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FDP: A DEVICE USED FOR ASSESSING THE PAVEMENT BEHAVIOR

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ABSTRACT

Nowadays, there is a growing need for infrastructure renewal worldwide. Highways pavements, bridges, parking garages and other exposed structures are becoming functionally obsolete or deteriorating while governments struggle to produce the funds to catch up. It has become clear in the past decade that these infrastructure rehabilitation challenges demand new technologies, mainly devices for assessing infrastructure deterioration. Nondestructive structural evaluation of pavements is an important part of the pavement management process, particularly at the project level. Measurements of pavement surface deflection are generally used for this purpose. These deflection data are analyzed to determine the structural adequacy of the pavement. The ever growing demand for faster, easier to use, and more mobile nondestructive testing devices for pavement evaluation has resulted in the development of dynamic devices to replace the conventional time- consuming Benkelman Beam. Due to pavement materials that do not exhibit ideal linear elastic behavior and because pavement response is affected by the applied stress level, as well as the rate and mode of loading, several other types of nondestructive test devices have also been developed. The development of commercially available nondestructive devices and increased research efforts towards applying a more rational and mechanistic approach for structural evaluation of pavements have resulted in the application of multilayered linear elastic theory for analyzing the measured deflection basins to estimate insitu material characteristics of pavement layers and for subsequent overlay design by predicting critical strains and stresses in the pavement. The FDP (Flexmeter Device for Pavements) measures the deflection basins of a relatively light magnitude load applied on the pavement surface. Therefore, the FDP is a device used for assessing the pavement behavior, which measures the tangent to basins deflection produced by a load applied on the pavement surface. This paper presents the FDP and its results from a test carried out to be compared to Benkelman Beam.

Keywords: Pavements, Structural evaluation, Surface deflection, Pavement flexmeter device

1. Introduction

Brazil is approximately 8 511 965 km^2 in area and has a road network of over 100 000 km. The road system carries 96% and 70% respectively of passengers and freight. Maintenance of asphalt

pavement is, therefore, an important task in keeping the transport system, and the economy, of the country running. Maintenance is controlled from offices throughout the road network, and in most cases, these maintenance offices also supervise road construction in their areas.
Highway maintenance teams are responsible for pavement inspections and for reporting any deterioration. Pavement damage is a risk to capital invested and, if a high level of deterioration is allowed to develop, structural repairs may be required. Hence, the amount, and consequently, the cost of time-consuming maintenance, will depend on the potential evolution of pavement damage.
In addition, pavement performance depends on its structure, which in turn is related to construction time and cost. Therefore, pavement evaluation is an essential tool both during construction and afterward.
Brazilian engineers are currently faced with the following problems:

- Evaluating highway pavement deflection at minimum cost with accuracy during construction;
- Evaluating highway pavement built 8, 10, 12 or more years ago in order to repair or rehabilitate them.

Pavement deflection evaluation ideally requires a test, which can be used for both of these purposes.
The development of commercially available nondestructive devices and increased research efforts towards applying a more rational and mechanistic approach for structural evaluation of pavements, have resulted in the application of multilayered linear elastic theory for analyzing the measured deflection basins to estimate in-situ material characteristics of pavement layers and for subsequent overlays design by predicting critical strains and stress in the pavement.
The FDP (Flexmeter Device for Pavement) measures the deflection basins of a relatively light magnitude load applied on the pavement surface. Therefore the FDP is a device used for assessing the pavement behavior that measures the tangent to basin's deflection produced by a load applied on the pavement surface.
The FDP (Flexmeter Device for Pavements) is a new device developed for assessing the maximum deflection related to a load applied under standard requirement. The test kit is portable, in order to conform with Brazilian characteristics, i.e., large distances in the interior of the country; easy to operate so as to expend less time on staff training; and price competitive in the test equipment market. The test kit allows drawing pavement deflection curves, in-situ and theoretical, from measuring point on point value of deflection elastic curve slope. The test also provides negative and positive radius of deflection curve, the dynamic elastic modulus of embankment.
This paper shows a comparison between results from FDP test and Benkelman Beam.

2. Objectives

The research objectives were as follows:

- to develop a commercially available device for nondestructive structural evaluation of pavements, which would be used for asphalt and rigid pavements;
- to compare the pavement behavior from measured FDP deflection and the Benkelman Beam for structural evaluation and overlay design of pavement;
- to develop a procedure for using FDP test.

