An Introduction to Deflection Testing

Reuben Williams, P.E.
November 15, 2011
Outline

- History of deflection testing
- What is an FWD?
- How does it work?
- Different uses
- Data from testing
- Analysis
- Limitations
- Advantages
There are two broad categories:

- Static devices
- Dynamic devices
  - Vibratory
  - Impulse
What is an FWD?
What is an FWD?
How does it work?

Pavement Surface

Deflections Measured by Geophones

Applied Load

Deflection Basin

E₁

E₂

E₃
Uses

- Structural Testing/Remaining Life
- Joint Load Transfer
- Void Detection
- Load Restrictions
- Super Heavy Load (Evaluation/Permits)
- Project Acceptance
Uses - Layer Moduli

1. Apply axial load
2. Measure axial deformation
3. Compute Modulus “E”

\[ E = \frac{\sigma}{\delta} \]

1. Apply FWD load
2. Measure Surface deflection
3. Compute Modulus
Uses - Load Transfer Efficiency

Zero Load Transfer

100% Load Transfer

- www.fugroconsultants.com -
Uses - Void Detection
Uses - Void Detection

a. Section without void under the slab.

b. Section with void under the slab.
Uses – Load Restrictions/Super Heavy Loads
Data

- Load and deflection readings
- Surface and Air Temperatures
- Additional measurements of HMAC layer temperature
Analysis

Objective

Determine Layer Moduli

Determine LTE

Identify Voids

Plot Deflection Profile

$LTE = \left( \frac{\delta_U}{\delta_L} \right) \times 100$

Plot the deflection under the load plate against the measured load.

Select Sampling Locations

Sampling

Lab Testing

Backcalculation of Layer Moduli

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Analysis – Additional Information Required

- Layer Thickness
- Material Types
- Moisture Contents
- Shallow bedrock layer
Analysis – Profile Plots

Runway 15/33 - Pass 1
10 ft Right of CL
16 kip Load

Deflection (mils)

Station (feet)
Analysis – Profile Plots

Runway 15/33 - Pass 1
10 ft Right of CL
16 kip Load
Sensor 7

Deflection (mils)

Station (feet)
Analysis – 2-D Profile Plots

Apron Area 1
16-kip Load, Sensor 7 Deflection (mils)

Pass Offset (ft) vs. FWD Test Station (ft) graph with color-coded deflections.
Analysis - Material information

CORING LOG

<table>
<thead>
<tr>
<th>FIELD</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Core</td>
<td>6/13/08</td>
</tr>
<tr>
<td>Location</td>
<td>St. Charles Ave.</td>
</tr>
<tr>
<td>Core Size</td>
<td>N 29° 55.38' W 90° 07'.71'</td>
</tr>
<tr>
<td>Core Material</td>
<td>New Orleans</td>
</tr>
</tbody>
</table>

CORE DATA:

- Material Type: AC, PCC, Continuously Reinforced Concrete
- Density: N/A
- Weathering: No
- Other Notes: N/A

CORE LAYER DATA (TOP TO BOTTOM):

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Thickness (in)</th>
<th>Layer Characteristics</th>
<th>Description of Layer Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>1.25</td>
<td>AC</td>
<td>N</td>
</tr>
<tr>
<td>AC</td>
<td>1.50</td>
<td>AC</td>
<td>N</td>
</tr>
<tr>
<td>AC</td>
<td>2.00</td>
<td>AC</td>
<td>Y</td>
</tr>
<tr>
<td>PCC</td>
<td>8.00</td>
<td>PCC</td>
<td>Y</td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
<td></td>
<td>Brown Silty Clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total Thickness: 12.75</td>
</tr>
</tbody>
</table>

Analysis - Material information

- 19 -
Analysis – Backcalculation

Layer Thicknesses → Seed Moduli → Deflection Calculations → Error Check → Results

Loads → Deflection Calculations

Measured Deflections → Error Check

Range of Moduli Controls → Search for New Moduli
## Cost Comparison

### Destructive Testing

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Average Unit Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cores/Bores</td>
<td>32*</td>
<td>cores</td>
<td>$300/core</td>
<td>$9,600.00</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>3</td>
<td>days</td>
<td>$1000/day</td>
<td>$3,000.00</td>
</tr>
<tr>
<td>Atterberg</td>
<td>32</td>
<td>tests</td>
<td>$55.00/test</td>
<td>$1,760.00</td>
</tr>
<tr>
<td>Gradations</td>
<td>32</td>
<td>tests</td>
<td>$55.00/test</td>
<td>$1,760.00</td>
</tr>
<tr>
<td>Moisture Contents</td>
<td>32</td>
<td>tests</td>
<td>$15.00/test</td>
<td>$480.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$16,600.00</strong></td>
</tr>
</tbody>
</table>

* 1 hole every 500 ft
# Cost Comparison

## NDT and Destructive Testing - 3 lane miles, 158 data points

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Average Unit Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWD Testing</td>
<td>8</td>
<td>hours</td>
<td>$250/hour</td>
<td>$2,000</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>2</td>
<td>days</td>
<td>$1000/day</td>
<td>$2,000</td>
</tr>
<tr>
<td>Cores/Bores</td>
<td>8</td>
<td>samples</td>
<td>300</td>
<td>$2,400</td>
</tr>
<tr>
<td>Atterberg</td>
<td>8</td>
<td>tests</td>
<td>$55/test</td>
<td>$440</td>
</tr>
<tr>
<td>Gradations</td>
<td>8</td>
<td>tests</td>
<td>$55/test</td>
<td>$440</td>
</tr>
<tr>
<td>Moisture Contents</td>
<td>8</td>
<td>tests</td>
<td>$15/test</td>
<td>$120</td>
</tr>
<tr>
<td>Analysis of FWD Data</td>
<td>8</td>
<td>hours</td>
<td>$100/hour</td>
<td>$800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$8,200</strong></td>
</tr>
</tbody>
</table>
## Cost Savings

<table>
<thead>
<tr>
<th>Subgrade Modulus, psi</th>
<th>SN Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50,000 ESALs</td>
</tr>
<tr>
<td>3,000</td>
<td>2.77</td>
</tr>
<tr>
<td>5,000</td>
<td>2.28</td>
</tr>
<tr>
<td>7,000</td>
<td>1.99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subgrade Modulus, psi</th>
<th>Difference in HMAC Thickness, in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50,000 ESALs</td>
</tr>
<tr>
<td>5,000</td>
<td>1.11</td>
</tr>
<tr>
<td>7,000</td>
<td>1.77</td>
</tr>
</tbody>
</table>

* Assuming a design modulus of 3,000 psi

<table>
<thead>
<tr>
<th>Subgrade Modulus, psi</th>
<th>Cost Savings/mi, $</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50,000 ESALs</td>
</tr>
<tr>
<td>5,000</td>
<td>15,244</td>
</tr>
<tr>
<td>7,000</td>
<td>24,267</td>
</tr>
</tbody>
</table>

* Assuming a design modulus of 3,000 psi
Limitations

- Shallow bedrock
- Interpreting results
  - Temperature
  - Moisture
- Model dependencies of analysis tools
  - Load Application
  - Material Characterization
- Temperature at time of LTE testing
Advantages of FWD Testing

- Nondestructive test
- Simulates Response of Moving Wheel
- In Situ response of pavement layers
- Better coverage
- Expediency in data collection
- Reduced evaluation costs
- Reduced construction costs
Summary

- History of deflection testing
- What is an FWD?
- How does it work?
- Different uses
- Data from testing
- Analysis
- Limitations
- Advantages
Questions