HIGHWAY ACCELERATED LOADING INSTRUMENT (HALI) FOR CONCRETE BLOCK PAVEMENT

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ABSTRACT

Pavement damage and axle load are very much related. Even though there are many studies evaluating this relationship, not many of them used a full scale experiment especially in concrete block pavement. This study is to develop on equipment which is named as Highway Accelerated Loading Instrument (HALI) to simulate the normal road axle load. This instrument is able to generalize different axle loads on the full-scale road pavements. Pavements constructed in this machine have been fully instrumented for the measurement of stress, strain and deformation. The tested pavement is restricted to repetitions of specific axle loads applied by this mechanically guided test wheel. However, the machine has the limitation on temperature control for the pavement under accelerated trafficking test. This paper will describe the development of HALI and its application to the studies on behavior and performance of concrete block pavement.

Keywords: Concrete block pavement; Accelerated trafficking test; HALI; Deformation

1 INTRODUCTION

The use of concrete block pavements (CBP) has increased markedly in recent years. Concrete block pavement are not only used for pedestrian walkway but also for a variety of commercial, municipal and industrial application (Teiborlang, 2005). Superior engineering properties, easy maintenance and repair, reuse of original block, availability in various shape and color, aesthetic appeal and intermediate availability are the primary reasons for choosing the concrete block pavement over other paving surface. The typical pavement consists of individual block of hand held size units laid on a thin bed of sand, called bedding sand. The blocks are separated by about 2 to 4 mm which filled with jointing sand. A granular or cement bound sub base is provided below the bedding sand to lower the stress on the sub grade layer (Panda and Ghosh, 2002).

Research has been undertaken to identify the influence of various components of the vehicle/ pavement interaction system, such as static and dynamic loading component of vehicle loading, the relative effects of vehicles, environment and pavement materials on the performance of concrete block pavements (Steven, 1999). Experimental pavements lay on public roads and subject to normal road traffic are essential to the development and proving of structural design standards (Shackel, 1979). 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. Therefore, Laboratory testing and computer analysis alone are inappropriate. Thus, trials utilizing full-scale equipment and pavement are necessary, either in the field or in a test track under controlled conditions. Therefore, the first Malaysia accelerated loading facility was developed in the year of 2006.

This first Malaysia accelerated loading facility is known as Highway Accelerated Loading Instrument (HALI). It is designed to achieve research priorities such as:

1. Evaluating the structural performance of concrete block pavements
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

This accelerated loading facility consists of a full-scale test track and loading apparatus capable of imposing realistic dynamic heavy vehicle loading which describes the advantages of:

1. The machine can be operated continuously for 24 hours without being interrupted for direction changes, thereby greatly increasing the rate of load cycling
2. After initial acceleration, the speed of the loading system can be kept constant for long periods of time or varied, depending on the requirements of specific projects
3. A test track can be divided into a number of longitudinal segments, each containing a pavement with some unique characteristics, and all segments can be tested simultaneously under the same or varying loading conditions
4. The configuration of each loading assembly in a multi-armed machine, such as tyre types and pressures, axle numbers and weights, suspensions and loads, can be altered so that the same pavement can be tested under various loading conditions

2 DESCRIPTION OF HALI

HALI is setup at the Highway laboratory, Universiti Teknologi Malaysia (UTM) as shown in Figure 1. It consists of a mild-steel rig main frame measuring 1.7 m width × 5.5 m length × 0.25 m depth, which provides sufficient rigidity and stiffness to absorb any vibration and movements during simulation process. The width of the test track is adjustable. It can be adjusted to the desired width by adjusting the length of steel rod at both sides where it is used to support the track bed frame. The examination of a pavement's durability is permitted since the design allows the evaluation of different base and surface materials. All the essential and peripheral components are rigidly attached to the base frame and the whole frame to be inclined to maximum angle of 12^{o} from horizontal.

Figure 1: HALI

Carriage for loading mechanism is placed above the test bed. It carries all the necessary components to create loading mechanism induced by a vehicle on the tested pavement specimens. The mechanism for producing vehicle load is designed using the precision hydraulic actuator so that a predetermined constant load is continuously applied on the tested pavement materials throughout the simulation period. The mobile carriage which mounted on two rigid and frictionless guide rails, enable the loading to be moved forward and back along the rail. The mobile carriage consists of the following essential components:

i. *Tyre Attachment/Mounting Arm*
   Suitable for mounting a standard radial inflatable tyre (the type for 10 ton heavy vehicle). The mounting is pivoted to the mobile carriage and equipped with heavy-duty hydraulic jacks so that the arm can be swing and locked in any position (0° to 30° from horizontal position). This design allows for a sufficient clearance when removal of sample tray. During test locking device provides a rigid and effective contact between tyre and the tested pavement materials.

ii. *Electric Motor*
   3-PHASE with maximum capacity of 5 HP to drive the mobile carriage and other attachments along the guide rails. Motor is a heavy-duty type that enables a continuous operation of at least 24 hours.

iii. *Hydraulic System*
   Used to generate a constant and continuous load from 0 to 45 KN. Supplied complete with appropriate valves and sensors to ensure generation of constant, pre-

selected load level throughout test duration. Hydraulic pressure for the loading mechanism and tyre attachment arm is provided by a closed-circuit system supplied complete with hydraulic reservoir, related valves and heavy-duty hydraulic piping and fittings.

iv. *Control Panels and Display Unit*
A separate unit for controlling and selecting the desired load level to be imposed on tested sample and for controlling the speed of the mobile carriage (range of speed of 0 to 1.2 m/s). Also included in the control panel are display panel exhibiting applied load and test duration, and a mechanism switch for selecting and setting the required test repetitions (selectable number of repetitions up to 20,000 cycles) and duration (selectable intervals at 1 hour and up to maximum 24 hours duration).

