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EVALUATION OF SPEED EFFECT OF VEHICLES ON ASPHALT PAVEMENT

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The main objective of this study was to investigate the speed effect of vehicles on the Hot Mix Asphalt. These effects were determined in terms of permanent deformation (rutting) and cracking since they are the major distresses in flexible pavement, which are caused due to overloading, speed of vehicles and high temperature variation. In this study, a total of 12 samples were prepared by Marshal Compactor. The Uni-axial repeated creep tests were carryout using a Universal Testing Machine (UTM-5P). The testing were done on asphalt samples for loading pulse period duration of 1,500 ms and pulse width of 200 ms (0.2 sec), 400 ms (0.4 sec), 600 ms (0.6 sec), 800 ms (0.8 sec), 1000 ms (1 sec) and 1,200 ms (1.2 sec). Two replicate samples were tested under each pulse width. The temperature was kept constant for all the samples, which was 40ºC. It was observed that with the increase in pulse width (i.e. loading time) the resilient modulus decreases. This is due to asphalt concrete behavior as visco-elastic material; which behaves like the elastic material at fast moving loads and then behaves like viscous material at slow moving loads. Hence increment in vehicle speed causes the pavement failure pre-maturely. Similarly, with the increase in pulse width the accumulated strain increases, which indicates that the low speed vehicles cause permanent deformation (rutting) to asphalt pavements.

Keywords: Rutting, Cracking, Asphalt pavement, Speed, Strain.

1 INTRODUCTION

Road network usually plays the key role in economic development of any country. Mainly two types of road network: National Highways and Motorways are existed in Pakistan. The total length of roads in Pakistan is approximately 188,000 kilometers which includes 2,857 km of Motorways, 8,829 km National Highways and remaining are of other road types. For the maintenance of our roads we spend Rs. 4.5 billion annually. Rutting and fatigue cracks are the two major flexible pavement distresses not only in Pakistan but worldwide. These distresses are caused generally due to overloading and high temperature variation. As there is almost no alertness on quantity of vehicle loadings in the road network hence the permanent deformation (rutting) in flexible pavement occurs prematurely. Also due to large variation of temperature in summer and winter seasons in most parts of the country generates temperature associated cracks. Several researchers are trying to improve the asphalt concrete performance in this failure context. Recently bitumen is mixed with some modified materials (i.e., PMB, HDPE, LDPE, Fiber Glass etc) to enhance the properties against rutting and cracking, which occurs due to heavy loading and high temperature conditions. In the past, due to unavailability of modern testing equipments it was very difficult to study the resilient behavior of Hot Mix Asphalt (HMA). Presently most of the modern equipments such as UTM-5P, Wheel Tracker, and DSR etc are available in our laboratories. Hence, in this research a UTM-5P was used to study the resilient behavior of HMA.

2 LITERATURE REVIEW

Kamal *et al.* (2005) concluded from their studies that increase in temperature from 25ºC to 40ºC the modulus of resilience decreases up to 85%. It was also concluded that the polymer modified bitumen shows better results as compared to the conventional binders. Research Performed by Abdullah *et al.* (2008) found that the strength and gradation of aggregate used in HMA influenced the performance of HMA to a great extent. The rutting and fatigue cracks are caused by severe increase in traffic load and high tire pressure. A proper HMA mix is needed to ensure the adequate durability, structural capacity, and performance for high loading condition and speed of the vehicles. Tigdemir (2007) performed different tests for permanent deformation and fatigue in laboratory using SDU asphalt tester. He concluded that repeated load axial test can be used to evaluate HMA for permanent deformation and fatigue characteristics in a well and satisfactory manner. Imran Hafiz *et al.* (2013) concluded that virgin binder of grade 60-70 showed higher temperature susceptibility as compared to bitumen modified with polymers at different loading frequencies.

Williams (2002) concluded that one of the most and serious types of structural distresses in asphalt concrete is the permanent deformation, which could be referred as rutting. In the recent years, the possibility for rutting on the nation’s highway has increased due to the higher inflation pressures. Therefore, the precise prediction and understanding of this special distress mechanism should be a vital issue for an efficient pavement system management. The pavement rutting can significantly be controlled by using different mixture characteristics.

Based on the above discussions and literature review we felt the necessity for performing a new research direction which may correlates the vehicle speed to the asphalt serviceability in the context of Pakistan.

3 EXPERIMENTAL PROGRAM

3.1 Selection of Aggregate Gradation:

Selection of aggregate is very important for construction of the pavement. In this study, mineral aggregates are used in combination with bituminous material to prepare mixes for different pavement construction. The function of these aggregates is to transmit the load from the surface down to the base course. In this project NHA Class-A Gradation was selected. Whereas the bitumen of grade 60/70 is selected as well which was used 4.3% by weight of total aggregate.

