW

This paper considers the effect of water on the durability of asphalt surfacing materials. This is particularly interesting given that a surfacing asphalt layer can be designed to be porous i.e. porous asphalt or be impermeable i.e. hot rolled asphalt.

It is generally accepted that climate change will affect rainfall patterns with increased frequency and intensity. This will result in the road being wet for longer periods of time and so affect levels of grip. This will also influence the effect of water contained within the interconnected void structure of the surface mix.

Ridgeway (1976) reported on permeability measurements on un-cracked specimens of Portland cement concrete and dense-graded bituminous concrete. It had found that the amount of infiltration through un-cracked areas was insignificant compared to the amount of infiltration that occurs through joints and cracks in the pavement surface. Ridgeway (1976) also stated that the amount of water that enters the pavement structure through the cracks or joints depends on: the water carrying capacity of the crack or joint; the area that drains to each crack or joint; and the intensity and the duration of the rainfall.

Review of existing literature has highlighted that the effect of rainfall on surfacing mix durability has not been the subject of significant investigation. This is important given the predictions of global climate change and rising costs of materials. The UK’s climate is likely to suffer greater extremes of wetness whilst world demand for oil based products is causing major increases in the prices of bitumen.

It is proposed that there may be an increasing number of asphalt surfacing materials failing prematurely due to rainfall or moisture sensitivity related issues.

Collop et al. (2004) reviewed existing literature and concluded that the primary factors affecting the durability of bituminous mixtures were age-hardening and moisture damage, assuming they are constructed correctly.

These are both important issues given global climate predictions. The research reported by Collop et. al (2004) resulted in the Saturated Aging Test (SATS) that is currently used to asses base layers.

Moisture damage can be described as separation of the bitumen coating from the aggregate surface in a compacted mixture in the presence of water under the action of repeated traffic loading Coree and Kim (2005).

METHODOLOGY

Test specimen preparation

The water retention characteristic of four asphalt mixes was assessed as they were allowed to dry. The test specimens used were 100mm in diameter and compacted using gyratory compaction at 10, 50, 100, 200, and 700 gyrations. This was to provide a range of void / interconnected void contents.

The base and sides of each test specimen was sealed using paraffin wax – see Figure-1. This ensured that any moisture loss during drying occurred from the top.

a. Before paraffin wax treatment

b. After paraffin wax treatment

Figure-1. 100mm specimens preparation

The test was carried out for two different temperatures i.e. 10 and 20^{o}C. At the start of each the test specimens were immersed in a water bath for 48 hours. Each test specimen was then removed, dried with a towel and weighed.

Figure-2 to Figure-5 show the relationship between the mass of absorbed water and the amount of compaction given as number of gyrations. The graphs plot the initial absorbed water mass of each test specimens for Test 1 (10^{o}C), Test 2 (20^{o}C) and its average value.

It shows that the saturation process repeatedly well for almost all specimens. As predicted, the higher number of compaction, the lower air void content and the lower absorbed water by the specimen.

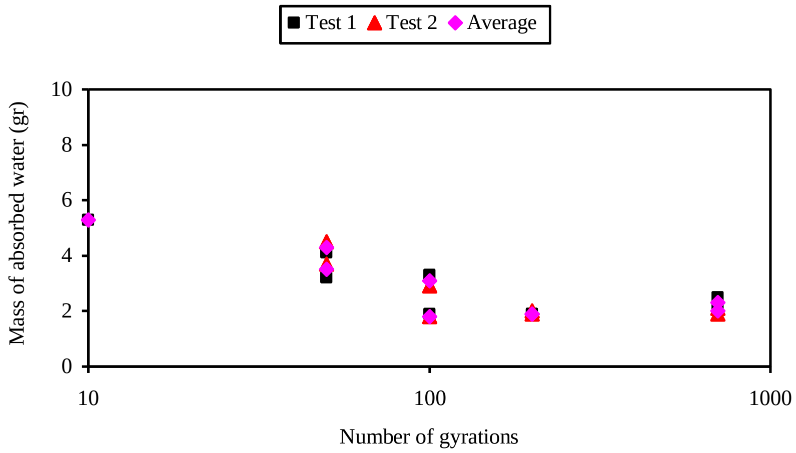

Figure-2. Mass of initial absorbed water in relation to amount of compaction for 14mm MA

