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Nondestructive Testing of Runway Pavements

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Module 1: Introduction

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the specific applications of NDT data in determining pavement load-carrying capacity and structural life.
- **Identify** the operational advantages and technical limitations of NDT compared to traditional destructive testing methods.
- **Select** appropriate NDT objectives to supplement Pavement Condition Index (PCI) data within an Airport Pavement Management System (APMS).

Executive Summary: Nondestructive testing (NDT) provides a rapid, economical, and technically robust alternative to destructive testing for evaluating the structural integrity of airport pavements. By measuring surface deflections under simulated wheel loads, NDT allows engineers to characterize in-situ material properties, identify structural variability, and design precise rehabilitation or reconstruction alternatives without significant disruption to airport operations.

General Fundamentals

Nondestructive testing (NDT) utilizes various equipment types and analytical methods to evaluate the structural or functional condition of a pavement. This course focuses on the collection and analysis of NDT data to achieve the following engineering objectives:

- **Evaluate load-carrying capacity:** Determine the current ability of existing pavements to support aircraft traffic.
- **Characterize in-situ properties:** Provide material properties of the pavement and subgrade for designing rehabilitation alternatives, including restoration, overlays, and reconstruction.
- **Perform comparative analysis:** Contrast segments of a pavement system to identify relative strengths and weaknesses, allowing for targeted follow-on testing.
- **Supplement APMS data:** Provide structural performance data to enhance visual Pavement Condition Index (PCI) survey data within management systems.

Technical Background

Advancements in hardware and software have moved NDT from a research tool to a standard engineering practice for interstates, seaports, and airport pavements worldwide. Organizations such as the FHWA and FAA utilize NDT at test facilities to refine pavement evaluation and design methodologies.



Operational Advantages

- **Rapid Data Collection:** Tests take only 2 to 3 minutes per location, allowing for up to 250 tests per day.
- **Minimal Disruption:** Runways and taxiways can often remain operational during testing if coordinated with Air Traffic Control.
- **Cost-Effectiveness:** NDT is more economical than traditional destructive tests, such as plate load tests, which require 4 ft. by 6 ft. excavation pits that are expensive to repair and can close a facility for days.

Mechanical Response and Data Outputs

NDT equipment measures the pavement surface response (deflections) from an applied dynamic load that simulates a moving wheel.

- **Load Application:** The dynamic load magnitude can be adjusted to match the single-wheel load of the design aircraft.
- **Deflection Recording:** Sensors record deflections directly beneath the load plate and at radial offsets ranging from 12 in (30 cm) out to 72 in (180 cm).
- **Qualitative Insight:** Deflection beneath the load plate indicates overall structure strength, while the outermost sensor indicates subgrade strength.
- **Quantitative Analysis:** Engineers use back-calculation software to determine the Modulus of Elasticity (E) and Modulus of Subgrade Reaction (k).

NDT Limitations

While NDT is a powerful tool for structural assessment, it is not a standalone solution. Engineers must recognize the following constraints:

- **Functional vs. Structural Condition:** NDT assesses structure; it does not measure visual condition, smoothness, or friction. Visual distress must be assessed via PCI surveys per ASTM D 5340.
- **Physical Property Gaps:** NDT does not provide grain-size distribution or permeability data needed to assess hydraulic capacity or swelling potential.
- **Model Dependency:** Quantitative results depend on the structural models and software algorithms used; exercise caution when evaluating non-traditional pavements like post-tensioned or pre-tensioned concrete.
- **Climatic Sensitivity:** Testing results vary with seasonal changes. Tests conducted during spring thaw or extended dry periods may yield non-representative data.

⚠ Safety Constraint: NDT operations on active airfields require close contact with Air Traffic Control to ensure the safety of the equipment operators and to prevent interference with aircraft movements.

💡 Design Tip: Use NDT-derived stiffness profile plots to identify relatively weak areas that are not apparent from visual inspections. These plots are invaluable for focusing destructive sampling (cores/borings) on areas that truly represent the pavement's limiting conditions.

📊 Calculation Note: The material property information required for structural design—specifically Modulus of Elasticity (E)—is primarily obtained by processing raw deflection data through back-calculation algorithms that simulate the pavement's response to load.

Checkpoint Quiz

1. Which NDT data point provides the best qualitative indication of the strength of the subgrade?

- a) The deflection directly beneath the load plate.
- b) The deflection recorded at the outermost sensor.
- c) The magnitude of the applied dynamic load.
- d) The visual distress captured in a PCI survey.

Answer: (b). Raw deflection data from the outermost sensor provides an indication of subgrade strength, whereas the sensor under the load plate indicates the strength of the entire structure.

2. When evaluating a jointed plain Portland Cement Concrete (PCC) pavement, why should an engineer exercise caution with NDT results obtained during the spring thaw?

