HIGHWAY ACCELERATED LOADING INSTRUMENT (HALI) TESTING ON PERMANENT DEFORMATION FOR CONCRETE BLOCK PAVEMENT

By
Tung Chai Ling
Hasanan Md Nor
Ming Fai Chow
(Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor)
MALAYSIA

ABSTRACT

Experiment concrete block pavements (CBP) are essential to study and assess the structural pavement performance. Accelerated loading testing is able to determine the pavement response and performance under a controlled, accelerated, accumulation of damage in a compressed time period. A test was performed in laboratory to investigate the permanent deformation development under Highway Accelerated Loading Instrument (HALI). A CBP model constructed from the bottom with hard neoprene, bedding sand and paving blocks filled with jointing sand was prepared and tested. Up to 2500 cycles load repetitions of a 1000 kg single wheel load were applied to the pavement model. The pavement deformation development was studied through its transverse deformation profile, mean rut depth in the wheel path, longitudinal rut depth profile and joint width between paving blocks. Test results indicated that the rut depth increase with increasing number of load repetitions and also the heaves at each side of the wheel path. It has also shown that the constant deformation, accelerating and braking sections of the pavement have been observed and determined.

Keywords: Concrete Block Pavement, Accelerated loading test, Rutting, Deformation.

1.0   INTRODUCTION

Experimental CBP subject to normal road traffic is essential to the development and proving of structural design standards [1]. In such experiments, however, performance can be assessed only in terms of the axle-load spectrum to which the sections are exposed and little quantitative information can be gained about the relative damaging effect of the different axle loads constituting the traffic. A separate study of the relationship between pavement damage and axle loading is necessary to enable the results from full-scale road experiments to be generalized and applied to other traffic conditions.

Such studies are made using accelerated trafficking test on which the loading can be strictly controlled. The track may use full-scale road pavements on which the traffic is restricted to repetitions of specific axle loads applied by normal road vehicles.

The performance of pavements is directly related to the magnitude and frequency of the applied load. The manner in which traffic loads are transferred to the pavement surface and the entire pavement structure is controlled by the tyre-pavement interaction. The distribution of stresses, strains, and displacement in the CBP structure is affected by a number of factors including pavers shape, size, thickness, laying patterns and bedding sand [2].

2.0   BACKGROUND OF THE PROJECT

One method to evaluate the performance of the CBP is to use accelerated pavement loading devices [3]. Accelerated loading devices have been widely used during the last decade to evaluate the long-term pavement performance in a relatively short period of time. Many accelerated pavement loading devices have been developed ranging from full-scale to model devices and can be operated under controlled laboratory conditions.

The facility shown in Figure 1 which is currently known as Highway Accelerated Loading Instrument (HALI) was developed in the year 2006. The operational characteristics and detail description of HALI can be found in [4]. This instrument is designed to achieve some research priorities such as:

1. Comparing CBP structural performance of diverse parameters setting.
2. Evaluating pavement design assumptions by collecting data describing the long term performance of pavements.
3. Investigating the relationship between vehicle loading conditions and the deterioration of pavement for a wide spectrum of pavement and loading characteristic.
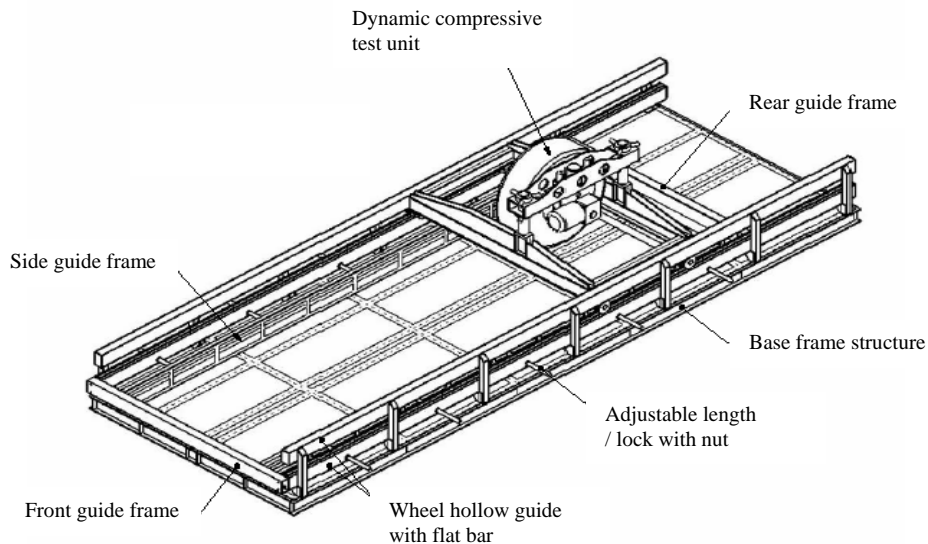4. Providing the facility for other types of pavement testing.

