Performance Testing of Bituminous Mixes Using Falling Weight Deflectometer

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1. INTRODUCTION

A Falling Weight Deflectometer (FWD) is a Non-Destructive Testing (NDT) Device used by civil engineers to evaluate the physical properties of pavement. It is designed to impart a load pulse to the pavement surface which simulates the load produced by a rolling vehicle wheel. FWD is a tool used to achieve rapid and repeatable in-situ characterization of the pavement layer stiffness and to evaluate pavement structural condition. It is being widely used in pavement engineering as it plays a crucial role in selecting optimum pavement maintenance and rehabilitation strategies.

FWD data is most often used to calculate stiffness-related parameters of a pavement structure. The process of calculating the elastic moduli of individual layers in a multi-layer system (e.g. asphalt concrete on top of a base course on top of the subgrade) based on surface deflections is known as "back calculation". Instead, initial moduli are assumed, surface deflections calculated, and then the moduli are adjusted in an iterative fashion to converge on the measured deflections.

Over a period of time, research has rendered FWD capable of not only predicting Elastic Modulii of Pavement Layers but for determination of Residual Life of Pavement, Designing of Overlays, assignment of Pavement Classification Numbers (PCNs) to airfield pavements, determination of load transfer characteristics of joints in Concrete Pavements, etc.

2. FAILURES IN FLEXIBLE PAVEMENTS

The major flexible pavement failures are fatigue cracking, rutting and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue test on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path. Thermal cracking includes both low-temperature cracking and thermal fatigue cracking. The principal modes of pavement distress of flexible pavements are as follows:

1.2.1 Rutting

The longitudinal deformation of the road along the wheel path is termed as rutting. Rutting is characterized by depressions along the wheel path. Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water. Limiting rutting is taken as 20 mm in 20% of the length for design traffic upto 30 msa and 10% of length for design traffic beyond.

1.2.2 Corrugations

A transverse undulation in the pavement surface or base is termed as corrugation. Corrugation most commonly is associated with spray seal or unsealed pavements but can occur in thin asphalt surfacing. Wavelengths of undulations can range between 0.3 to 2.0 meters.

1.2.3 Cracking

Block cracking means interconnected cracks forming a series of blocks approximately rectangular in shape, typically distributed over a large area of pavement. Crocodile cracking means interconnected or interlaced cracks forming a series of small polygons resembling a crocodile skin. Crocodile cracking is often confined to the wheel paths and may have a noticeable longitudinal grain. The presence of crocodile cracking usually signifies the end of design life.

1.2.4 Stripping of Asphalt

Stripping of hot-mix asphalt mixtures is the separation of asphalt binder film from aggregate surface. Stripping is the loss of bitumen and/or mineral aggregate or filler from an asphalt layer. It could occur on the surface or within the layer. Stripping within the layer may lead to the development of potholes.

1.3 MAJOR COMPONENTS OF FWD

The FWD trailer contains the following parts:

(a) Weight Assembly

(b) Load Cell

(c) Geo-Phones

(d) Micro-Processor

(e) Laptop

(f) Distance Measuring Instrument (DMI) Meter

(g) Air Temperature Sensor and Infra-Red Surface Temperature Transmitter

1.4 MAJOR USES OF THE FWD

Following are the uses of FWD :-

(a) Evaluation of structural capacity of in-service flexible, semi-rigid and rigid pavements.

(b) Quality control of sub grade and granular layers of pavements during the construction stage.

(c) Assessment of the need for and design of thickness of overlays.

(d) Determination of the rate of deterioration of pavement structures.

(e) Evaluation of the degree of bonding between pavement layers.

(f) Assessment of equivalent moduli of concrete blocks in block pavements.

(g) Evaluation of the load transfer capacity in the joints of concrete pavements.

(h) Detection of voids under rigid pavements.

1.5 OPERATING PRINCIPLE OF FWD

The basic working principle of the impulse loading equipment is to drop a mass on the pavement to produce an impulse load and measure the surface deflections. The mass is dropped on a spring system, which in turn transmits the load to the pavement through a loading plate. The resulting deflection bowl characteristics are observed and used in the back calculation of pavement material properties. The principle is illustrated in Figures 1 & 2.

