Nondestructive Testing of Runway Pavements

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Course Author: Mathew Holstrom

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CHAPTER 1. INTRODUCTION

1. **General.** Nondestructive testing (NDT) can make use of many types of data collection equipment and methods of data analysis. In most cases, the data can be used to evaluate the structural or functional condition of a pavement. This AC focuses on collecting and analyzing NDT data, which is used to accomplish the following:

a. Evaluate the load-carrying capacity of existing pavements.

b. Provide material properties of in-situ pavement and subgrade layers for the design of pavement rehabilitation alternatives that include extensive maintenance and repair work (restoration), functional and structural overlays, partial reconstruction (for example, runway keel), and complete reconstruction.

c. Compare parts of a pavement system to each other to gain relative strength and/or condition within that section. The results of the NDT can show which segments are the strongest and which are the weakest. These results can then be used to focus follow-on testing.

d. Provide structural performance data to supplement pavement condition index (PCI) survey data in an airport pavement management system (APMS).

To accomplish these objectives, this AC provides an overview of the various types of NDT equipment; identifies those scenarios where NDT provides the most benefit to the engineer and owner; describes how NDT test plans should be developed for data collection; presents several methods for using the NDT data to characterize a pavement; and describes how the results from NDT should be used as inputs to evaluation, design, and pavement management analyzes that comply with FAA policy.

There are many software programs that can be used to collect and analyze NDT data, and this AC will reference many of them. The FAA's back-calculation program, BAKFAA, can be downloaded from the FAA website and can be used to analyze NDT data, subject to the limitations discussed herein.

2. **Background.** Recent advances in hardware and software technology have significantly improved NDT equipment, data collection, and analysis software. Not only has NDT work been conducted on hundreds of airport pavements throughout the world, but it has also been extensively used to evaluate and design interstate highways, state highways, tollways, county roads, city streets, and seaports. NDT is also being used by researchers to improve pavement evaluation and design methodologies.

The Federal Highway Administration (FHWA) uses NDT equipment to collect data at hundreds of test section sites throughout the U.S. The FAA currently uses NDT equipment to collect data at the National Airport Pavement Test Facility (NAPTF) in Atlantic City, NJ, to advance airport pavement evaluation and design methods.

There are several advantages to using NDT in lieu of or as a supplement to traditional destructive tests. Most important, is the capability to quickly gather data at several locations while keeping a runway, taxiway, or apron operational during these 2- to 3-minute tests, provided the testing is in close contact with Air Traffic Control. Without NDT, structural data must be obtained from numerous cores, brings, and excavation pits on an existing airport pavement. This can be very disruptive to airport operations. For example, to conduct a plate load test for measuring the in-situ modulus of subgrade reaction (k), 4 ft. (1.2 m) by 6 ft. (1.8 m) pits are prepared by removing each pavement layer until the subgrade is exposed. Once the plate-bearing test is completed, the repair of a test pit can be expensive and may keep the test area closed for several days.

Nondestructive tests are economical to perform, and data can be collected at up to 250 locations per day. The NDT equipment measures pavement surface response (i.e., deflections) from an applied dynamic Load that simulates a moving wheel. The magnitude of the applied dynamic load can be varied so that it is similar to the load on a single wheel of the critical or design aircraft. Pavement deflections are recorded.

Directly beneath the load plate and at typical radial offsets of 12 in (30 cm), out to typical distances of 60 in (150 cm) to 72 in (180 cm).

The deflection data that is collected with NDT equipment can provide both qualitative and quantitative data about the strength of a pavement at the time of testing. The raw deflection data directly beneath the load plate sensor provides an indication of the strength of the entire pavement structure. Likewise, the raw deflection data from the outermost sensor provides an indication of subgrade strength.

In addition, when deflection or stiffness profile plots are constructed with deflection data from all test locations on a pavement facility, relatively strong and weak areas become readily apparent.

Quantitative data from NDT include material properties of each pavement and subgrade layer that engineers use with other physical properties, such as layer thicknesses and interface bonding conditions, to evaluate the structural performance of a pavement or investigate strengthening options. Most of the material property information is obtained using software programs that process and analyze raw NDT data. Once material properties, such as modulus of elasticity, E, and modulus of subgrade reaction, k, are computed, the engineer can conduct structural evaluations of existing pavements, design structural improvements, and develop reconstruction pavement cross-sections using subgrade strength data.

3**. Limitations to NDT.** Although NDT has many advantages, it also has some limitations. NDT is a very good methodology for assessing the structural condition of an airfield pavement; however, engineers must use other methods to evaluate the functional condition of the pavement, for example, visual condition, smoothness, and friction characteristics. The visual condition is most frequently assessed using the PCI in accordance with American Society for Testing and Materials (ASTM) D 5340, Standard Test Method for Airport Pavement Condition Index Surveys, and AC 150/5380-6, Guidelines and Procedures for Maintenance of Airport Pavements. Once the NDT-based structural and functional conditions are known, the engineer can assign an overall pavement condition rating.