Figure 1: HALI

However, the HALI is a new fabricated instrument and no evaluation works are carried out on it. Therefore, the test was carried out to assess and compare the permanent deformation achieved for a (4 m × 1 m) constructed pavement model under HALI testing. The other part of this study is to determine the test section for constant traffic loading, sections for braking and accelerating.

3.0   PROJECT DESCRIPTION

The test sections of CBP were constructed within the steel box. A steel plate was covered with a 3 mm thick hard neoprene which simulates subgrade layer. Over the hard neoprene, a plastic sheet was used to cover it in order to avoid contaminating the hard neoprene with the bedding sand. This is not a field installation; however as the plastic was used as an experimental expedient [5]. The dry bedding sand was spread in a uniform layer to give a depth of 50 mm. This value was selected based on the experimental results discussed in the previous study [1]. Over the bedding sand, the rectangular blocks with 60 mm depth were laid manually by hand. Where necessary, at the edges of the test frame, blocks were sawed to fix the box. The paving was installed with joints nominally 5 mm wide. The jointing sand was placed on the pavement and filled up in each cell. The whole pavement was compacted by a plate vibrator. The second joint filling operation was carried out to ensure that the joints were fully filled. Finally, the pavement was compacted again until the entire pavement was fully compacted.

Prior to the commencement of the testing, load cell and data logger were used for the instrument calibration. The control panel was programmed to a constant speed of 0.18 m/s. It undertakes a complete cycle in 22 seconds. The axle load of 1000 kg (9.81 kN) was set to the wheel load in order to simulate the traffic load. The machine was run at 50, 100, 250, 500, 1000 and 2500 repetition of axle load.

Permanent deformation under the HALI testing is measured with reference to a fixed datum. The rut depths were measured using dial gauges after 50 repetitions to the maximum repetitions of 2500 cycles of a 1000 kg single wheel load. The dial gauges were positioned at the marked point to measure the deformation of pavement after the commencement of the accelerated trafficking test. The test bed is positioned initially to survey the surface profile at a distance of 110 mm between the dial gauges along the test bed's width (x-axis). The test bed is also positioned at a distance of 220 mm between each cross section along the test bed's length (Y-axis). The system provides 162 height measurements at known plan positions on the surface (on a 1.0 x 4.0 m grid test bed). 9 dial gauges are mounted at 110 mm apart on the rigid beam of HALI. This HALI is moved along the test bed to take the measurement of each cross section. Once the data is recorded, the instrument is moved to the next cross section and the process is repeated. When all the cross sections have been measured, the survey data is processed using the SURFER program which uses a Kriging routine to generate a representative surface from the survey data [6]. A three-dimensional view of the deformed surface is obtained from using the SURFER computer program. In addition, joint widths at section beside the wheel path were measured [7].

4.0 RESULTS AND ANALYSIS

4.1 Transverse Deformation Profiles

Figure 2 shows the results of transverse deformation profiles of the wheel track loaded with the standard wide single tyre. The results are the mean of 18 adjacent transverse profiles. As expected, most of the rutting occurred under the wheel path. It is clearly seen that not only the rut depth increase with the increasing number of load repetitions, but also the heaves at the both sides of the wheel track. The total mean rut depth in the wheel path after 2500 load repetitions of 1000 kg load magnitude is approximately 9.09 mm. An interesting observation obtained is that the right side heave level of the wheel path is higher than the left side heave level. There is a difference of 5.92 mm between the right heave level and the left heave level after 2500 cycles of load repetitions.