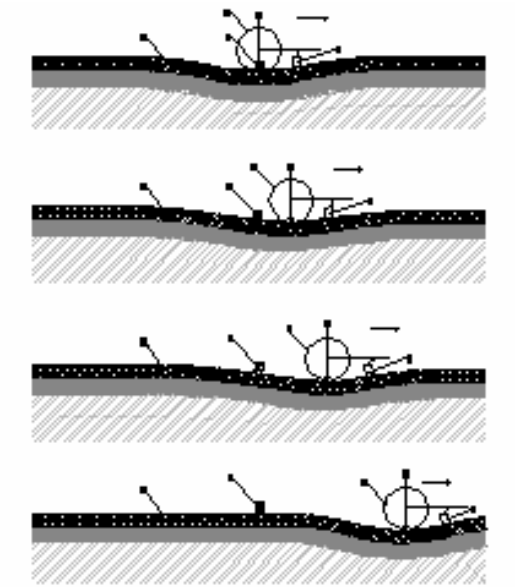
An extensive experimental program was carried out to compare the FDP with the Benkelman Beam and the results of this program are summarized. In addition, the experimental program was designed to evaluate the FDP measurements, including data collection from the field. The present paper describes the development of FDP devices, which are considered to have advantages over existing tests, a discussion of the use of the FDP and recommendations following research. FDP is protected by the patent n^{o} PI 9707088.

3. Pavement model

The theoretical model assumes that the pavement is a rectangular and continuous beam on elastic foundation, which is the embankment. The model was adopted after the research of M.Hetényi, *"BEAMS ON ELASTIC FOUNDATION"*, published by Michigan University. FDP software was developed in accordance with this mathematical assumption.
When carrying out a test on site it is possible to verify, by comparing practical and theoretical deflection curves, that the mathematical model assumed is significantly accurate to represent the real performance of the pavement structure.
The FDP device continuously measures 100 point values per meter of the load curve deflection slope. By knowing the deflection slope curve, the following parameters are taken:

- Restored deflection;
- Deflection curve radius;
- Positive curve radius;
- Negative curve radius;
- Dynamic elastic modulus of the embankment.

Fig. 1 shows a sketch of the theoretical deflection development in asphalt pavement, when a load rolls on the surface.



Note: 1 –Tire / 2 –Pavement / 3 FDP / 4 Distance measurer / 5 Load

Fig 1: Pavement: theoretical deflection development.

4. The FDP System

The pavement fleximeter system, as shown in Fig. 2, is used to measure the tangent to basin's deflection produced by a load applied on the pavement surface. Therefore, the FDP device measures elastic deflection of a pavement structure when a load is applied on the road surface. A specific load is applied to the road surface which produces a graphic of deflection by load position. The graphic is straight related to the pavement deflection basin.
The FDP is a relatively light device that can be carried by any standard passenger car or van. The total weight of the *Note Book, Box of Data* Acquisition *System, Truck Position Measurer and Deflection Sensor* is less than 10 kg. The Note Book must have a serial port of 9 pins and work on 12 Volts. The Box of Data Acquisition System (BDA) has an A/D converter and a signal counter that is linked to the Note Book, to the Deflection Sensor and to the car's cigarette

lighter socket. The Truck Position Measurer (TPM) is capable of measuring the truck distance, (i. e., the load position referred to the Deflection Sensor). The TPM is a pulse-generating device that is attached to the back truck wheel and is moved on the pavement surface. The Deflection Sensor (DES) is a device of high resolution, which measures the deflection of the pavement surface through the specific load applied by the truck.