The differentiation between structural and functional performance is important in developing requirements for pavement rehabilitation. For example, a pavement can have a low PCI due to environmental distress, yet the pavement has sufficient thickness to accommodate structural loading. The converse may also be true, whereby a pavement may be in good condition, but have a low structural life due to proposed heavier aircraft loading.

In addition, while NDT may provide excellent information about structural capacity, the engineer may still require other important engineering properties of the pavement layers, such as grain-size distribution of the subgrade to determine swelling and heaving potential. For subsurface drainage evaluation and design, grain-size distribution and permeability tests may help assess the hydraulic capacity of the base, subcase, and subgrade.

It should also be noted that quantitative results obtained from raw NDT data are model dependent. The results depend on the structural models and software algorithms that are used by programs that process NDT data and perform a back-calculation of layer material properties.

Because of the model dependencies of NDT software analysis tools, the engineer should exercise caution when evaluating selected pavement types, such as continuously reinforced concrete pavement, post-tensioned concrete, and pre-tensioned concrete. The structural theory and performance models for these pavement types are significantly different from traditional pavements, which include asphalt cement hot mix asphalt (HMA), jointed plain Portland Cement Concrete (PCC), jointed reinforced PCC, and HMA overlaid PCC, and PCC overlaid PCC.

Finally, NDT conducted at different times during the year may give different results due to climatic changes. For example, tests conducted during the spring thaw or after extended dry periods may provide non-representative results or inaccurate conclusions on pavement at subgrade strength.

4. **General.** NDT, using static or dynamic testing equipment, has proven useful in providing data on the structural properties of pavement and subgrade layers. The data are typically used to detect patterns of variability in pavement support conditions or to estimate the strength of pavement and subgrade layers. With this information, the engineer can design rehabilitation overlays and new/reconstructed cross-sections or optimize a rehabilitation option that is developed from an APMS.

This AC focuses on nondestructive testing equipment that measures pavement surface deflections after applying a static or dynamic load to the pavement. NDT equipment that imparts dynamic loads creates surface deflections by applying a vibratory or impulse load to the pavement surface through a loading plate. For vibratory equipment, the dynamic load is typically generated hydraulically, as is the case for the Road Rater, or by counter-rotating masses, as is the case for the Dynaflect. For impulse devices, such as the Falling Weight Deflectometer (FWD), the dynamic load is generated by a mass free-falling onto a set of rubber springs, as shown in Figure 1. The magnitude of the impulse load can be varied by changing the mass and/or drop height so that it is similar to that of a wheel load on the main gear of an aircraft.

For both impulse and vibratory equipment, pavement response is typically measured by a series of sensors radially displaced from the loading plate, as shown in Figure 2. For static devices, such as the Benkleman Beam, a rebound deflection from a truck or other vehicle load is measured. Typically, the rebound deflection is measured only at the location of the load and not at the other radially spaced sensors shown in Figure 2.

5. **Pavement stiffness and sensor response:** The load-response data that NDT equipment measures in the field provides valuable information on the strength of the pavement structure. Initial review of the deflection under the load plate and at the outermost sensor, sensors D1 and D7 in Figure 2, respectively, is an indicator of pavement and subgrade stiffness. Although this information will not provide information about the strength of each pavement layer, it does provide a quick assessment of the pavement's overall strength and relative variability of strength within a particular facility (runway, taxiway, or apron).

Pavement stiffness is defined as the dynamic force divided by the pavement deflection at the center of the load plate. For both impulse and vibratory devices, the stiffness is defined as the load divided by the maximum deflection under the load plate. The Impulse Stiffness Modulus (ISM) and the Dynamic Stiffness Modulus (DSM) are defined as follows for impulse and vibratory NDT devices, respectively:

$$I(D)SM = L / d_o$$

Where:

I(D)SM	= Impulse and Dynamic Stiffness Modulus (kips/in)
L	= Applied Load (kips)
d_o	= Maximum Deflection of Load Plate (in)

