AUSTROADS TEST METHOD AG:AM/T006

PAVEMENT DEFLECTION MEASUREMENT WITH A FALLING WEIGHT DEFLECTOMETER (FWD)

1 SCOPE

This test method defines the procedure for measuring the deflection response of road pavements using a Falling Weight Deflectometer (FWD).

This test method does not address all occupational health and safety issues associated with its use. It is the responsibility of the user to operate in accordance with appropriate legislation.

2 REFERENCED DOCUMENTS

COST Transport Program 1999, *COST 336: use of falling weight deflectometer in pavement evaluation: FWD calibration protocols*, viewed 31 March 2011, http://82.143.209.48/fog/fwd/cost336.htm

Protocol C1-1999: dynamic reference calibration of FWD load cell
Protocol C2-1999: laboratory reference calibration of dismounted FWD deflection sensors
Protocol U2-1999: FWD short term repeatability verification
Protocol U4-1999: relative calibration of FWD deflection sensors
Protocol U5-1999: reference calibration of FWD temperature probe.

International Organization for Standardization (ISO) 2007, International vocabulary of metrology:- basic and general concepts and associated terms (VIM), ISO/IEC Guide 99, 3rd edn.

International Organization for Standardization (ISO) 2005, *Quality management systems: fundamentals and vocabulary*, ISO 9000:2005.

AASHTO 2011, *Standard practice for calibrating the load cell and deflection sensors for a falling weight deflectometer*, R32-11, American Association for State Highway and Transportation Officials, Washington, DC, USA.

Irwin, L, Orr, D & Atkins, D 2009, *FWD calibration center and operational improvements: redevelopment of the calibration protocol and equipment*, FHWA-HRT-07-040, Federal Highway Administration, Washington, DC, USA, viewed 31 March 2011, http://www.pooledfund.org/documents/TPF-5_039/FWD_Cal_Report_2009_Mar_8.pdf.

3 DEFINITIONS

(a) Falling Weight Deflectometer

A vehicle-mounted or towed device that records pavement surface deflection bowls at discrete test points on the pavement surface. Surface deflections are measured at distances ranging from 0 mm to a user-defined maximum (normally 1500 mm, but up to 2400 mm) from the centre of an impulse test load. The load is applied to the pavement surface through a standard loading plate, normally 300 mm in diameter, by a falling weight with a variable drop height while the FWD is at rest.

(b) Calibration

ISO (1993) defines 'calibration' as:

> [a] set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, of values represented by a material measure or a reference material, and the corresponding values realised by [measurement] standards.

(c) Validation

ISO (1994) defines 'validation' as:

> confirmation, through the provision of objective evidence that requirements for a specific intended use or application have been fulfilled.

4 EQUIPMENT

4.1 Minimum Equipment Specification

Table 4.1 lists the minimum requirements for FWD equipment suitable for use with this method.

Table 4.1: Minimum FWD equipment specification

Parameter	Displacement sensor	Load cell	Data acquisition system
Instrument type	Geophone, accelerometer or equivalent	Strain gauge bridge	Supply information in required format
Resolution	1 μm	100 N	16 bit
Measuring range	0–2000 μm	7–120 kN	Sensors
Temperature stability	50 ppm/°C	50 ppm/°C	25 ppm/°C
Operating temperature range	0–50 °C	0–50 °C	0–50 °C
Long term drift	< 0.25%	< 0.25%	< 0.002% ± 1 LSB
Repeatability	5 μm	0.5%	± 1 LSB
Recorded/displayed resolution	1 μm	100 N	Not applicable

In addition to the above requirements the following three requirements must also be met.

(a) Distance

The measurement offset (i.e. the distance from the Reference Station), must be recorded as a data field along with the deflection and impact load results.

(b) Loading plate

The load pulse must be applied through a loading plate with a diameter of 300 mm. The loading plate must have a rubber pad of at least 5 mm thickness. This pad will be ribbed or be patterned to allow reshaping.

(c) Load pulse duration

The load pulse shall have a duration of between 25 and 35 milliseconds.

4.2 Automatic Data Quality Checks

The data acquisition system must include software to automatically check and identify the quality of the data recorded.

4.3 Manual Data Quality Checks

If the system software does not provide the automatic data quality checks listed in Section 4.2, manual checking of the recorded results, for each test result, is permitted.

5 CALIBRATION AND VALIDATION

5.1 Calibration Scheme

This test method requires a two part calibration of FWD equipment, as follows:

(a) an annual fully traceable *reference calibration* that must be current at time of data collection

(b) a *relative calibration* performed regularly between reference calibration exercises.

The results of all calibrations must be recorded, and will be submitted to the Contract Supervisor upon request.

5.2 Reference Calibration

The reference calibrations of the load cell, deflection and temperature sensors must be completed in accordance with the calibration scheme, be traceable to international standards and be conducted using the procedures in Table 5.1.

5.3 Relative Calibration

The purpose of the relative calibration is to calibrate the deflection sensors against each other. The relative calibration procedure must be completed in accordance with the calibration scheme and be conducted using the procedures in Table 5.2.