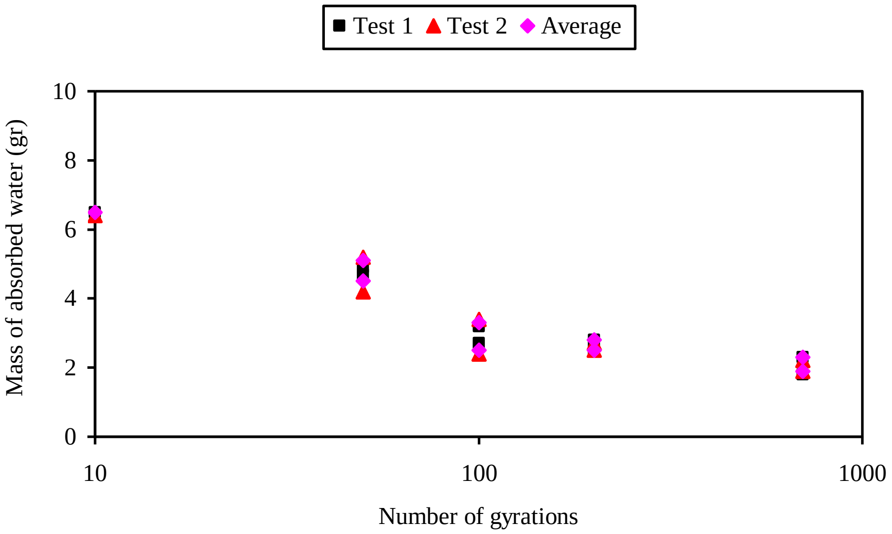

Figure-3. Mass of initial absorbed water in relation to amount of compaction for 10mm MA

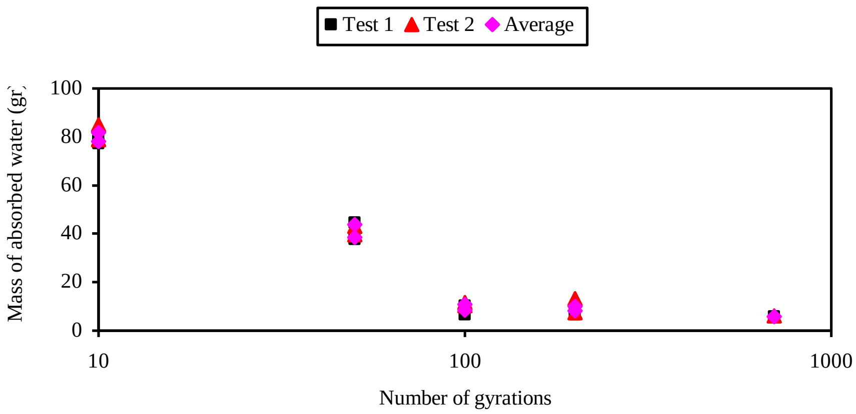

Figure-4. Mass of initial absorbed water in relation to amount of compaction for 10mm DBM