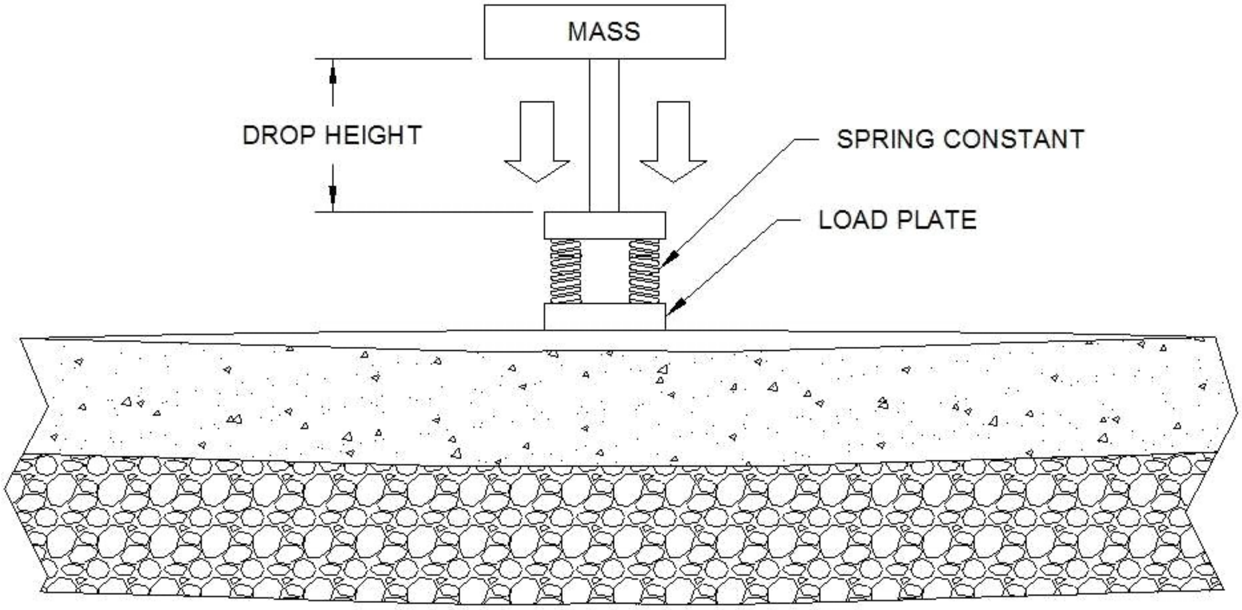

Figure 1. Impulse Load Created by FWD

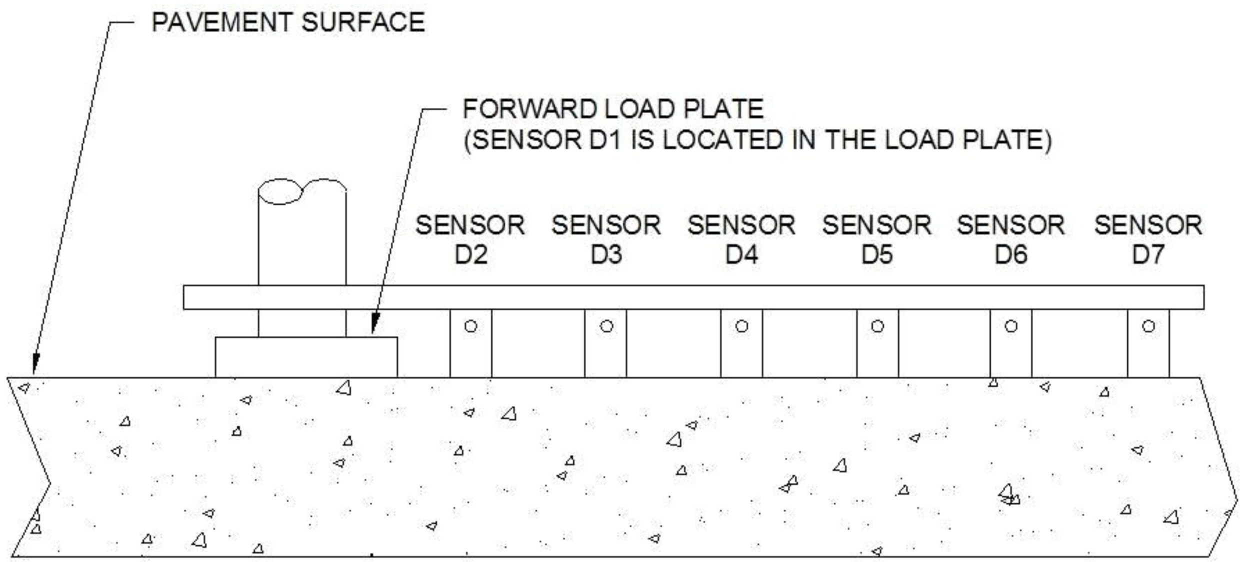

Figure 2. Sensors Spaced Radially from the Load Plate

6. **Deflection Basin.** After the load is applied to the pavement surface, as shown in Figure 1, the sensors shown in Figure 2 are used to measure the deflections that produce what is commonly referred to as a deflection basin. Figure 3 shows the zone of load influence that is created by a FWD and the relative location of the sensors that measure the deflection basin area. The deflection basin area can then be used to obtain additional information about the individual layers in the pavement structure that cannot be obtained by using deflection data from a single sensor.