

Pavement Deflection Data Exchange

Technical Data Guide

Version 1.0



**American Association of State
Highway and Transportation Officials**

April 1998

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Overview

Introduction

Nondestructive deflection testing (NDT) devices have become integral tools in the evaluation and analysis of pavement facilities. Over the years, the technology of deflection testing has evolved through the use of static, steady-state vibratory, and dynamic impulse loading devices. These devices have been developed by numerous equipment manufacturers, and each device has experienced its own evolution as advancements in hardware and software technologies have been incorporated. Historically, the data produced by deflection devices have been stored in output files with the type, extent, and organization of collected data being left to the discretion of the individual equipment manufacturers. As a result, a multitude of non-interchangeable file formats currently exist. These file formats inhibit the efficient analysis of data collected with more than one system (or even more than one version of a given system) and preclude the efficient exchange of pavement deflection data between users.

In the past, the problems caused by multiple file formats have been minimal, as users and agencies were primarily concerned with only their specific data. However, as the Federal Highway Administration and individual State highway agencies continue to develop large databases of deflection data and other pertinent pavement-related information, the efficient exchange of data between these agencies is crucial. Therefore, a universal file format is essential. The universal format should be straightforward and logical, and it should not be biased toward a specific deflection measuring device or methodology. In addition, the universal format should accommodate current and future pavement deflection data needs.

This document describes a device-independent universal pavement deflection data exchange (PDDX) specification that achieves the objectives discussed above. These specifications are not intended to replace pavement deflection testing device manufacturer native data collection formats. This universal exchange format utilizes the data management concept of section blocks, similar to the software initialization file format used by many computer operating systems. The use of section blocks has proven to be an efficient and flexible method in the management of data and can be applied successfully to pavement deflection testing technology.

Current Practices

Introduction

This section summarizes the practices and standards currently used throughout the pavement deflection testing industry. The purpose of this summary is to identify current practices, highlight the limitations of the current data file formats, and illustrate the need for a universal data file format. Included in this section are descriptions of the various types of deflection testing devices, a brief discussion about the current uses of deflection data, descriptions of current deflection data file formats, and discussion about the limitations of the current file formats.

Deflection Devices

The three general classes of NDT deflection equipment are static, steady-state vibratory, and impulse loading devices. A fourth class, rolling wheel deflection devices, is currently under development. The basic characteristics of these are presented in table 1 and brief descriptions are presented below.

Static Load Deflection Devices

Static load deflection devices were among the first to be used for nondestructive deflection testing. Static load devices measure the maximum deflection response of a pavement to a static or slowly applied load. The most commonly used static device is the Benkelman Beam. Some static devices require that the data be recorded by hand; however, others have been automated to store results automatically. Other examples of static load devices are the LaCroix Deflectograph and the California Traveling Deflectometer.

Steady-State Vibratory Deflection Devices

Steady-state vibratory devices apply an initial static preload to the pavement and then apply a sinusoidal vibratory load by means of a force generator. The most commonly used devices in this category are the Dynaflect and the Road Rater. Vibratory devices are able to vary the loading frequency, which measures the pavement's response to varying load duration. In general, the magnitude of the dynamic load applied by steady-state vibratory devices is in the range of 1,000 to 9,000 lbf.

Impulse Load Deflection Devices

Impulse devices deliver a single, dynamic impulse load to the pavement. Loads are generated by means of falling weights dropped on a set of rubber buffers. The falling weight/buffer combination is connected to a loading plate positioned on the pavement surface. Devices in this category are commonly referred to as falling weight deflectometers (FWDs). Current models include the Dynatest, KUAB, JILS, and Phonix FWDs. In recent years, the use of falling weight deflectometers for NDT testing has grown significantly throughout the U.S. and worldwide.

Rolling Wheel Deflection Devices

The rolling wheel deflectometer (RWD) is a new device that is currently under development. The goal of the RWD is to collect pavement deflection data under a continuously moving wheel load. The RWD consists of a loaded wheel and laser scanners to measure loaded and unloaded pavement profiles. A detailed description of the RWD concept is included in appendix C.