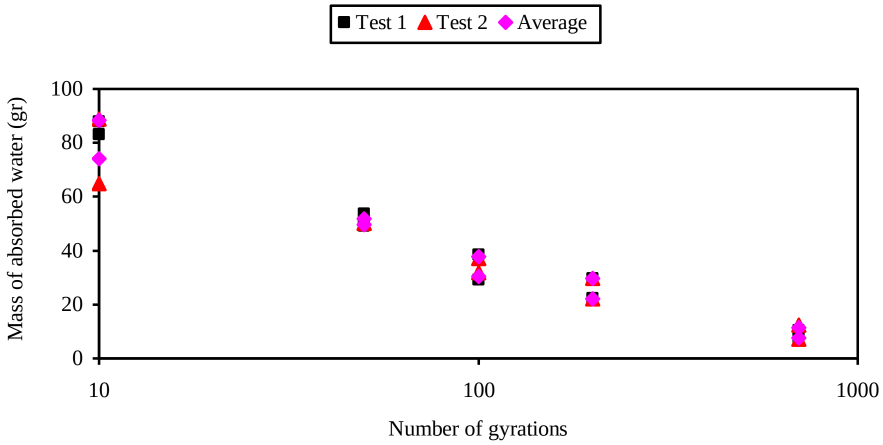

Figure-5. Mass of initial absorbed water in relation to amount of compaction for 6mm OT

RESULT

Measurement of moisture loss

Moisture loss was measured periodically over 170 hours period. This was determined by weighing each specimen in the temperature controlled room. As the base and sides of each test specimen was sealed with wax any change in specimen mass was due to evaporation.

The change in mass and percentage water retained in each test specimen is given in Appendix D. Figures 7.9 and 7.10 represent the general trend during the drying process for the dense 10mm MA and open 6mm OT at 20^{o}C. It was found that the greatest amount of water loss occurred within the first 20 hours particularly for the 10mm MA.

Since there were two test specimens for each number of compactions, the average value was taken and re-plotted as shown in Figure-6 and Figure-7.

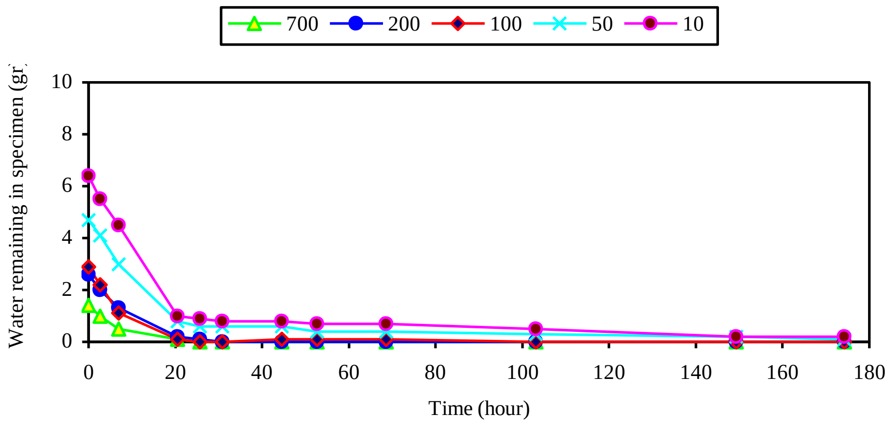

Figure-6. Average water remaining in specimen for 10mm Marshal Asphalt at room temperature 20^{o}C

