THE EFFECT OF RAINFALL ON ASPHALT SURFACING MATERIALS

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ABSTRACT: This paper reports the findings of a laboratory investigation to determine the effect of rain on the 3-d drainage characteristics of asphalt surfacing mixes. A rainfall simulator was developed to apply differing rainfall intensities and surface flow assessed at different crossfall slopes. Different stages in the development of surface flow during simulated rainfall were evaluated for 5 different types of surface. A model was developed to related rainfall intensity, crossfall and texture depth with Time of Transition Flow. This is the duration into a rainfall event at which road surface texture has filled with water and surface runoff starts. The findings illustrate that surface runoff characteristics can be evaluated in the laboratory prior to full-scale road trials.

Keywords: rainfall, surfacing, simulator, intensity, crossfall, Time of Transition Flow

1. INTRODUCTION

This paper reports findings of an investigation to determine the effect of rainfall on the properties of asphalt surfacing materials. The effect of rainfall is important for a number of reasons. For example, it can significantly reduce skid resistance. Excessive spray generation can make driving dangerous due to reduced visibility. Water has also been shown to cause reduction of aggregate / bitumen adhesion due to moisture sensitivity related issues.

This paper considers the development of surface runoff during simulated rainfall. In particular the relationship between rainfall intensity, crossfall and texture depth with Time of Transition Flow i.e. the duration into a rainfall event at which the surface texture has filled with water and surface runoff starts to happen.

2. MATERIALS USED IN THE INVESTIGATION

Five types of test surface were assessed in the investigation. The asphalt materials were selected as being representative of the wide range of road surface materials currently used in the UK. These consisted of the following:

- Proprietary 6mm Open textured asphalt surface (6mm OT).
- 10mm Dense Bituminous Macadam (DBM) wearing course to BS 4987.
- Proprietary 10mm Marshall Asphalt (10mm MA)
- Proprietary 14mm Marshall Asphalt (14mm MA).
- Plywood to give a very low value of texture depth (assumed to be close to zero as measured using the sand-patch test method).

3. RESEARCH METHODOLOGY

The research developed a laboratory based methodology to investigate the interaction of rainfall with a range of road surfaces. This resulted in development of the Ulster Rainfall Simulator (URS).

Development and subsequent use of the URS involved the following stages i.e. preparation large test specimen slabs, mounting the large test specimen slabs at three crossfalls, simulation of three rainfall intensities under controlled laboratory conditions allowing the inter-relationships between rainfall intensity, rainfall duration, texture depth and crossfall to be determined.

The test specimens were 1400 x 600 x 50mm in size. The different types of hot mix asphalt were sampled at a number of mixing plants in the UK. Sufficient 25kg bags of asphalt were reheated in the laboratory and placed in a specially designed compaction mould.

The compaction mould used a concrete shuttering panel to provide the strong base with the sides made with 50mm thick timber. A vibratory pedestrian roller was used to compact the hot asphalt. Reheating and compaction temperatures were recorded.

The finished surface texture of each asphalt test specimen was determined at 8 locations using the Sand Patch method in accordance with BS 598:Part 105 (2001).

The Ulster Rainfall Simulator (URS) is shown in Figure 1. It consists of the following main components i.e. mains water supply and storage tank, water pump to pump water to the spray nozzles, a flume on which the asphalt slab is located, a flow meter and water pressure gauge, a spray nozzle and water capture tank.

The spray nozzle was located 1.43m above the test surface. Three different capacity nozzles were used. Initial tests were carried out to standard the appropriate water pressure and nozzle type to give three rainfall intensities.

The edge of the asphalt slab in contact with the edge of flume was sealed using mastic sealant to avoid water leakage. The slope of the flume arrangement was adjusted using a hydraulic jack.