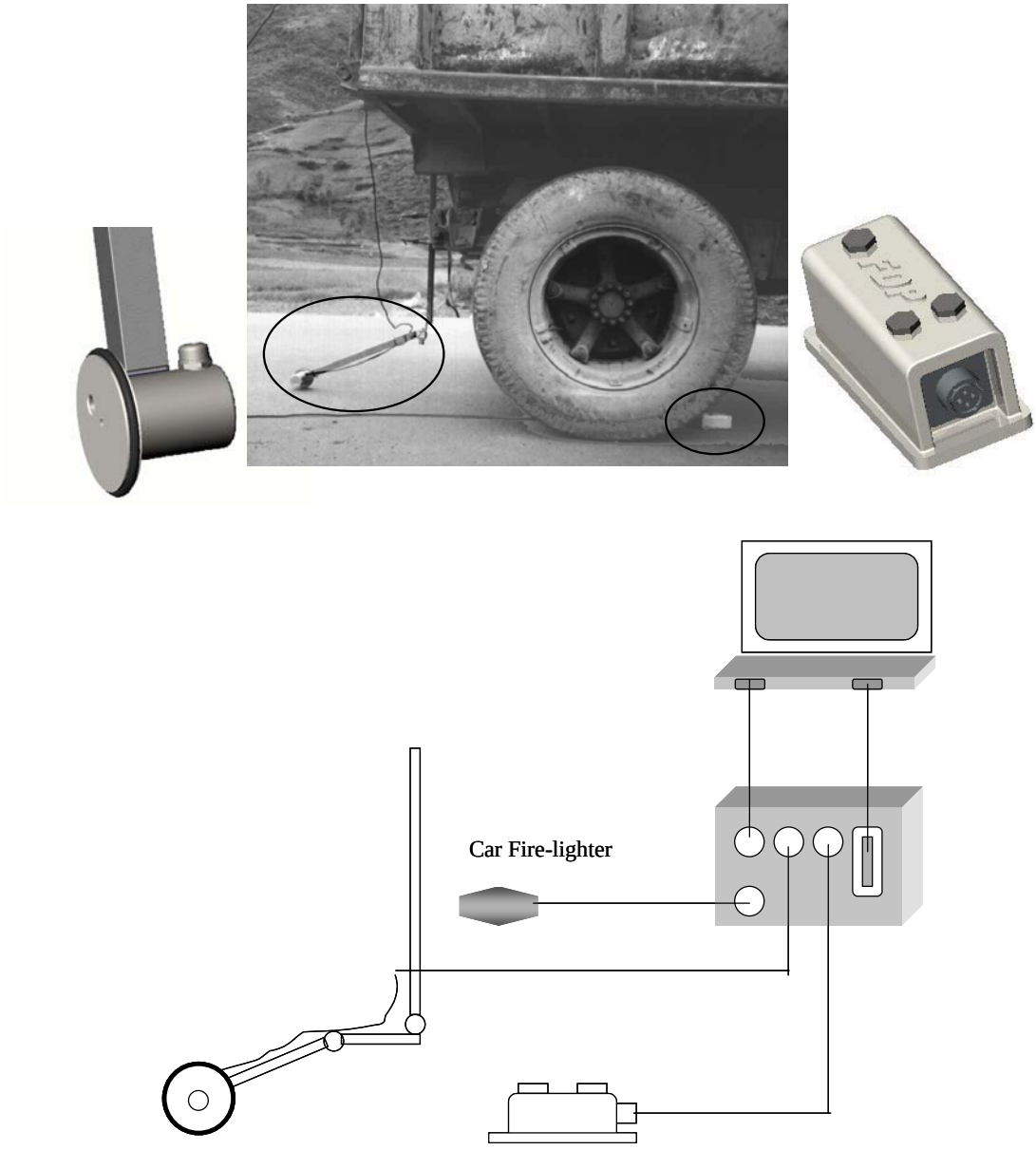


Fig 2: FDP device.

5. The test procedure

The requirements and the routine test procedure is briefly described as follows:

- truck of a single back axle with double wheel;
- truck tires calibrated to 80psi;
- truck cigarette lighter of 12 Volts;
- truck must be loaded for the standard load of the FDP test;
- the Truck Position Measurer (TPM) must be assembled at test location by attaching it to the back buffer or truck floor;

- the upper TPM rod must be on vertical position, perpendicular to the road surface, while the other end sits 35 cm from the pavement.
- rotate the TPM measuring arm all directions, (i.e., 360^0 making sure no truck part is touched by the TPM wheel or rods;)
- the Deflection Sensor (DES) must be set up among the double wheel at almost 20 cm forward of the single back axle, as shown in Fig. 3;
- make sure the DES cable rests on the pavement surface and that the truck does not run over it;
- the DES cable length must be enough for the truck to run of 10 m when plugged to the Box of Data Acquisition System (BDA) in the truck cabin.
- connect the DES cable to the BDA;
- make sure all FDP system is linked and connected to the 12V source;
- set up the computer program to start;
- the test begins by the operator ordering the FDP wheel be lowered to the pavement surface and the truck to run at the test speed of 10 Km/h
- the measured set of deflection data is displayed on the Note Book screen for direct visual inspection;
- if the operator does not enter a skip command, the deflection data are stored on the Note Book.

Note that the FDP sensor carried out 100 measures per seconds while the truck is run for 10 m at a speed of 10 km /h.