This difference of heaves level at both sides is believed due to the single side of load application from the instrument. The load applied to the tyre is generated from the hydraulic jack, located at the right hand side of the tyre. Therefore during loading, the load distribution of the tyre concentrates more on the right hand side of the wheel path. As a result, the heave level at the right side is higher.
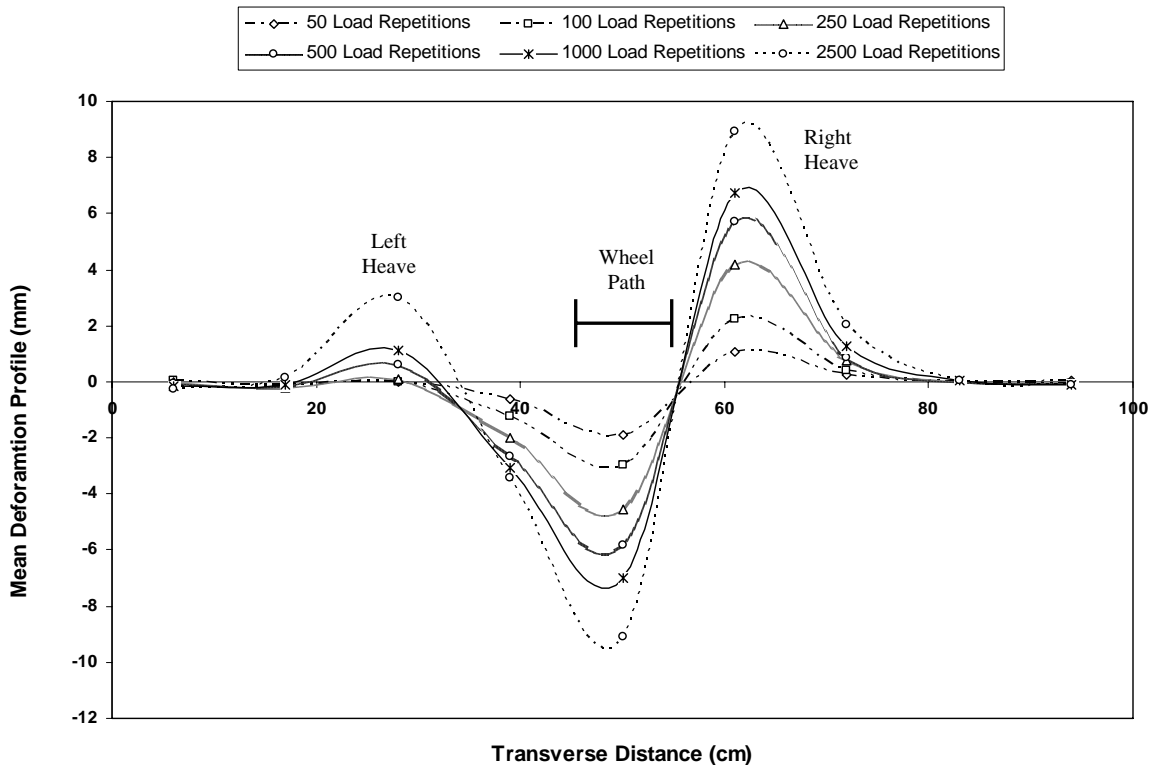

Figure 2: The development of the transverse deformation profiles for different load repetitions

4.2   Analysis of Mean Rut Depth in the Wheel Path

Figure 3 shows the graph of mean rut depth in the wheel path of the pavement with different load repetitions. It is seen that the pavement deflection increases in a nonlinear manner when the load repetition cycles keeps increasing. It is also noticed that the rate of deflection decreases when the load repetitions keep increasing.

