PAVEMENT DEFLECTION AND CURVATURE MEASUREMENT: Falling Weight Deflectometer (FWD)

SCOPE

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

This test method does not address any of the occupational health and safety issues associated with its use.

REFERENCED DOCUMENTS

AGPT05-11 Austroads Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design

Austroads Report: Standardised Measurement of Road Condition: Pavement Deflection Measurement with a Falling Weight Deflectometer (FWD) – September 2006

COST 336 Protocol U2 -1999, FWD Short-term Repeatability Verification

MAIN ROADS Western Australia Calibration Method WA 2060.5 - Calibration of Falling Weight Deflectometers

Main Roads Western Australia Test Method WA 330.1 – Layer Thickness Direct Measurement

DEFINITIONS

1. 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 1,500 mm, but up to 2,400 mm) from the centre of an impulse test load, which is applied to the pavement surface through a Standardised Measurement of Road Condition: Pavement Deflection Measurement with a Falling Weight Deflectometer (FWD) standard loading plate normally 300 mm in diameter by a falling weight with a variable drop height while the FWD is at rest.

2. Weighted Mean Annual Pavement Temperatures (WMAPT)

   The WMAPT characterises the in-service pavement temperature at select locations throughout Australia and New Zealand. Figures provided by determination of the WMAPT are used for the adjustment of measured deflections and curvatures obtained from flexible overlays on flexible pavements.

APPARATUS

1. The FWD shall have as a minimum the requirements listed in Table 1.

Table 1: Minimum FWD Equipment Specifications

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, the following requirements must also be met.

(a) Distance
The test location must be recorded, to an accuracy of ± 5 m in 1000 m, 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) The data acquisition system may include software to automatically check, identify and alert the operator of the following:

- decreasing deflections: a check to ensure the deflections decrease with distance from the impact location
- out of range: a check on the magnitude of the deflection
- load variation: a check that the load is within the specified tolerance
- deflection variation: a check to ensure the geophone deflections are within a specified tolerance
- sensor checks: automatic system checks of the load cell and deflection sensors

(d) If the system software does not provide the automatic data quality checks listed above, manual checking of the same parameters, for each test result must be undertaken.

2. Other optional equipment includes;

- Camera

- Global Positioning System (GPS)
- Paint marking system for the identification of individual test sites

CALIBRATION AND VALIDATION

1. Calibration

Falling Weight Deflectometer must have a current calibration in accord with Main Roads Western Australia Calibration Procedure WA 2060.5.

2. Validation

2.1 Deflection sensor monitoring and replacement

If repeatability monitoring (COST 336 Protocol U2-1999) of the performance of deflection sensors determines that replacement of one or more sensors is necessary then one of the following options shall be followed.

- If the replacement deflection sensor(s) were certified in the previous and currently valid reference calibration, then the sensor(s) can be used following the successful completion of a relative calibration in accordance with Main Roads Western Australia Calibration Procedure WA 2060.5 Part 10.
- If the replacement deflection sensors were not certified at the last reference calibration then a full reference calibration performed in accordance with Main Roads Western Australia Calibration Procedure WA 2060.5 shall be completed prior to the FWD being used.

2.2 Distance measurement

Validation of distance measurements shall be undertaken in accordance with the manufacturer's instructions and recorded.

TEST PROCEDURE

1. FWD Setup

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) shall be used. Test loads must be within 10% of the target load level.
For the Dynatest FWD Equipment, the test load shall be achieved by using four pairs of weights and four rubber buffers.

1.2 Smoothing

The peak smoothing processor must be turned on before commencing testing.

1.3 Deflection sensor spacings

FWD devices allow for a range of deflection sensor spacings to be used during testing. Unless otherwise specified, the spacing's shown in Table 2 are to be used.

Table 2: Deflection sensor spacing's

Number of deflection sensors	Sensor spacings (mm) (measured from the centre of the applied load)
7	0, 200, 300, 400, 600, 900, 1500
9	0, 200, 300, 400, 500, 600, 750, 900,1500

Note: Sensors to be placed to a position within +/- 5 mm of Table 2

2. Deflection survey

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

2.2 Transport the FWD device to the test location and position the loading plate over the desired test point. The test location shall be cleaned of all loose stones and debris to ensure that the loading plate and deflection sensors are properly seated.