6. Software package for data processing

An operating software package is provided with the FDP system and used to control the test operation from the keyboard of the computer in an interactive mode. The menu driven program guides the operator during testing with appropriate messages on the screen and audio signals.
The software package also prints out a report, which plots the deflection and load history in a graphical representation. A typical FDP curve is shown in Fig 4.

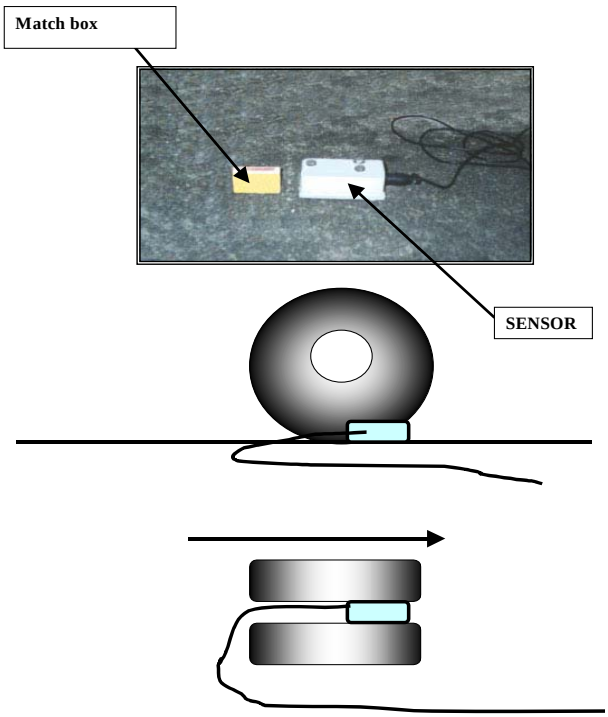
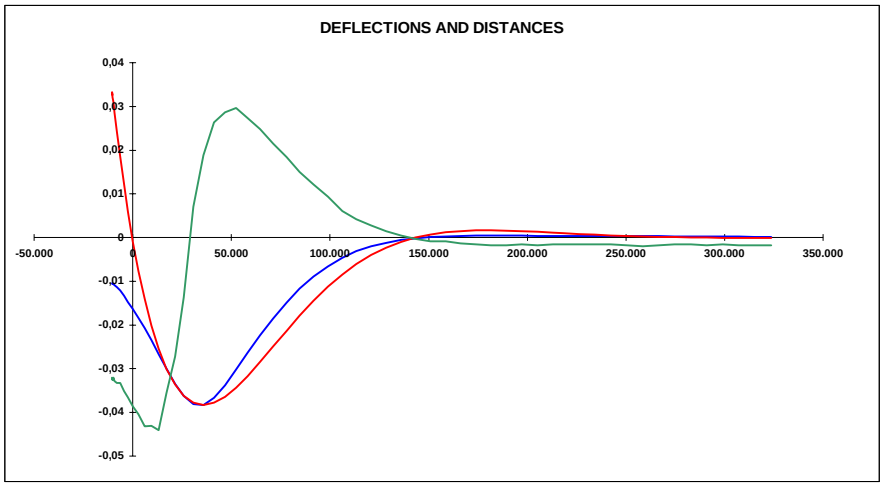


Fig 3: Set up of the FDP sensor.



Note:

- *curve in blue color represents the theoretical curve*
- *curve in red is provided by the FDP immediately after the test*
- *curve in green is the inclination.*

Fig. 4: FDP typical curve

7. Experimental program

In order to evaluate the FDP measurements an experimental program was designed using several pavement structure, all of asphalt surface.
The load level was that used for Benkelman Beam Test. Using the guidelines provided by the Brazilian Federal Highway Department, the appropriate mass was set up on truck so that the nominal load was achieved. The stiffer the pavement structures the higher the load for a given deflection. Therefore, load level might be different for asphalt and rigid pavements.
The deflection level is a function of the pavement structure and is influenced by the strength and / or stiffness and the thickness of each layer and the strength and / or the stiffness of the supporting subgrade. For two locations with the same surface structure, higher deflection will be measured at locations with the wicker subgrade support.
In all cases, for the particular experimental program, tests were made at the wheel way. This purpose of the experiment was to evaluate the equipment under the same conditions as recommended to the Benkelman Beam Test.
Two test conditions were used to measure repeatability and reproducibility. One condition was to record the deflection of each road sample segment and measure it again at other seasons, which means at different temperature and day moisture.