Both control systems were designed so that the HALI could operate continuously without operator intervention, and if a sensor reported a level outside a preset limit, the control system would bring the HALI to a stop. Testing routines can be programmed in terms of start/stop times, loading rate and traveling speed. Any combination of these may be included in a programmed testing routine because the HALI software will use default values for those items not defined in the supervisory computer program. Manual control can be imposed when desired, to override the current program. The operational limits of the HALI are shown in Table 1.

TABLE1. Operational Characteristics of the HALI

Item	**Characteristic**
Test Wheels	Single –tyres; standard radial inflatable tyre (the type for 10 ton heavy vehicle); overall tyre pressure of 600 kPa
Loading	Up to maximum loading of 45 KN can be generated
Power drive to wheel	Controlled variable hydraulic power to generate a constant and continuous load
Electric motor	3-PHASE with maximum capacity of 5 HP
Speed	0 – 1.2 m/s, programmable
Complete cycle time	6 second
Tyre Attachment/ Mounting arm	Pivoted to the mobile carriage and equipped with heavy-duty hydraulic jacks; arm is allowed to swing and locked.

3 CONSTRUCTION OF TEST PAVEMENT

The test sections of CBP were constructed within the steel test bed. A steel plate is covered with hard neoprene of a 3mm thick which simulates the subgrade layer (as shown in Figure 2). A plastic sheet is used to cover the neoprene to avoid mixing with the bedding sand and also to contain water if sand had to be saturated (Figure 3). This is not a field practice; however the plastic was used as an experimental expedient.

Figure 2: Hard neoprene on test bed Figure 3: Neoprene cover by plastic sheet

Figure 4 shows bedding sand of a particular gradation and thickness as per test requirements uniformly screeded to a loose state. The sand should be of uniform moisture content and should be protected from rain whilst stockpiled. Pavers were then manually placed on the bedding sand in the desired laying pattern. Once the pavers were placed, they were compacted by a vibrating plate compactor of 250 N static weights vibrating at a frequency of 3,000 rpm. The compaction was continued until the top of each paving block was level with the adjacent blocks and to refusal of further settlement under vibration. The joints were then filled by brushing in the jointing sand of a particular gradation and joint width as per test requirements. The joint filling operation was continued until all joints were completely filled with sand. Then the pavement is compacted again until the entire pavement is fully compacted. Finally the top surface of pavement was cleaned of excess sand (Figure 5).

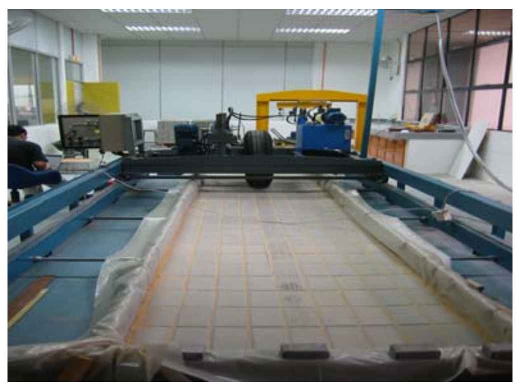

Figure 4**:** Screeding bedding sand Figure 5: Concrete block tested pavement.

4 ACCELERATED PAVEMENT TESTING

4.1 HALI Operation

The entire operation of HALI is controlled by a microprocessor. After the electrical switch is on, the wheel starts to move back and froth without any lateral wander. It commences a cycle at one end of the site and accelerates linearly over the full test site so that the load wheel has attained a speed of 1.2 m/s at the centre of the test site. It then decelerates towards the end of the test site. It undertakes a complete cycle in 6 seconds. Levels of the surface of the pavements were recorded before and after the test.

4.2 Instrumentation and Data Acquisition

Various measuring techniques can be implemented to measure the dynamic and residual strains, displacements in the pavement structure and surface profile of the tested pavement. The Linear Voltage Displacement Transducer (LVDT) is a suitable device to measure the surface deformation of a pavement under a wheel load (Mills, 2001). The LVDT will be placed on the pavement surface and connected to a local computer controlled Data Acquisition System. The LVDT's are mounted on a stiff beam which is positioned across the width of the test bed. The beam is positioned initially to survey a surface profile at a distance from end zero of the test bed. Once the data is downloaded, the beam is moved to the next cross section and the measurement process repeated. This measurement process involves the manual positioning of the LVDTs for each of the cross section along the tested track. When positioned, a button is pressed and a measurement from each of the LVDTs is downloaded to a computer. Each of the LVDT measurements is assigned with a unique plan position. The survey data is fed to the SURFER program which uses a Kriging routine to generate a representative surface from the survey data (Knapton, 2000). This initial surface is stored on the processing computer for subsequent subtraction from later results so that a series of cumulative surface profiles can be viewed.

5 CONCLUSIONS

The development and operation of the HALI including the instrumentation systems and construction techniques have been described in this paper. This HALI is designed to generate realistic dynamic wheel loads on the tested pavement to investigate the relationship between pavement design and the damage effects under the simulated normal road axle loading.

This accelerated loading facility has been beneficial in evaluating the structural performance of interlocking concrete block and pavement design assumptions by collecting data describing the long-term performance of pavements, and investigating the relationship between vehicle loading conditions and the deterioration of pavements for a wide spectrum of pavement and loading characteristics.

HALI is applicable to different type of pavements and able to investigate the service life of the tested pavement. The pavement-related problems can be assessed through full-scale accelerated pavement testing of Highway Accelerated Loading Instrument (HALI). The pavement surface deformation characteristics under the accelerated trafficking test provide valuable information for determination of structural adequacy of surface layer in a pavement.

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