2.3 Lower the loading plate and the sensors.

2.4 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.

2.5 Perform two additional load sequences [AGPT: 05-11 s6.2.4] 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.

2.6 The pavement surface temperature must be measured at each test location. For asphalt thicknesses of greater than 80 mm, asphalt temperature shall be measured in accordance with Section 4.2.

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

Notes:

(a) Example factors include:

- surface type
- deviation from the test lane or wheel path, or designated test location
- flush sprayed seal surfacing
- deviation from the selected target load level
- test location not representative of surrounding pavement, e.g. located on a back filled trench or pavement repair, etc
- pavement surface shape loss

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

2. Asphalt thickness determination

Asphalt thickness data for the purpose of temperature correction shall be collected in the following manner;

3.1 For existing roads the asphalt thickness shall be determined using Main Roads Western Australia Test Method WA 330.1. Layer thickness: Direct Measurement. Layer thickness shall be determined at a minimum of 3 sites within the test section.

3.2 For new construction asphalt design thickness data will be available or preferably, if available, asphalt compliance measurement core thickness data.

4. Asphalt temperature measurement

Surface temperature measurements shall be recorded at all FWD tests sites. In addition for asphalt surfaced pavements the following shall apply;

4.1 For asphalt surfacing of less than 80 mm total thickness, the asphalt surface temperature shall be used for temperature correction. The asphalt surface temperature shall be measured at each test site by use of an infra-red or a digital thermometer with sensor probe (the sensor probe shall remain in contact with the asphalt surface until the reading stabilises).

4.2 For asphalt greater than 80 mm thickness, the asphalt layer temperature shall be measured by drilling an 8 mm to 12 mm diameter hole to a depth of half to two thirds of the total asphalt thickness. Pour glycerine or other suitable oil in the hole to a depth of approximately 15 mm. Insert the probe of the digital thermometer into the hole and allow the temperature reading to stabilise for at least 5 minutes prior to recording the temperature of the asphalt. The frequency and location of the asphalt temperature measurements shall be sufficient to satisfy the purpose of the FWD testing.

4.3 Unless specified otherwise by the Principal FWD testing must not be undertaken on asphalt when either the surface temperature or the asphalt layer temperature is more than 10°C different to the WMAPT. The WMAPT must be determined in accordance with the process outlined in AGPT05-11 Austroads Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design.

CALCULATIONS

1. Deflection Normalisation

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:

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

Where

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

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

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

L_{target} = the target load level

2. Temperature Correction

The asphalt surface temperature shall be used for temperature correction when the asphalt thickness is less than 80mm.

The temperature of the asphalt layer determined in accordance with Section 4.2 shall be used for temperature correction when the asphalt thickness exceeds 80mm.

All deflection data for asphalt surfaced pavements shall be temperature corrected in accordance with AGPT05-11 Austroads Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design.

REPORTING

The following shall be reported for each location:

1. Location of the test point.
2. Time of test.
3. Surface type.
4. Target load.
5. Impact peak load measured during the final (i.e. third) loading cycle to the nearest 1 kPa.

6. Pavement deflection measured at each of the deflection sensors during the final loading cycle to the nearest 1 μm.

7. Normalised and temperature corrected (if applicable) maximum pavement deflections (D_0) and curvature ($D_0 - D_{200}$) corresponding with the final loading cycle to the nearest 1 μm.

8. Surface temperature for each test to the nearest 1°C as a minimum.

9. Asphalt thickness.

10. Asphalt layer temperature (for asphalt thicknesses of greater than 80 mm) to the nearest 1°C as a minimum.

ISSUING AUTHORITY

Document Owner	Delegated Custodian
Manager Materials Engineering	Pavements Manager

REVISION STATUS RECORD

Page No.	Section	Revision Description / Reference
1	Definitions	Description added for 'Weighted Mean Annual Pavement Temperatures'
2	Reporting	Addition of minimum requirements for reportable values
3	Deflection Sensor Spacing	Adjusted acceptance criteria
1 to 7	Various	Complete Review