During loading, additional compaction of sand under blocks occurs, and some part of the energy is lost in that way. After a certain number of repetitions, the compaction of the underlying layers reaches its full extent and no energy is lost during additional loadings. As a result, the deflection and recovery become the same. Thus, it is established that block pavements stiffen progressively with an increase in the number of load repetitions.
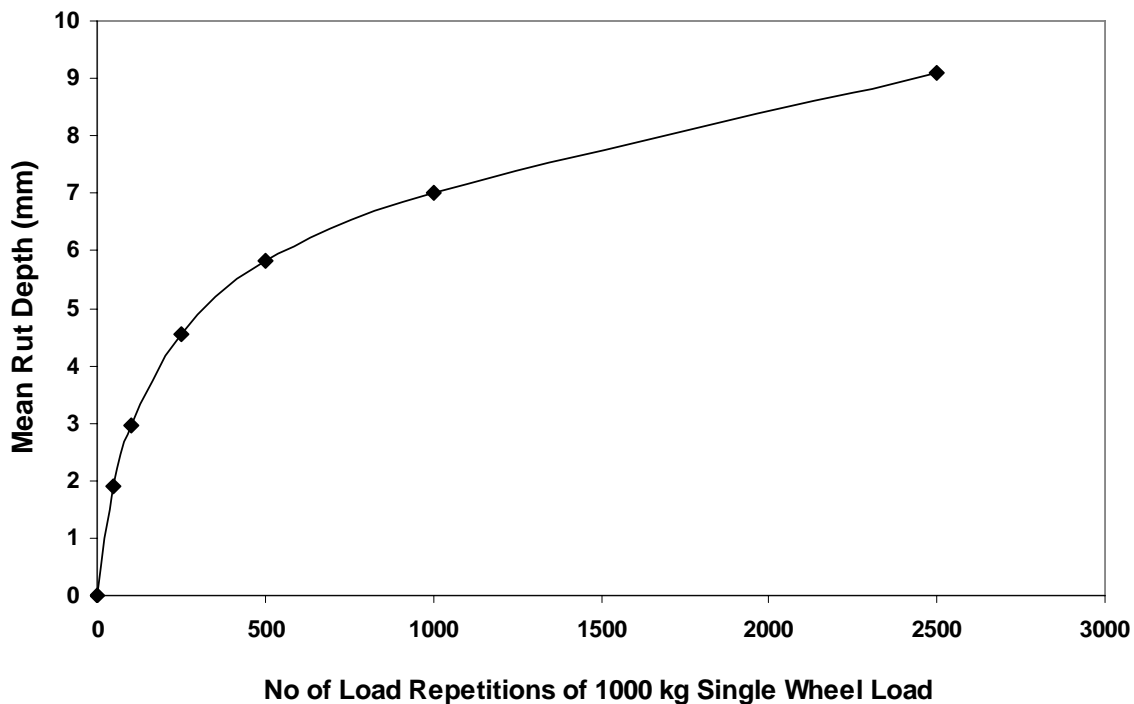

Figure 3: Mean rut depth of CBP up to 2500 load repetitions

4.3   Analysis of Longitudinal Rut Depth for Various Load Repetitions

Figure 4 shows the typical longitudinal view of rut depth for different load repetitions. The rut depths are taken from the central wheel path along the pavement. It is seen that the front part and the end part of the pavement track have a greater deflection than the middle section. For the front part section, rutting subjected to be increased significantly until the 3th cross section of the pavement track with a distance of 44 cm. After that, the rutting remains constant at the middle section of the pavement track. The constant rutting distance of the pavement section is approximately 242 cm which started from the 3th cross section to the 14th cross section of the pavement.