Table 1. Summary of various deflection devices

Device Name	Loading Type	Means of Transmitting Load	Deflection Measuring Device	Number of Versions of Output Format
Benkelman Beam	Static	Truck wheels	Dial gauge	NA
LaCroix Deflectograph	Static	Truck wheels	Deflection transducer	NA
California Traveling Deflectometer	Static	Truck wheels	Deflection transducer	NA
Dynalect	Vibratory	Two 16-in dia. circular wheels	5 Geophones	NA
Road Rater	Vibratory	18-in dia. circular plate	6 Geophones	NA
Dynatest	Impulse	300-mm dia. solid or split plate, 450-mm dia. solid plate	7 to 9 Geophones	20 (includes U.S. and metric)
KUAB	Impulse	300-or 450-mm dia. segmented plate	7 to 9 Seismometers	4 (in the U.S.)
JILS	Impulse	300-mm dia. solid or segmented plate, 450-mm dia. solid plate	7 Geophones	NA
Phonix	Impulse	300-mm dia. plate	3 to 6 Geophones	NA
Phoenix Scientific	Rolling	Truck wheels	Laser scanners	NA
Quest	Rolling	Truck wheels	Laser triangulation	NA

Deflection Data Usage

Nondestructive testing data have been incorporated into the field of pavements in the following ways:

- Identification of uniform pavement sections.
- Calculation of pavement strength parameters.
- Determination of joint and crack load transfer efficiency.
- Detection of subsurface voids.
- Backcalculation of subgrade moduli.
- Backcalculation of pavement layer moduli.
- Design of pavement overlays.
- Provision of structural indices for pavement management systems.

Uniform pavement sections are identified using parameters such as normalized deflections and basin area. Structural evaluation of concrete pavements is performed by testing joints and cracks for load transfer efficiency and testing slab corners for the presence of voids. Another widely employed and comprehensive use of deflection data is the determination of pavement layer moduli through backcalculation. Also, many overlay design methodologies have incorporated the use of deflection criteria based on NDT results. Finally, many agencies have elected to perform network-level testing of pavements to include in pavement management systems.

To perform the above analysis techniques, deflection data analysis programs require several inputs, including the size of the loading plate, deflection sensor location and spacing, load magnitude, and deflection magnitudes. Because nondestructive deflection testing is an expedient process, typical data files contain thousands of data elements. Therefore, to increase the rate at which deflection data are analyzed, most analysis programs are automated to read directly from the device output files. Due to the lack of standardization of output files, most software programs are written to read only a single version of output from a single make of equipment. Currently, the widespread use of deflection data is hindered due to the incompatibility of data analysis programs with device output formats.

Existing Deflection Data File Formats

The data formats generated by deflection devices can be accurately classified as fixed format outputs. Data are entered either manually by the device operator or recorded automatically by the testing device. The data are then stored in ASCII file format in a manner specific to individual equipment manufacturers.

The output files of various devices vary greatly in the number and type of data elements collected and the organization and presentation of stored data. However, all data can be generally characterized as one of three types—informational, device configuration, and deflection basin data. The following sections provide descriptions of all three types.

Informational Data

Informational data are general data that are recorded once for purposes of verification or provision of additional information about the testing project. The extent of the informational data stored in the deflection data file varies greatly from manufacturer to manufacturer, but can include the following: file name, project location, operator name, date, calibration factors, weather conditions, and description of the pavement type.

Device Configuration

Equipment-specific information that identifies the exact configuration of the deflection device at the time of testing is commonly stored in the data output file. The device configuration data are a direct input to data analysis. For steady-state dynamic and impulse loading devices, this information usually includes the size of load plate, number and spacing of deflection sensors, and orientation of deflection sensors with respect to the load plate.

Deflection Data

The most important information collected is the actual load and deflection data collected at each test location. As a minimum, these items include test location (station), load magnitude, and deflection magnitudes. In instances where multiple pavement locations are tested (i.e., at the slab center, slab corner, transverse joint, and longitudinal joint), the test type (or location) is also identified. Many manufacturers include additional information for each deflection basin location, including air and pavement surface temperatures, date, time of day, drop or impact number, and other secondary information of the user's choice. In addition, most device operating programs allow comment lines to be inserted manually during testing, which appear intermittently throughout the test data. Some devices also provide the ability to store deflection time history data for each drop.

Limitations of Existing Data Formats

There are a number of limitations in the existing deflection file output formats, including the following:

- Lack of a universally accepted standard.
- Difficulty in processing fixed format output files.
- Difficulty in the visual interpretation of output file.
- Inability to accommodate hardware changes (e.g., additional sensors).
- Sequential accessing of output file data.
- Difficulty in analyzing device-dependent output files with third party software.

Due to the absence of a universally accepted output specification, each deflection device generates a distinct output format. These varied formats makes it difficult for deflection data users to process results obtained from different devices. Currently, deflection devices generate output files using a fixed format structure. This means that the location of every cell in a file must be defined in terms of a row and column. Because of this fixed structure, the data can be inadvertently

misplaced during the manual editing of a data file in a text editor. The misplaced data can cause data analysis programs to incorrectly read the stored data (or not read it at all). In addition, fixed format output files are often difficult to visually interpret because of a lack of descriptive headings and labels.