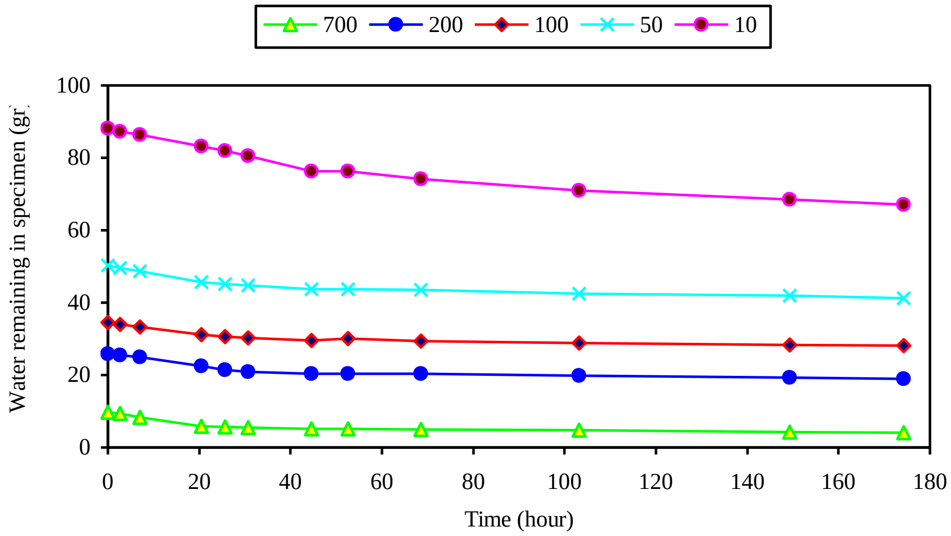

Figure- 7. Average water remaining in 6mm Open Texture specimens for differing number of compactions, at room temperature 20°C

The effect of temperature on moisture mass loss

Figure-8 and Figure-9 show the effect of temperature on drying process for 10mm Marshall Asphalt and 6mm Open Texture respectively. The figures show that the two temperatures used has no significant effect on the drying process.

