
Standard Practice for Calibrating the Load Cell and Deflection Sensors for a Falling Weight Deflectometer

AASHTO Designation: R 32-20 (2024)¹

Technically Revised: 2020

Reviewed but Not Updated: 2024

Technical Subcommittee: 5a, Pavement Measurement



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1. SCOPE

- 1.1. This standard practice covers the annual calibration of the load cell and the deflection sensors and monthly relative calibration of the deflection sensors of a falling weight deflectometer (FWD) or a heavy weight deflectometer (HWD). It is used to establish calibration factors for correcting FWD and HWD measurements. For this practice, the term “FWD” also refers to an HWD unless otherwise noted.
- 1.2. This procedure is not applicable to the calibration of lightweight deflectometers or of cyclic loading and other types of pavement deflection testing equipment.
- 1.3. A reference calibration is performed once per year or after the load cell has been replaced on the FWD. It shall be performed by a certified technician (see Note 1).
- 1.4. Monthly relative calibration is performed on the deflection sensors at least once per month and immediately after a deflection sensor is replaced. A certified technician is not required (see Note 1).
Note 1—For more information on certification for FWD calibration center operators, visit www.aashtoresource.org.
- 1.5. Calibration procedures may vary slightly among FWD types. This procedure can be used for all types of FWDs with minor modifications within the limits of the reference calibration equipment.
- 1.6. The values stated in SI units are to be regarded as standard. U.S. Customary units given in parentheses are for information purposes only.
- 1.7. *This standard practice may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard practice to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standard:*
 - R 33, Calibrating the Reference Load Cell Used for Reference Calibrations for a Falling Weight Deflectometer
- 2.2. *Other Document:*

3. TERMINOLOGY

3.1. *Definitions of Terms Specific to This Standard:*

- 3.1.1. *certified technician*—an individual who has demonstrated proficiency at performing FWD calibrations during a quality assurance review and is issued certification as an FWD calibration center operator.² The individual shall be re-certified every two years. The certification procedure is described in detail in Report No. FHWA-HRT-07-040.³
- 3.1.2. *data acquisition system*—the signal conditioner, data acquisition board, data acquisition software, computer, and cabling. It is connected to either the reference load cell or the accelerometer.
- 3.1.3. *drop sequence*—the sequence of replicate drops at one or more load levels used during reference or relative calibration.
- 3.1.4. *final gain factor*—the calibration factor for a load or deflection sensor at the end of the calibration procedure.
- 3.1.5. *FWD*—falling weight deflectometer; pulse loading device for measuring pavement structural response. The peak load is adjustable over a range from 13 kN (3000 lb) to 125 kN (28,000 lb).
- 3.1.6. *FWD deflection sensor*—device used to measure the pavement deflection response for a given load (e.g., geophones, seismometers, accelerometers, or other devices).
- 3.1.7. *FWD load cell*—device located under the loading mechanism in an FWD that measures the load response of the FWD system.
- 3.1.8. *HWD*—heavy weight deflectometer; pulse loading device for measuring pavement structural response. The peak load is adjustable over a range from 27 kN (6000 lb) to 270 kN (60,000 lb).
- 3.1.9. *initial gain factor*—the calibration factor for a load or deflection sensor that was present in the FWD operating program before the start of calibration.
- 3.1.10. *interim gain factor*—the calibration factor for a deflection sensor resulting from averaging all trials of reference calibration.
- 3.1.11. *Pavement Deflection Data Exchange (PDDX)*—the file format required by *WinFWDCal*. This format is described in Report No. FHWA-HRT-07-040.
- 3.1.12. *reference calibration*—the calibration of either the FWD load cell or deflection sensors against a separate reference measuring system. For load cell calibration, the reference system is a custom-made reference load cell, and for deflection sensors, it is a precision accelerometer.
- 3.1.13. *reference gain factor*—the calibration factor for a load or deflection sensor determined by one trial during reference calibration.
- 3.1.14. *relative calibration*—a calibration procedure in which the deflection sensors are calibrated relative to one another. No outside reference system is used.
- 3.1.15. *relative gain factor*—the calibration factor for a deflection sensor determined by one trial during relative calibration.

- 3.1.16. *WinFWDCal*—the software required for data acquisition and data analysis for FWD calibration.