- a) The back-calculation software cannot process low-temperature data.
- b) The sensors are calibrated only for dry, high-stiffness conditions.
- c) Climatic changes can produce non-representative results for subgrade strength.
- d) NDT is strictly prohibited on PCC pavements during temperature fluctuations.

Answer: (c). NDT results are sensitive to climatic conditions; testing during the spring thaw may lead to inaccurate conclusions about the typical strength of the structure throughout the year.

3. An engineer needs to determine the hydraulic capacity of a base layer and the swelling potential of the subgrade. Can NDT provide this information?

- a) Yes, the outermost sensor data can be used to calculate permeability.
- b) Yes, the back-calculated Modulus of Elasticity (E) is directly proportional to grain size.
- c) No, NDT evaluates structural capacity but does not provide grain-size distribution or permeability data.
- d) No, NDT is only used for functional condition assessments like friction and smoothness.

Answer: (c). NDT is focused on structural response; laboratory tests for grain-size distribution are still required for drainage and swelling assessments.

Module 2: Description Of NDT Process

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** pavement and subgrade stiffness using Impulse Stiffness Modulus (ISM) and Dynamic Stiffness Modulus (DSM) calculations.
- **Identify** structural layer variations by analyzing the shape and area of the deflection basin.
- **Evaluate** NDT data through both qualitative and quantitative procedures to identify causes of pavement distress.

Executive Summary: The Nondestructive Testing (NDT) process relies on measuring the pavement's reaction to applied loads to estimate the strength of individual layers and the subgrade. By analyzing the deflection basin—the area of load influence—engineers can distinguish between structural and functional distress, detect voids, and characterize material properties such as the modulus of elasticity (E) and modulus of subgrade reaction (k).

Design Fundamentals

NDT utilizes static or dynamic equipment to provide data on the structural properties of pavement and subgrade layers. This information allows engineers to detect support variability, estimate layer strength, and optimize rehabilitation options developed from an Airport Pavement Management System (APMS).

Load Application Methods

Dynamic loading equipment creates surface deflections by applying vibratory or impulse loads through a loading plate:

- **Vibratory Equipment:** Generates dynamic loads hydraulically (e.g., Road Rater) or via counter-rotating masses (e.g., Dynaflect).
- **Impulse Devices:** The Falling Weight Deflectometer (FWD) drops a mass onto rubber springs. Engineers can vary the mass or drop height to simulate specific aircraft wheel loads.
- **Static Devices:** Equipment like the Benkleman Beam measures rebound deflection from a non-moving truck or vehicle load, typically only at the point of application.

Pavement Stiffness and Sensor Response

The load-response data collected in the field provides an immediate indicator of pavement and subgrade stiffness. While this initial data does not detail every layer's strength, it offers a rapid assessment of overall facility strength and variability.

Defining Stiffness Modulus

Pavement stiffness is the ratio of the dynamic force to the deflection at the center of the load plate. For both impulse and vibratory devices, stiffness is defined as the load divided by the maximum deflection under the load plate.

Equation 2-1:

$$I(D)SM = \frac{L}{d_0}$$

Where:

- **I(D)SM** = Impulse and Dynamic Stiffness Modulus (kips/in)
- **L** = Applied Load (kips)
- **d₀** = Maximum Deflection of Load Plate (in)

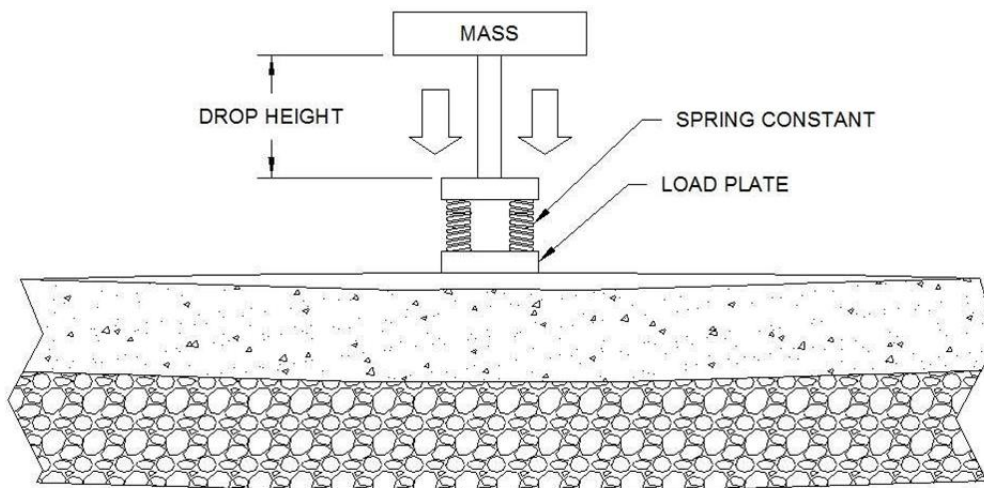


Figure 1: Impulse Load Created by FWD



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