Then the rutting begins to increase until the 17th cross section before it decreases at the last cross section. It is noticed that this section of rutting magnitude is greater than the rutting magnitude occurred at the front part of the pavement track. This significant increase in rut depth is resulted from the loading application from the instrument when it started to move forward along the pavement track. The front part and end part of the pavement section is considered as the accelerating and decelerating part. The length of the front part is about 44 cm, while for the end part of the pavement it has a length of 88 cm.
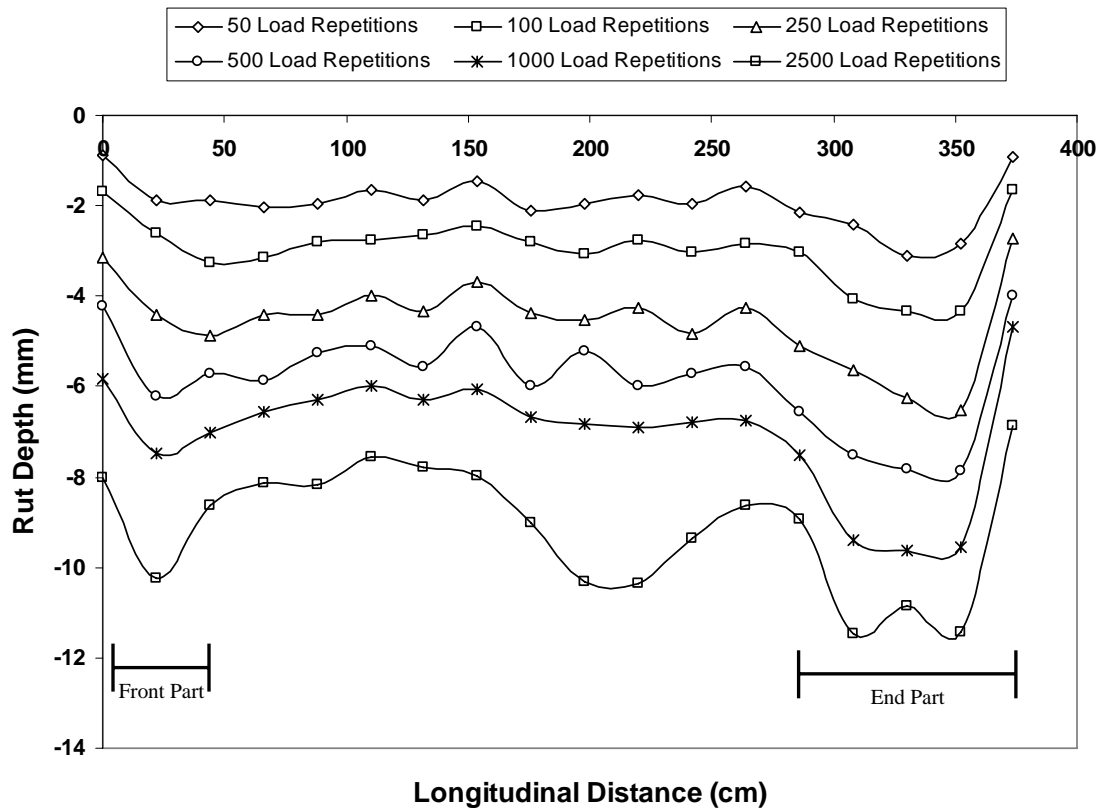

Figure 4: Typical longitudinal view of rut depth for various load repetitions

4.4   Three-Dimensional View of Deformed Pavement

A three-dimensional view of the deformed surface is obtained from using the SURFER computer program. These three-dimensional view graphs are plotted in order to investigate the development of deformation on pavement after having undertaken various load repetitions.

Figure 5 (a) and Figure 5 (b) are the three-dimensional view of deformed pavement for 50 and 2500 load repetitions, respectively. A comparison was made between these two three-dimensional views of deformed pavement.

From the Figure 5, it is clearly observed that shoving occurs at the right hand side of the wheel path. The shoving begins to increase after 200 cm from the origin of measurement point. Compare to deformation after 50 load repetitions, deformation that occurs on the pavement after

2500 load repetitions is more critical. The deformations became excessive and substantial rotations and heaving of the individual blocks occurred.
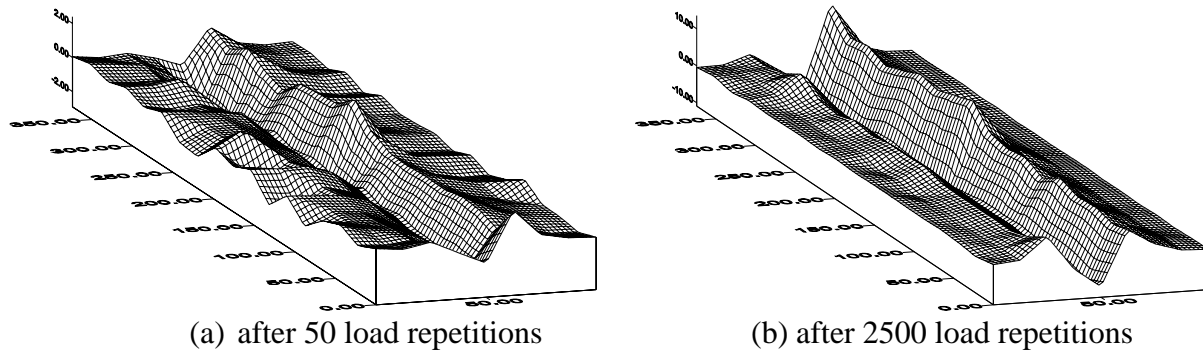