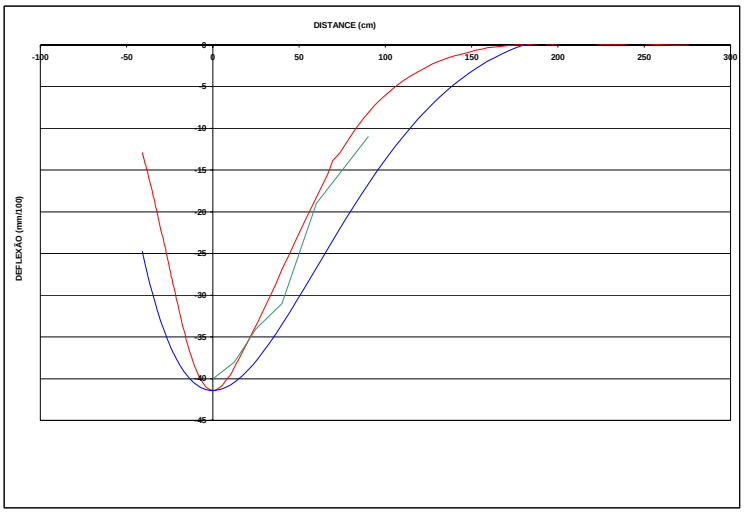
8. The FDP evaluation analysis

There were two phases in this evaluation of the FDP capabilities:

- evaluate the repeatability of the deflection applied to the pavement surface by the Benkelman Beam Test measurement and carried out FDP deflection measurements;
- evaluate the capability of the FDP to produce a well defined measurement of the deflection basin.

To accomplish phase one, tests were performed at 120 sites, with 8 repetitions per site. The results show clearly that at the 8 sites, the trend was the same. It should be noted that deflection data define a reasonable deflection basin as shown in Fig. 5.

As can be seen in Fig. 6 there is no significantly difference between the deflection basins by Benkelman Beam Test and FDP measurements.
Insitu module of pavement layers are determined by the self-iterative inverse application of FDP software program.



Note:

- *curve in blue color represents the theoretical curve*
- *curve in red was provided by the FDP immediately after the test*
- *curve in green was provided by Benkelman Beam .*

Fig. 5: pavement deflection basin

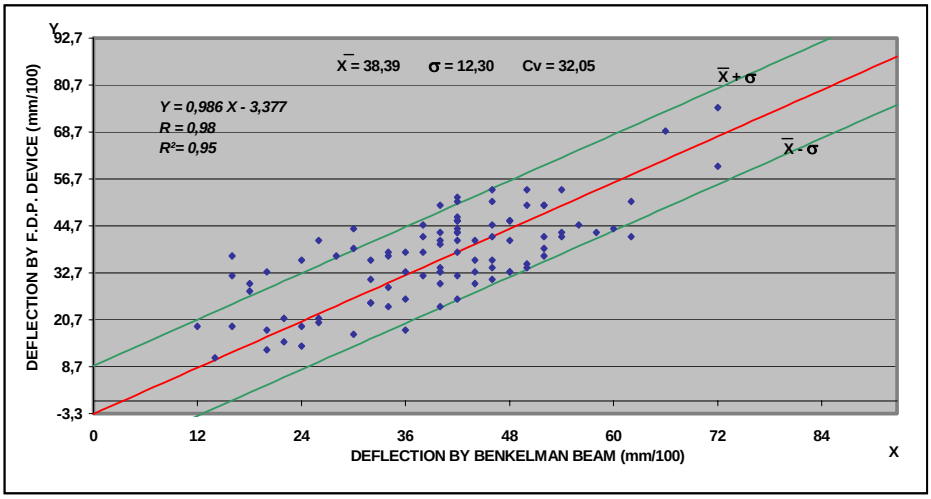


Fig. 6: Deflection: Benkelman Bean – FDP correlation

9. Conclusions

A major goal of this study was to develop, evaluate and implement the use of a commercially available device for nondestructive structural evaluation of pavements. The overall conclusions are:

- the FDP is a satisfactory tool for structural evaluation of both asphalt and rigid pavements;
- the FDP can predict values of moduli for surface layers;

- the FDP results are significantly related to Benkelman Beam Test.

Another experimental program has shown that the FDP can be used for assessing load transfer efficiency of joints, and void detection underneath a concrete slab.

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Note

This paper was written in honor of the memory of Engineer Aloysio Bello Gomes de Mattos.