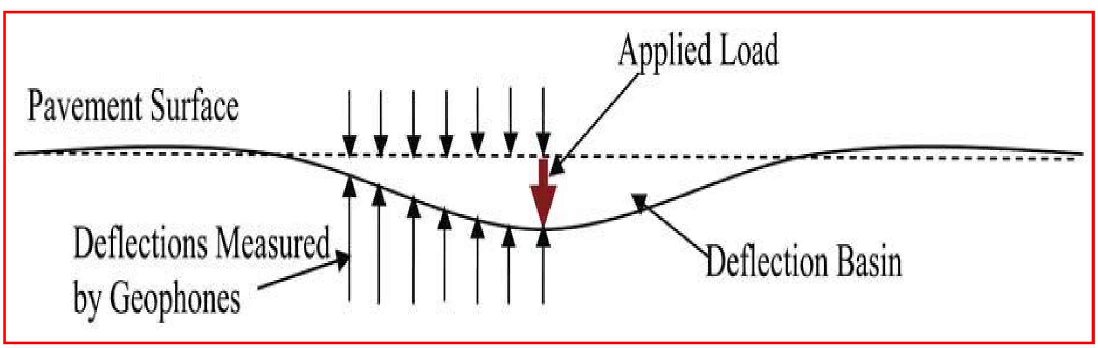

Fig 1 Schematic of FWD Load and Deflection Measurement

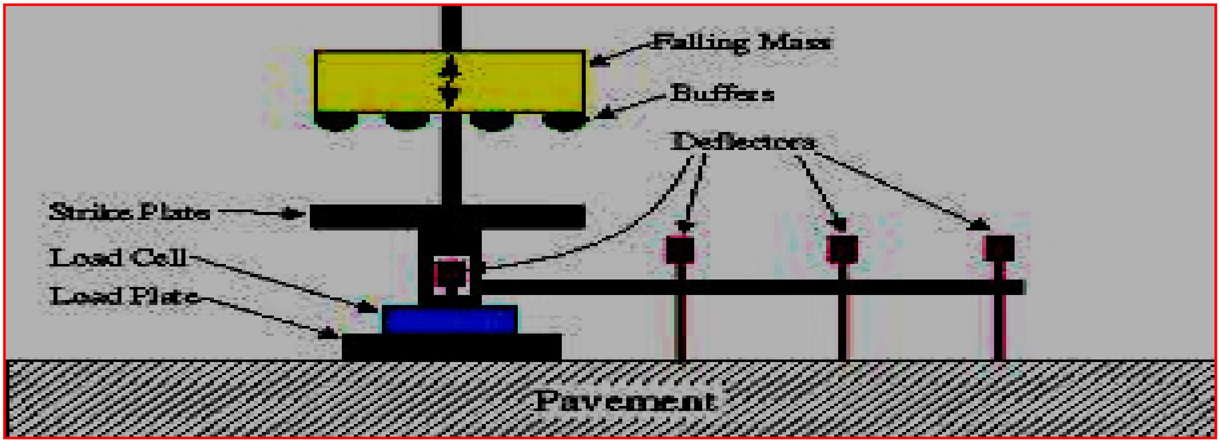

Fig 2 Working Principle of FWD

The magnitude of the impact load applied to the pavement surface by a falling weight deflectometer depends on the number of masses dropped and the height from which they are dropped. The load magnitude is measured by a load cell at the centre of the load plate. The deflections are measured by transducers.

1.6 BACK CALCULATION OF PAVEMENT LAYER MODULI

The response measured with the FWD is the surface deflection of the pavement at different distances from the centre of the load. The measured deflections along with other relevant information are used as inputs either to back calculate the effective pavement layer moduli for use in analytical evaluation methods or to estimate the overlay requirement from empirical relationships. Salient features of some existing back calculation procedures are presented in the following sections.

Determination of Young's Modulus of elasticity for pavement materials using measured surface deflections by working "backwards" is generally called "Back calculation", more specifically, it is the process of selection of layer moduli using a suitable technique (iteration, database searching, closed-form solution, and optimization) so that the deflections computed using the layer moduli are close to the measured deflections. With advances in the computational facility, a number of computer based back calculation programs are available now.

It is seen that almost all the back calculation programs use linear multi-layer elastic theory. Most of the methods follow an iterative approach in which an initial set of layer moduli is assumed and the moduli are then used to compute surface deflections.