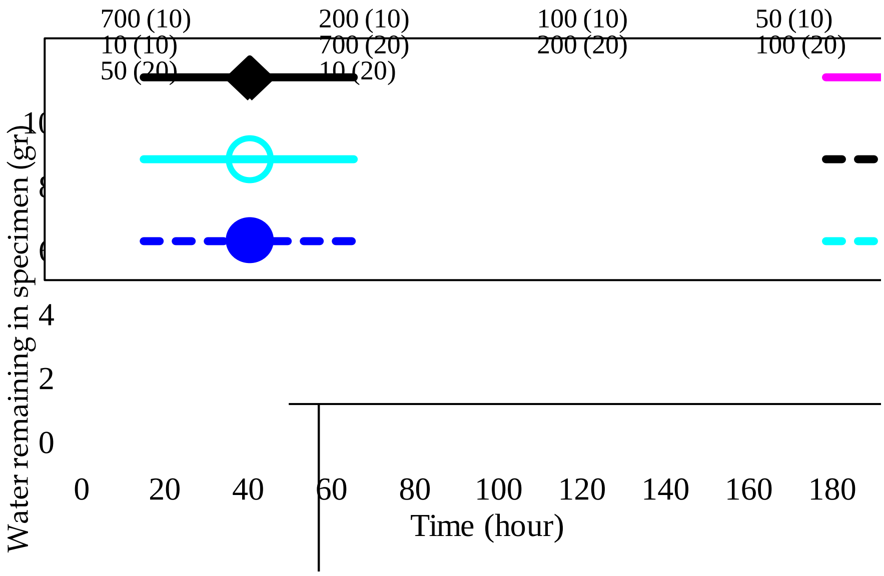

Figure-8. Average water remaining for 10mm Marshal Asphalt

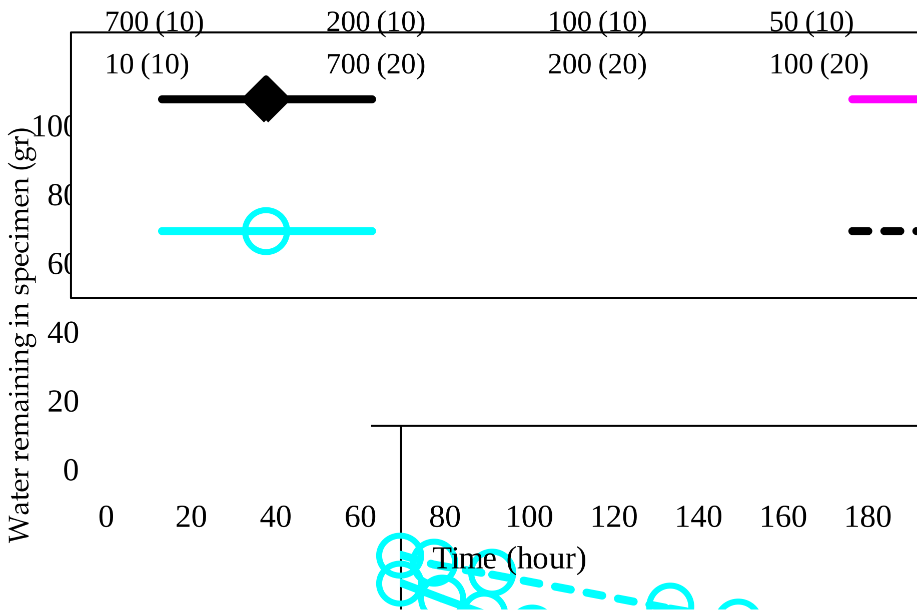

Figure-9. Average water remaining for 6mm Open Texture

DISSCUSION

The drying out process is a dynamic process and influenced by many environmental factors such as air temperature, relative humidity, solar radiation and wind speed. It can be affected by the temperature of the asphalt material and its surface area where a larger surface area will result in a faster drying time.

Due to the large number of test samples (40) the typical vacuum method of saturation was not carried out. However, a road surface is not subjected a vacuum and so the pre conditioning process using a water bath may have been a better simulation of a wet road surface.

It clearly shows that the 14mm and 10mm MA behaved very differently compared to the 10mm DBM and 6mmOT in terms of the amount of water that could be initially absorbed by the test specimen. This was dependant on void content or to the amount of compaction.

In simple terms evenly poorly compacted 14mm and 10mm MA absorbed small amounts of water and so should have good resistance to moisture sensitivity issues. In contrast, poorly compacted 10mm DBM and 6mm OT will absorb a much larger amount of water and potentially be at greater risk from moisture sensitivity issues.

Comparison of Figure-6 and Figure-7 show how the 10mm MA and 6mm OT materials dry out. The 10mm MA had absorbed very little water irrespective of how well they were compacted. Figure-6 shows that the material lost this water quickly within the first 20 hours. In contrast the much greater amounts of water within the 6mm OT was not significantly reduced even after 170 hours or 7 days.

This was unexpected as it was thought that the interconnected voids would have allowed the drying out process to have quickly occurred. This may be attributed to the wax coating around the edge and base of the test specimens acting as an impermeable barrier. Any drying would be simply due to evaporation and not lateral drainage as would occur in a road.

It is believed that the experiment represents a worse case condition where the rain that has already percolated through the porous surface material is trapped and cannot flow freely to the drainage system. In this case it will take a long time for the road surface layer to dry out by natural processes.

Two temperatures were assessed during the drying out test process. The results shown in Figure-8 and Figure-9 show that there is no significant difference in the drying out process between the two air temperatures used i.e. 10^{o}C and 20^{o}C respectively. The graphs show that was very little difference in drying rate for these two different temperatures.

Harwood et al. (1988) concluded that solar radiation and wind speed gave the strongest effects on the drying time of pavements. They found that relative humidity air temperature had a significant effect but were less important than solar radiation and wind speed.

Based on the drying out test, where only temperature effect was observed, it was concluded that for dense well compacted materials, the drying process related only to the water trapped on the road surface i.e. trapped within the depth of its surface texture.

In the case of porous materials and road surfaces that may be cracked or suffering from other types of deterioration water will typically penetrate into the material and take a long time to slowly dry out. If the frequency of rainfall events is high this can lead to moisture induced damage on mix durability.

CONCLUSION

- The dry-out test investigation showed that there is a distinct difference between the more impermeable materials (e.g. 10mm and 14mm MA) and the more permeable materials used (e.g. 6mm OT and 10mm DBM).

- Most of the mass loss for the 10mm and 14mm MA related to water trapped in the depth of surface texture.
- A significant amount of water remained in the permeable 10mm DBM and 6mm OT after 7 days.

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