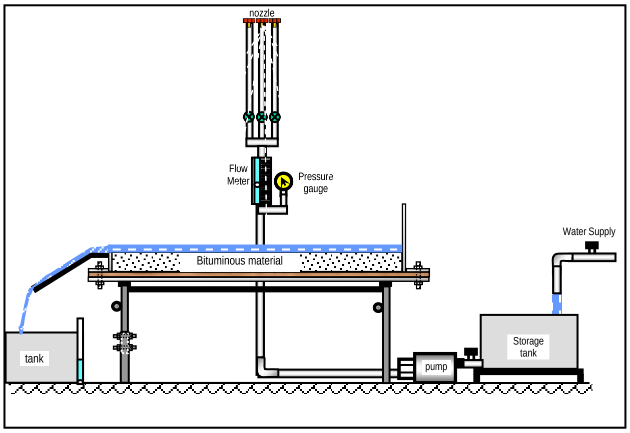

Fig. 1. The Ulster Rainfall Simulator

The uniformity of rainfall intensity distribution across the large asphalt test slab was determined by placing 13 catch cans evenly across its surface. The simulated rainfall for each of the three spray nozzles was collected over a 10 minute duration for each catch can.

This data was analysed to determine the uniformity of each spray nozzle distribution using Christiansen Uniformity Coefficient (CU) as detailed by Zoldske and Solomon (1988):

A summary of the nozzle performance data is given in Table 1. This shows the pressure and flow rate values used for each of the spray nozzles to give the increasing rainfall intensities used during the experiments.

Table 1. Summary of nozzle performance data

Nozzle Number	**Pressure (bar)**	**Flow rate (l/s)**	**Average Rainfall Intensity (mm/h)**	**CU (%)**
1	0.75	2.00	31.4	86.6
2	1.20	4.20	54.2	91.2
3	1.60	5.75	78.3	85.7

4. TESTING

Table 2 shows the four groupings of variable assessed i.e. those belonging to the test surface, the test condition, variables measured during testing and those calculated from the test data.

Table 2. Summary of test variables

Variable Group	Variable
Test surface	Surface type Texture depth Air voids Hydraulic conductivity
Test condition	Crossfall Rainfall intensity Duration of testing
Measured during testing	Runoff Percolation
Calculated from test data	Time for transition flow (Tft) Time for steady state flow (Tsf) Total flow rate

A typical test consisted of setting up the slab at the required crossfall angle. The nozzle type and pump conditions selected to ensure the required rainfall intensity.

The test was then started and the amount of water captured at the down slope end of the flume every 10 seconds. Testing typically lasted for 10 minutes during which period runoff reached equilibrium.

Some of the asphalt materials were designed to be porous and so surface runoff and percolation down through the material was also recorded.

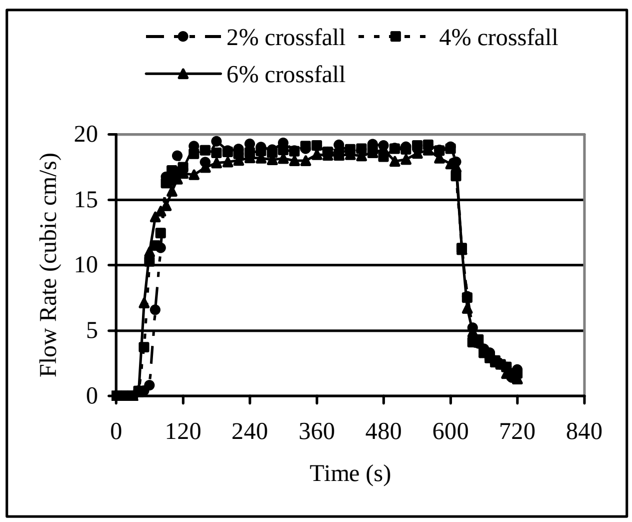

Fig. 2. Example of flow rate plotted against time (14mm Marshall Asphalt, Rainfall Intensity 78.3mm/h and crossfalls of 2, 4 and 6%)

Figure 2 shows an example of flow rate against time for 14mm Marshall Asphalt at a rainfall intensity of 78.3mm/h and crossfalls of 2, 4 and 6%. This example shows that at the greatest rainfall intensity crossfall had a minimal effect in the time it took for the surface texture to reach a condition of steady flow.