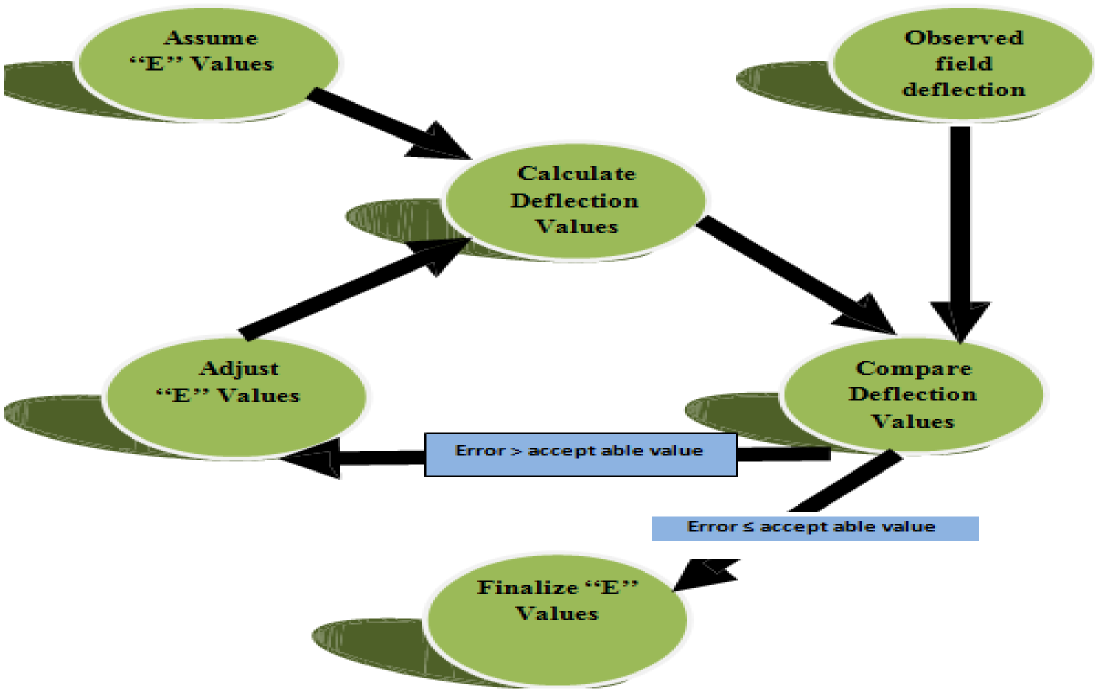

Fig 3 Schematic Diagram Representing the Process of Back Calculation

3. OBJECTIVES OF THE STUDY

The main objective of this study is to carry out a study on performance of bituminous mixes using Falling Weight Deflectometer (FWD). In doing so**,** emphasis is laid on structural evaluation of flexible pavements to include the following:-

(i) Strength evaluation of layers of the flexible pavements with different bituminous layers by determining the corresponding E- values of the layers.

(ii) Estimation of Remaining Service Life (RSL) of these pavements.

(iii) Determination of strengthening requirement, if any, like overlays.

(iv) Laboratory testing of samples as obtained from drilling cores from Test Pavements and effect of physical properties on E-Values obtained using FWD.

(v) To develop a correlation between load carrying capacity of bituminous mixes determined using Marshall Stability Test, E-values and deflection values obtained from FWD.

4. EXPERIMENTAL SET UP

Following combinations of courses have been constructed as test tracks:

<table>
<tr><td>Sub-Base</td><td>Base</td><td>Wearing Course</td><td>Case</td></tr>
<tr><td rowspan="6">GSB
(200 mm)
+
WMM
(250 mm)</td><td rowspan="3">DGBM
(50 mm)</td><td>BC (40 mm)</td><td>Case 1</td></tr>
<tr><td>SDBC (25 mm)</td><td>Case 2</td></tr>
<tr><td>PC (20 mm)</td><td>Case 3</td></tr>
<tr><td rowspan="3">BM
(50 mm)</td><td>SDBC (25 mm)</td><td>Case 4</td></tr>
<tr><td>PC (20 mm)</td><td>Case 5</td></tr>
<tr><td>Recycled Bituminous Mtrl (25 mm)</td><td>Case 6</td></tr>
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5. ANALYSIS

The results have been analyzed with the following subheads:

(i) In- situ testing of existing pavements and laboratory analysis of core samples obtained from these test locations.

(ii) Calculation of E-Values of the above mentioned pavements from FWD testing and calculation of strain values in the pavements using these E-Values.

(iii) Estimation of Remaining Service Life (RSL) of these pavements.

(iv) Determination of strengthening requirement, if any, like overlays.

(v) Calculation of tensile strain at bottom of bituminous layer and on top of subgrade for each of the six cases using E-Values obtained from FWD testing and IITPAVE software and also comparing them with permissible critical strain values to ascertain their performance.

Fig 4 Construction of Test Track for FWD Testing

Fig 5 FWD Testing of Test Pavements & Other Chosen Locations

6. CONCLUSIONS

From the study, it has been possible to compare the performance of various type of bituminous courses.