As a result of the evolving nature of deflection device hardware, fixed format output files are constantly being revised to accommodate the addition of new data elements. Existing fixed format output files do not offer the flexibility of adding new types of data without a disruption to the current format. This results in multiple versions of output files being generated by equipment made by the same manufacturer. In addition, existing data files are commonly structured around a single system of units. If a device collects data in one set of English units, a data analysis program written for metric units will not be able to access the data. Finally, to perform data calculations on a fixed format output file, the entire file must be read and stored by the data analysis software. This is very inefficient in terms of memory use and data storage.

Data Format Configuration

Introduction

Traditionally, pavement deflection data files have been structured using ASCII columnar or tagged formats that are very device dependent. The ASCII format is beneficial and has allowed users and agencies to easily access the data output files. Unfortunately, a separate program (or procedure) is needed to access the output file for each type of testing device. In some instances, a separate program is needed to access each version of a specific manufacturer's output files.

To address the shortcomings of multiple file formats and provide users with easy access and data exchange capabilities for all of the deflection testing data output files, universal pavement deflection data exchange (PDDX) format specifications have been developed. PDDX will not only address the shortcomings of multiple file formats but will also provide a standard communication platform between researchers, engineers, transportation agencies, equipment manufacturers, and software developers.

Provided in the paragraphs that follow is a brief description of the general configuration of the PDDX format. A more detailed description of the PDDX format specifications is provided in the next section of this report.

Data Organization

Following is a description of the organization of the PDDX data files. Data storage, format, and structure are discussed.

File Type

The PDDX format includes data storage in a universally compatible American Standard Code for Information Interchange (ASCII) format. As noted earlier, most existing deflection data files are in ASCII format. The ASCII file type will allow users to easily edit and organize data files using a standard text editor. This is an important feature, as it is common for files to be "cleaned up" immediately after the data collection process. A PDDX file browser can also be developed for viewing data during and after data collection. The browser could also check the syntax of the file for specification compliance.

File Structure

The PDDX file format specification has a modular structure. Data elements of similar characteristics are grouped together in an individual section. The first line of the section contains a data description demarcated with brackets. Each section will contain a number of variables, each with its associated value or values. In this method, a comprehensive structure is established that allows inclusion of numerous data elements from all types of devices. If data from a specific device are not present due to differences in equipment hardware, software, or loading type, that data line is simply eliminated from the output file for that device. In this manner, the proposed file structure can accommodate as much or as little data as the deflection devices provide.

The following is an example of the general format of this modular approach:

```
[Section 1]
Entry1 = Value(s)
Entry2 = Value(s)
Entry3 = Value(s)

[Section 2]
Entry4 = Value(s)
Entry5 = Value(s)
Entry6 = Value(s)
```

This format will allow data users to understand what is contained in the deflection files that follow the specifications. This format will allow for greater flexibility in terms of amounts of data to be stored and accommodate the addition of future data elements that may be collected by deflection devices. A description of each of the format parameters is provided in the paragraphs that follow.

Section

A section in a PDDX file defines a logical block of data. Each section consists of a section header enclosed in square brackets (ASCII character 91 and 93) and a set of data entries. Depending on the type of deflection measuring device and the data collection practice, entries may or may not exist (e.g., no entries for device calibration section may exist if no calibration procedure are available for a particular device). Also, no order of sections within a file is required; however, a specific section can only appear once in a data file. The following mandatory sections are specified in the PDDX file specifications:

- [Pavement Deflection Data Exchange File]
- [Operations Information]
- [Units]
- [Device Information]
- [Device Configuration]
- [Device Calibration]
- [Location Identification]
- [Data Configuration]
- [Test Location *counter_{location}*]

Entry

Entries within a section are data placeholders. All entries defined in the PDDX file format are unique case-insensitive strings that serve as a descriptive name for each data item. The subsequent releases of the PDDX format will include entries for data attributes to accommodate emerging pavement deflection testing technologies.

Values

Each entry within a section is associated with data values separated by the delimiter symbol. Also, the entry and the data value or values are separated by an equal sign (ASCII character 61) with or without padding spaces (ASCII character 32). Table 2 provides a description of different data types used to designate values in this document.

Table 2. Description of Data Types.

Data Type	Description	Example
number	A free-form real or integer value.	2.35 24
string	A literal string using printable ASCII character set. Note: The ASCII character reserved for the Delimiter Symbol cannot be embedded in a string.	This is a comment
date	A literal string using <i>dd-mmm-yyyy</i> date format.	02-Jan-1996
time	A literal string using <i>hour:minute:second</i> 24-hour clock format.	16:23:49
angle	A literal string using <i>ddd mm ss.sss</i> format representing degrees, minutes, and seconds.	120 45 34.456