(a) after 50 load repetitions   (b) after 2500 load repetitions

Figure 5: Three-dimensional view of deformed pavement after load repetitions

4.5 Analysis of Joint Width

Table 1 shows the mean joint width at both sides of the wheel path for various load repetitions. From the data, it is clearly seen that the mean joint width for section A and section D increases with the increments of the load repetitions. Meanwhile, the mean joint width for Section B and C decreases significantly when the load repetitions keep increasing. These two sections finally decrease to 0 mm when 2 blocks nearby are stuck together adjacently and no joint width is exposed. Figure 6 shows the location of the joint width section of A, B, C and D.

Table 1: Mean joint width for various load repetitions

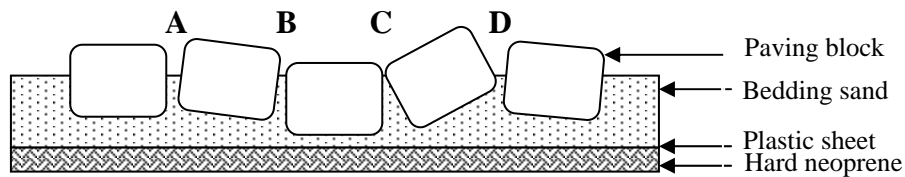| No of Load Cycles	Mean Joint Width (mm) at			
	Section A	Section B	Section C	Section D
0	5.00	5.00	5.00	5.00
50	5.72	4.44	3.38	6.60
100	5.99	4.07	0.78	8.16
250	6.47	3.41	0.07	9.37
500	6.55	2.53	0.12	9.60
1000	7.04	1.29	0.00	10.94
2500	7.52	0.00	0.00	12.54

Figure 6: Joint width at section A, B, C and D of the transverse deformation profile

5.0   CONCLUSION

The principal conclusions that can be drawn based on the test results provided in this study are as follows:

1. The block pavement exhibited progressive stiffening with the increase in the number of load repetitions.
2. The magnitude of the heave at the right hand side is higher if compared to the heave at the left hand side of the wheel path.
3. The constant deformation length of block pavement has been determined at about 2.42 m of length at the middle section of the pavement
4. The accelerating and braking area of the pavement has been determined at about 0.44 m at the front part and 0.88 m at the end part sections of the pavement.

6.0   ACKNOWLEDGEMENT

REFERENCES:

[1]   Shackel, B. (1994). Introduction to concrete block paving. 14-15th November 1994. Parkroyal, Kuala Lumpur.

[2]   Panda, B. C. and Ghosh, A. K. (2002). Structural behaviour of concrete block paving. II: concrete blocks. *Journal of Transportation Engineering*. 128 (2): 130-135.

[3]   Steven, B. D., Pont, J. J de., Pidwerbesky, B. D. and Arnold, G.(1999). Accelerated dynamic loading of flexible pavements at CAPTIF. *1999 International Conference on Accelerated Pavement Testing,* Paper GS2-3.

[4]   Ling, T. C., Hasanan, M. N., Rosli, H. and Chow, M. F. (2006). Highway Accelerated Loading Instrument (HALI) for concrete block pavement. *SPEKA*. 19th – 20th December 2006. Universiti Teknologi Malayisa, Skudai, Malaysia.

[5]   Teiborlang, L. R., Mazumdar, M. and Pandey, B. B. (2005). Structural behaviour of cast in situ concrete block pavement. *Journal of Transportation Engineering*, Vol. 131, No. 9: 662.

[6]   Mills, J. P., Newton, I. and Pierson, G. C. (2001). Pavement deformation monitoring in a rolling load facility. *Photogrammetric Record*, 17(97): 7-24.

[7]   Knapton, J. (2000). The performance of pavers for mechanical installation. *Report on:* Department of Civil Engineering, University of Newcastle upon Tyne.