This time period has been termed the Time of Transition Flow (Ttf) and relates to the time it takes for the surface voids and interconnected voids within a mix to become infilled by water. After this period surface runoff will start.

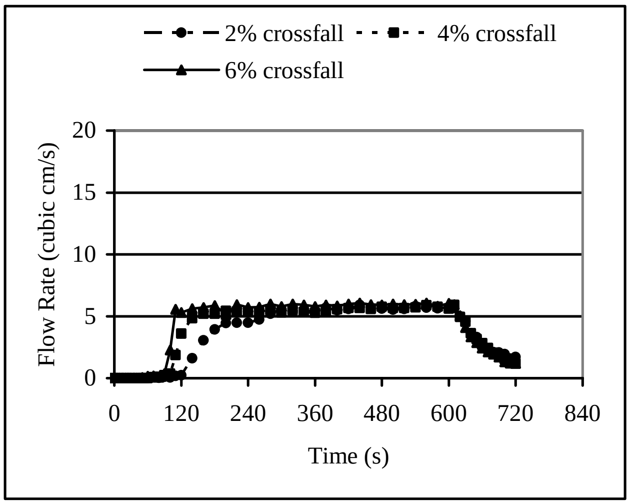

Fig. 3. Example of flow rate plotted against time (14mm Marshall Asphalt, Rainfall Intensity 31.4mm/h and crossfalls of 2, 4 and 6%)

Figure 3 shows an example of flow rate against time for the 14mm Marshall Asphalt at a rainfall intensity of 31.4mm/h and crossfalls of 2, 4 and 6%. This example shows at the reduced rainfall intensity crossfall has a significant effect on Time of Transition Flow (Ttf).

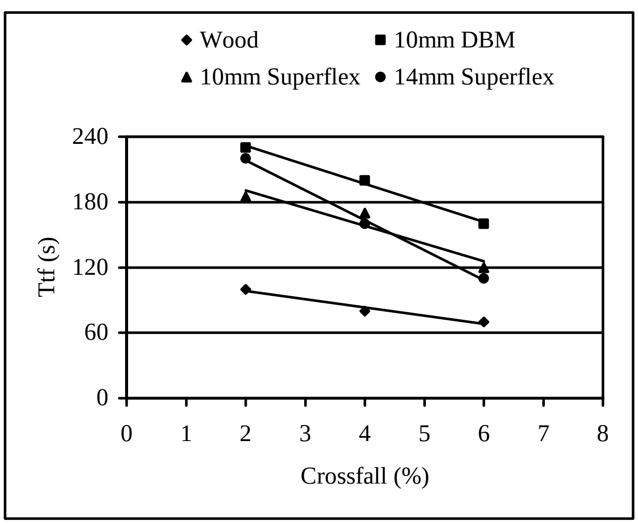

Fig. 4. Effect of crossfall on Time of Transition (Rainfall Intensity 31.4mm/h)

Figure 4 plots the effect of crossfall on Tft for the 5 surfaces assessed at rainfall intensity 1 (31.4mm/h). The plots have strong linear relationship and show that Tft reduces as crossfall increases.

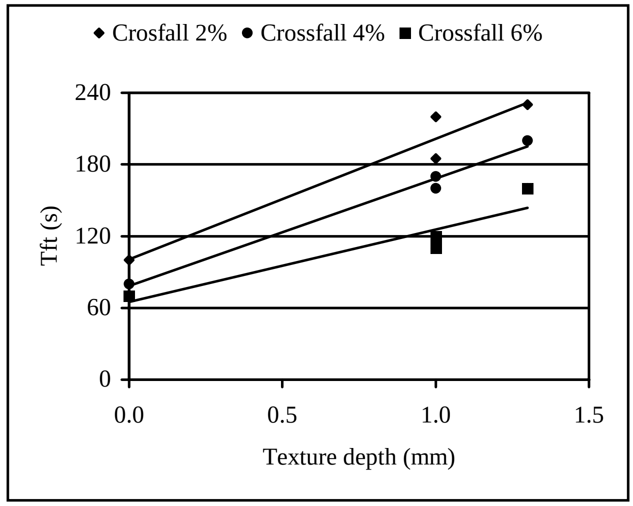

Fig. 5. Effect of texture depth on Time of Transition flow (Rainfall Intensity 31.4mm/h)

Figure 5 plots the effect of texture depth measured using the sand patch method on Tft. Again this shows strong linear relationships i.e. as the surface texture of the road increases it takes longer for Tft to be reached.