4. SUMMARY OF METHOD

- 4.1. In annual calibration, the deflection sensors and load cell from the FWD are first calibrated against independently calibrated reference devices. This calibration process, which is called “reference calibration,” can be performed at a regional calibration center or any other properly equipped location.
- 4.2. The FWD load cell is calibrated against a custom-made reference load cell, which enables the FWD load cell to be calibrated without being removed from the testing equipment.
- 4.3. The FWD deflection sensors are removed from their holders on the FWD and mounted in a rigid stand where they are calibrated against a precision accelerometer (with the accelerometer signal being double integrated by *WinFWDCal*). The sensors are stacked vertically in the stand, one above another in one or two columns, so that all sensors, including the accelerometer, are subjected to the same pavement deflection.
- 4.3.1. Next, the calibration of the FWD deflection sensors is further refined by comparing them to each other in a process referred to as “relative calibration.” In annual calibration, the same sensor stand is used for both reference and relative calibration.
- 4.4. Monthly relative calibration uses a relative calibration stand supplied by the FWD manufacturer. It is a quick means to periodically verify that the sensors are functioning properly and consistently. Monthly relative calibration assumes that the overall mean deflection, as determined from simultaneous measurements by the full set of deflection sensors, yields an accurate estimate of the true deflection. This assumption requires that the deflection sensors must have first been subjected to the annual calibration procedure.
- 4.4.1. The relative calibration procedure used for monthly relative calibration is different from that used for annual calibration.
- 4.5. The procedure results in calibration factors that are entered into the FWD software as multipliers. When the FWD measurements are multiplied by the calibration factors, the result is a set of measurements that have been corrected to agree with the calibration instrumentation.
- 4.6. Acceptance criteria for annual calibration and monthly relative calibration, based on the repeatability of the calibration factors, are identified in the calibration procedure. If accepted, the final gain factors shall be entered into the FWD operating program.

5. SIGNIFICANCE AND USE

- 5.1. Calibration of both the load cell and the deflection sensors provides a means of comparison of results from different FWD types and manufacturers.
- 5.2. Calibration ensures consistency in the data collection among various agency FWDs.
- 5.3. Calibration improves the accuracy of pavement layer moduli derived from FWD data by means of backcalculation and other interpretive methods.

6. APPARATUS

- 6.1. *Facilities*—Indoor space with easy access for FWD and towing vehicle, a level floor large enough so that the FWD can sit level during the test, a reasonably constant temperature (between 10 and 40°C (50 and 100°F)), heated, but not necessarily air-conditioned, and good security for the calibration equipment. The facility shall be free of electromagnetic interference and radio frequency interference.

Electrical Supply—Adequate for operating all FWD calibration equipment and free of line noise.

Note 2—Line noise will typically become apparent during use of the reference load cell. To remedy the situation, a car battery, trickle charger, or similar independent system may be used to isolate the electrical signal.

- 6.2. *Test Area*—Concrete test slab having a smooth, crack-free surface with a clear zone around the perimeter for maneuvering FWDs and the reference data acquisition system. If the test area develops cracks that are visibly open (1.5 mm (0.06 in.) or more), it shall be replaced or the calibration area relocated. The FWD shall sit level on the test area to within ± 2 degrees.

Note 3—The test area may be isolated (by impregnated felt bond breaker, sawed and caulked joint, or similar means) from the surrounding floor area. While an isolated portland cement concrete test slab is recommended, it is not required, provided that all other facilities requirements, especially the deflection characteristics of the test area, are achieved.

Note 4—Slab dimensions of 4 by 5 m (12 by 15 ft) with a clear zone around the perimeter of 2.5 m (8 ft) wide are suggested.

Note 5—A modest amount of hairline cracking in the slab is permissible.

- 6.2.1. The deflection characteristics of the test area shall be deemed satisfactory, provided that the maximum acceleration and maximum number of replicate drops required by the *WinFWDCal* software are satisfied.

Note 6—For preliminary screening of a potential test area, the concrete slab should have a deflection of 300 μm (12 mils) or more due to a 70-kN (16,000-lb) load at the position of the deflection sensor calibration stand when the FWD is in the specified position for calibration. The maximum acceleration at any drop height of the FWD should not exceed the allowable range of the accelerometer being used. This range is limited in *WinFWDCal* to 0.1 g less than the range of the accelerometer being used (see Section 6.3.7). In general, a concrete pavement on a relatively weak subgrade will yield the required deflection amplitude.