3.2 Preparation of Samples

The samples are prepared and compacted by the Automatic Marshal Compacter with 75 blows on each side of cores. The selected input parameters and output parameters for finding out a good correlation between the pulse width/count and resilient modulus from the laboratory experiments are listed below:

3.3 Input Parameters

Temperature (40º C for each sample); total pulse period (1,500 ms for each sample); pulse width (200 ms, 400 ms, 600 ms, 800 ms, 1,000 ms, 1,200 ms); loading stress (100 Mpa); specimen length (70 mm) and specimen diameter (100 mm).

3.4 Output Parameters

Creep stiffness (MPa), Resilient modulus (MPa), Accumulated strain (%), and Resilient strain (%).

3.5 Testing of Samples in UTM-5P

Universal Testing Machine (UTM) which is equipped with an advance computer based apparatus was used for the determination of modulus of resilience (M*r*) and permanent deformation (rutting) character of asphalt concrete. Resilient Modulus is generally affected by varying temperature and pulse width. UTM software can be replicated by varying road conditions through the increment in frequency and force of the axial loads. In this project the samples were tested by varying the pulse width (time of loading) and keeping the temperature as constant.

3.6 Testing Conditions for UTM-5P

Asphaltic concrete samples were tested in UTM-5P by varying pulse width and keeping the temperature constant in order to simulate speed of vehicles in the laboratory. The tests were carried out on asphalt cores at 40º C and on loading pulse period of 1,500 ms and pulse width of 200 ms (0.2 sec), 400 ms (0.4 sec), 600 ms (0.6 sec), 800 ms (0.8 sec), 1,000 ms (1 sec), and 1,200 ms (1.2 sec).

Repeated load for uniaxial strain test was performed on the cores of samples at 100 kPa loading stress and at constant temperature of 40ºC. The loading pulse period of 1,500 ms (1.2 sec) and pulse width of 200 ms, 400 ms, 600 ms, 800 ms, 1,000 ms, and 1,200 ms each for 2 samples. The magnitude and the applied time duration for sample conditioning stress were set to l0 kPa and 30 seconds respectively.

Following the conditioning period, when the delay time expires, the specimen was subjected to a repeated total pulse loading for 1,500 cycles. As pulse loading continues, the accumulated strain was measured and displayed as a plot with the linear scale axis. The functions of two Linear Variable Displacement Transducers (LDVTs) are to measure the specimen strains during the conditioning and pulse loading stages.

4 RESULTS AND DISCUSSIONS

4.1 Effect of Pulse Width on Resilient Modulus

Resilient modulus is the stress divided by recoverable strain. Due to the visco-elastic nature of asphalt resilient modulus it varies with vehicle speed and also with its time of imposed loading. Resilient modulus shows that how much material will deform by application of load. After testing all the samples in UTM-5P for the given conditions, below results were taken from computer. Table 1 shows the average results of all the output parameters found from the laboratory tests.

Table 1. Average data for output parameters.

Pulse Width	Accumulated Strain (%)	Resilient Strain (%)	Creep Stiffness (MPa)	Resilient Modulus (MPa)
200	0.4960	0.1563	102.6905	530.35
400	0.4785	0.1564	32.9855	481.62
600	0.7208	0.1067	99.6965	462.73
800	1.1480	0.1078	45.1510	472.94
1000	1.5061	0.1036	150.9500	322.79
1200	1.5301	0.0937	101.7200	318.99

As mentioned earlier, at the same temperature, two asphalt pavement cores were tested for each pulse widths of 200 ms, 400 ms, 600 ms, 800 ms, 1,000 ms, 1,200 ms. The pulse width is related to the time of applied loading in actual pavements under the vehicle loading. All these parameters are shown in the above graphs.

The Figure 1 below shows the graphical representation of the statistical analysis of resilient modulus and pulse width relation. The suggested reason is due to asphalt concrete behavior as the visco-elastic material; which behaves like the elastic material at the fast moving loads and then behaves like the viscous material at slow moving loads. The R^2 value is found to be close to 1.