As texture depth increases the road surface is able to act as a reservoir until such time as it reachs capacity and there is excess water to cause runoff.

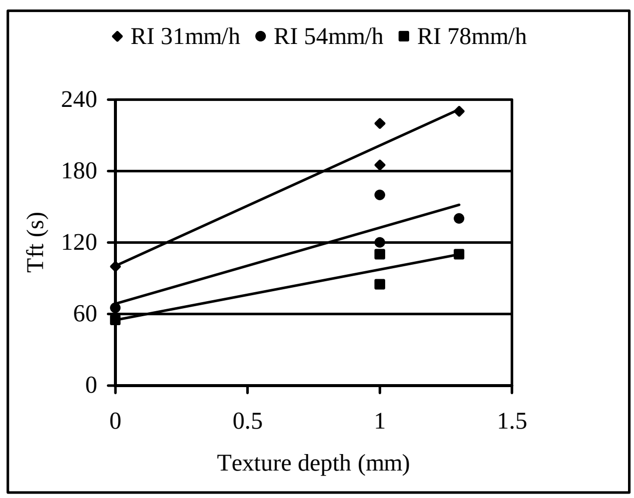

Fig.6. Effect of texture depth on Time Concentration for Slope 2%

Figure 6 shows the effect of rainfall intensity on the relationship between Tft and texture depth. The general relationship is similar to that shown in Figure 5.

6. ANALYSIS OF DATA

Multivariate regression analysis was carried out to model the data. The dependant variable was Tft with the independent variables being rainfall intensity, crossfall and texture depth. This resulted in the general equation (1):

$$Ttt = 189.39 - 1.53 \times RI - 10.63 \times S + 58.22 \times TD \quad (1)$$

Where:

RI = rainfall intensity (mm/h)

S = crossfall (%)

TD = Texture depth (mm)

Figure 7 plots calculated and predicted Tft values using this model and shows strong linear correlation.

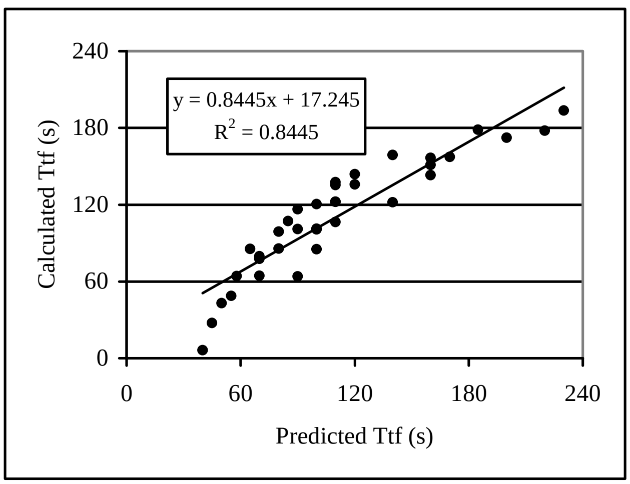

Fig. 7. Plot of predicted and calculated Tft data

7. CONCLUSIONS

The investigation found predictable correlations between the main variables. The ranking of variables in order of importance was found to be rainfall intensity, slope and texture depth.

Multivariate regression analysis was used to model the variables and derived a linear equation model relating rainfall intensity, crossfall and texture depth with Tft.

The research shows that it possible to derive fundamental understanding of surface water runoff using simulatory laboratory investigation without the need for expensive full-scale road trials.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support provided by Aggregate Industries UK.

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