Table 5.1: Reference calibration procedures

FWD component	Calibration procedure (Option 1)	Calibration procedure (Option 2)
Load cell and deflection sensors	*AASHTO 2009, Standard practice for calibrating the load cell and deflection sensors for a falling weight deflectometer, R32*	*COST 336 C1* and *COST 336 C2*
Temperature measurement sensors	*As per manufacturers specification*	*COST 336 U5*

Note: Use of different calibration procedure options for different components is permissible. For example, Option 1 could be used for load cell and deflection sensors and Option 2 for temperature sensors.

Table 5.2: Relative calibration procedures

FWD component	Calibration procedure (Option 1)	Calibration procedure (Option 2)
Deflection sensors	*AASHTO 2009, Standard practice for calibrating the load cell and deflection sensors for a falling weight deflectometer, R32*	*COST 336 U4*

5.4 Deflection Sensor Monitoring and Replacement

If monitoring of the performance of all deflection sensors determines that replacement is necessary, the entire measurement system must undergo a reference calibration in accordance with Section 5.2.

However, if the replacement deflection sensor is certified to have formed part of a previous valid reference calibration (within the last 12 months), then an additional reference calibration of the system is not required and only a relative calibration exercise (Section 5.3) involving the replacement sensor need be completed.

5.5 System Validation

(a) Validation of distance measurement must be conducted in accordance with AG:AM/T005.

(b) Validation of the repeatability of the deflection sensors must be conducted in accordance with COST 336 U2.

6 PROCEDURE

6.1 FWD Set-up

6.1.1 Test Load

FWD devices allow for a range of load levels to be used during testing. Specific load levels maybe selected for particular pavement types or strengths, and for use in different types of analysis.

Unless otherwise specified, a target applied stress of 566 kPa (corresponding with a load of 40 kN) is to be used. Actual test loads must be within 10% of the target load level.

6.1.2 Deflection Sensor Spacings

FWD devices allow for a range of deflection sensor spacings to be used during testing. The device should have a minimum of seven (7) sensors with sensors located at 0, 200 and 900 millimetres from the centre of the applied load being mandatory.

6.2 Deflection Survey

(a) The operator must follow the manufacturer's instructions for use of the equipment (refer to manufacturer's User Manual).

(b) Raise the loading weights to the appropriate height to generate the target load level, and drop the weight. Record the peak load and the resulting peak surface deflections.

(c) The pavement surface and ambient air temperature must be measured at each test location, and this information provided in the reported data.

(d) Perform two additional load sequences [6.2(d)] and compare the results of the second and third test sequences. If the difference is greater than 5% or 5 micron (whichever is greater) for any sensor, note the variability in the report. Differences of this magnitude may affect subsequent analysis of the data.

(e) The peak load, temperatures and deflection sensor readings resulting from the third and final drop constitute the test results.

6.3 Factors Affecting the Test

(a) There are a range of factors that may affect deflection measurements, and when encountered during surveys, the resultant test result must be marked and reported with a note or flag. Example factors include:

- deviation from the test lane, or designated test location
- deviation from the selected target load level
- test location not representative of surrounding pavement, e.g. located on a culvert, bridge deck, access covers, filled trenches, rail crossings, etc.
- localised areas of contamination of the road surface, e.g. mud, debris, etc.
- uneven pavement surface resulting in uneven seating of the load and deflection sensors during testing.

(b) Record any unusual features and events that might influence the results.

7 CALCULATIONS

The deflection sensor readings of the final loading cycles shall be adjusted to estimate the deflection readings that would have resulted from a load level exactly equal to the target load level. This process is called 'normalising'. Normalised deflections shall be determined using the following equation:

$$D_i^* = \frac{L_{\text{target}}}{L_{\text{test}}} \cdot D_i$$

where

D_i = the deflection reading for the sensor located i mm from the centre of the applied load L_{test}

D_i^* = the normalised deflection reading for the sensor located i mm from the centre of the load

L_{test} = the load level applied during the test

L_{target} = the target load level

8 REPORTING

8.1 Data

The data to be collected and recorded, but not necessarily reported, for each location must include the following:

(a) location of the test point with regard to the client specified location reference system

(b) target load level

(c) impact peak load measured during the final (i.e. third) loading cycle

(d) pavement deflection measured at each of the deflection sensors during the final loading cycle

(e) normalised pavement deflections for each of the deflection sensors corresponding with the final loading cycle

(f) ambient air temperature during the test

(g) pavement surface temperature during the test.

8.2 Data Precision

The precision of reported parameters should meet the minimum levels shown in Table 8.1.

Table 8.1: Minimum data precision levels for reporting

Parameter	Minimum reporting precision
Impact peak load level	1 kPa
Deflection sensors	1 μm
Temperature	1 °C

8.3 Filtering of Deflection Sensor Readings

Some FWD devices allow the selection of additional filtering or smoothing of the deflection sensor readings prior to reporting the test results. If such an FWD device is used it is an additional requirement that the status of this filtering be reported (i.e. a statement as to whether the filtering has been applied or not).

AMENDMENT RECORD

Amendment No.	Sections amended	Action [1]	Date
1 (Initial release)	All (Michael Moffatt, ARRB)	New	26 March 2007
2 (Revised release)	All (Richard Wix, ARRB, project AT1484)	Substitution	31 March 2011

[1] Key:

Format	change in format
Substitution	old section removed and replaced with new section
New	insertion of new section
Removed	old section removed