Note 7—Calculations indicate acceptable fatigue life can be achieved with a 125-mm (5-in.) thick portland cement concrete slab resting on a 200-mm (8-in.) open-graded crushed aggregate base. A layer of filter fabric should be placed below the base to protect it from intrusion of subgrade fines. To achieve adequate deflections, the subgrade modulus should be less than 80 MPa (12,000 psi) when bedrock is deeper than 8 m (25 ft). Where bedrock exists at depths of 3 to 8 m (10 to 25 ft), the subgrade modulus should be 50 MPa (7500 psi) or less. Test areas located where bedrock is less than 3 m (10 ft) deep are likely to be very sensitive to minor variations in subgrade moisture and hence are not advisable.

- 6.2.2. The calibration stand holder (ball-joint anchor) shall be located not closer than 300 mm (12 in.) from the edge of the test area, but it is not required, nor is it possible, that the test area shall deflect uniformly across the entire area of the pad. The ball joint anchor shall be affixed to the concrete slab with anchor bolts that do not allow the ball joint anchor plate to move during the calibration.

Note 8—Placing the stand holder too close to the edge of the slab may result in excessive accelerations due to the nature of the surface waves near the edge of the slab.

Note 9—Using an asphalt concrete slab is acceptable for a limited number of tests, but the anchor will work loose after a short period of time. Use of asphalt concrete is only recommended for field calibrations where it is logistically easier to perform the FWD calibration away from a calibration center. A fixed-base calibration center should use a portland cement concrete slab.

- 6.3. *Equipment*—The following equipment is needed in the calibration facility. Adequate security shall be provided to prevent unintended access or damage to the calibration equipment.
- Note 10**—Drawings of each of the special items of equipment, cabling diagrams, and the data acquisition software, *WinFWDCal* and *PDDXconvert*, are available from AASHTO re:source. The signal conditioner and data acquisition board described in the following sections are required for compatibility with the *WinFWDCal* software.
- 6.3.1. *Signal Conditioner*—Measurements Group Inc. Vishay Model 2310 signal conditioner with power cable and stabilizer bar or equivalent.⁴
- 6.3.2. *Data Acquisition Board (DAQ)*—Keithley Model KUSB-3108 data acquisition or Measurement Computing Model DT9804 data acquisition board or equal.⁵
- Note 11**—The DAQ board should be placed in a box housing to protect the wire connections.
- 6.3.3. *Connecting Cables*—Accelerometer to signal conditioner load cell to signal conditioner, signal conditioner to DAQ, and DAQ to computer USB port. A push-button cable powered by the DAQ is also required for communication with the *WinFWDCal* software.
- 6.3.4. *Computer*—A laptop or desktop computer capable of running Windows 10 or higher software, having at least two and preferably four USB ports. The FWD computer shall be capable of electronic data transfer using the DAQ board.
- 6.3.4.1. *Computer Software*—The most recent viable versions of *WinFWDCal* and *PDDXConvert* shall be downloaded and installed on the computer.
- Note 12**—Data files for all types of FWDs can be read by the *WinFWDCal* software. The PDDX file format (Section 3.1.11) is required for data input. FWD data files that are in native format can be converted to PDDX format using *PDDXconvert*, which is an integral component in *WinFWDCal*.
- 6.3.5. *Data Backup and Storage*—A method of saving and storing a backup of all data associated with each calibration performed by the center.
- 6.3.6. *Reference Load Cell*—Custom-built reference load cell (300-mm diameter) calibrated annually to a 100 kN (24,000 lb) capacity.
- 6.3.7. *Reference Accelerometer*—Silicon Designs Model 2220-005 ± 5 g or Silicon Designs Model 2220-010 ± 10 g accelerometer mounted in a custom-built aluminum box housing. The accelerometer shall be stored in a +1 g field of gravity (level) when not in use.
- Note 13**—The reference accelerometer may experience hysteresis if not stored properly, resulting in inaccurate deflection measurements.
- 6.3.8. *Accelerometer Verification Platform*—Custom-built aluminum platform capable of being leveled. Used for daily verification of the accelerometer and for storage of the accelerometer when it is not in use.
- 6.3.9. *Data Acquisition Software*—*WinFWDCal* and *PDDXconvert*.²
- 6.3.10. *Deflection Sensor Calibration Stands*—Custom-built welded aluminum stands with shelves and associated hardware for ten deflection sensors and one reference accelerometer. Two designs are available; one design is used with geophones and another with seismometers. If the FWD has 11 to 20 deflection sensors, an alternative design stand with space for 20 geophone sensors and one reference accelerometer shall be used (see Figure 1). This 20-sensor stand has the same shelf