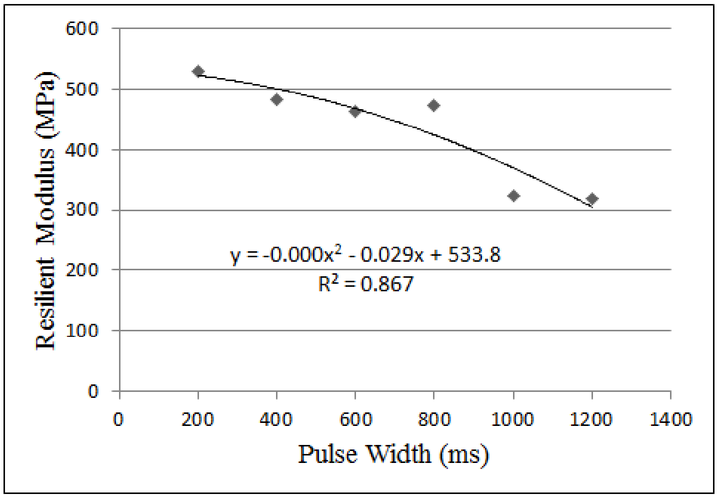

Figure 1. Relationship between resilient modulus and pulse width.

4.2 Resistance to Permanent Deformation of Asphalt Concrete

The correlation between accumulated strain and Pulse count are presented in figure 2. It is clear from figure 2 that at pulse width of 200 ms to 800 ms, which represents slow to medium speed vehicle, the asphalt behaves as viscous fluid and is more susceptible to rutting because the accumulated strain increases. While at pulse width of 1,000 ms and 1,200 ms, which represent fast moving vehicles, the asphalt behaves as elastic solid and the binder is less susceptible to permanent deformation as the accumulated strain decreased. This is the reason that at intersection points the road surface shows severe rutting.

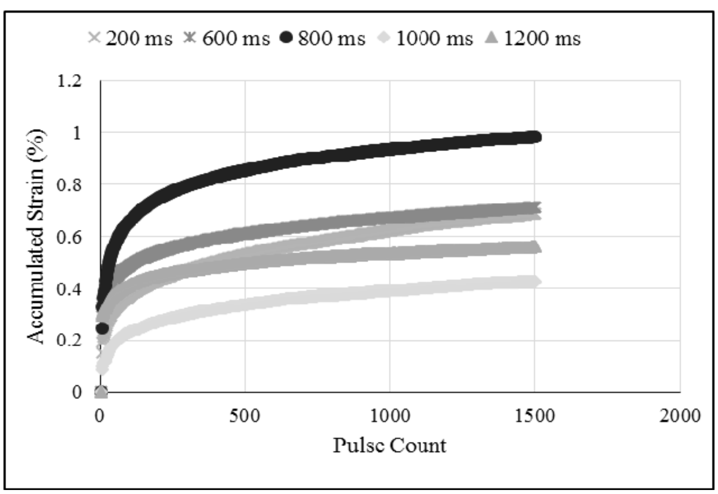

Figure 2. Relationship between accumulated strain (%) and pulse count.

5 CONCLUSIONS AND RECOMMENDATIONS

Following are the conclusion of this research.

- The resilient modulus (Mr) decreases from 30 % to 18 % with increase in pulse width (loading time), which indicates that with increase in time of loading of vehicle, will deform the pavement rapidly.
- Accumulated strain increases with increase in loading time which shows that pavement will susceptible to permanent deformation (rutting) when time of loading increases.
- In summer asphalt behaves like a viscous fluid and its load caring ability decreases, so the control on Axle load limit is essential.
- There is need to use different bitumen modifiers to increase the performance of HMA against rutting and cracking.

References

Abdallah, I., Mahmoud, E., Nazarian, S., and Masad, E., *Quantifying the Role of Course Aggregate Strength on Resistance to Load in HMA for Blended Aggregates.* Center for Transportation Infrastructure Systems, TX 79968, Report No. FHWA/TX 08/0-5268-3.

Hafiz, I., Zaidi B. H., Ahmad, N., Hussain, J., Khan, M. I., and Khitab, A., Influence of Time and Temperature on Asphalt Binder Rheological Properties, *Wulfenia Journal of Multidisciplinary Sciences*, Austria. 20 (5) May 2013 (355-365).

Kamal, M., Shazib F., and Yasin B., Resilient Behavior of Asphalt Concrete Under Repeated Loading & Effects of Temperature, *Journal of the Eastern Asia Society for Transportation Studies*, 6, 1329-1343, 2005.

Tigdemir, M., Dynamic permanent deformation testing of asphalt mixes and deformation waveform analysis, *Indian journal of Engineering & Material Sciences*, 15, 29-35, Feb, 2005.

UTM-5P (Universal Testing Machine), *Manual,* Wykeham Farrance International UK.

Williams, S., The Effects of HMA Mixture Characteristics on Rutting Susceptibility, *Transportation Research Board,* Washington, 2003.