Embedded Data Collector Piles
Estimation of Pile Tip and Skin Capacities in Real Time

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Current Technology:

Data Acquisition System And Analysis Software Are Complicated (i.e. multiple software) And Require A Highly Experienced User

Expensive Gages Are Attached After The Pile Leads Are In Place And Removed Prior To The Leads Being Removed

To Attach And Detach The Gages Someone Must Climb The Leads

Does Not Provide A Reliable Estimate Of Pile Toe Capacity

Analysis Software Does Not Provide A Unique Solution
New Technology:

Dual Strain Gage and Accelerometer Sensor Packs

Battery and Antenna Assembly

Wireless Networking Based on Bluetooth Industry Standard

- Rugged Notebook Computer
- Acquisition Software
- Review Software
New Technology:

- Sensor Antenna
- Data Acquisition Antenna
- Data Acquisition System
- Battery Pack
New Technology:

Strain Gage

Accelerometer
New Technology:

Battery and Transmitter / Receiver

Antenna
New Technology:

- Real-Time Capacity Calculations
- Force – Velocity Top of Pile
- Wave Up - Wave Down
- Force – Velocity Toe of Pile
- Pile Displacements
Total Pile Capacity [Canadian Geotech, 2001]

Static Pile Capacity - Based on Case Damping, JcL, Determined from Ratio of Total (static + damping) Resistance/Toe Resistance, [Can. GeoTech J. 2001]

\[ F_{d,\text{top}} = \frac{(P_{t1} + ZV_{t1})}{2} \]

\[ F_{d,\text{toe}} = \frac{(P_{t2} + ZV_{t2})}{2} \]

\[ \text{STR} = \frac{\text{Tip/Skin}}{= \left(\frac{F_{d,\text{toe}}}{F_{d,\text{top}} - F_{d,\text{toe}}}\right)} \]

\[ R_{\text{STATIC}} = \left(1 - J_c\right) \frac{\left[P_1 - ZV_1\right]}{2} + \left(1 + J_c\right) \frac{\left[P_2 - ZV_2\right]}{2} \]
Pile Tip Capacity: When pile tip velocity attains zero value, damping forces become zero. The corresponding pile tip force becomes the static tip resistance.
I-95 @ Moncrief Creek
Bent 1 Pile 2
Compression Stress (Bottom of Pile) Comparison

Compressive Stress - Pile Toe (ksi)

Embedded Data Collector (Measured)  PDI PDA (Computed)

Begin Drive  Stop To Remove Template  Resume Driving

Resume Driving  Stop to Change Cushion  End of Drive
Tensile Stress Calculated Using Top Gages Only. Significant Improvement May Be Realized Using Top And Toe Gages.
I-95 @ Moncrief Creek
Bent 1 Pile 2
Maximum CASE Capacity (Jc=0.4) Comparison

Maximum CASE Capacity (kips)

Time

Begin Drive
Resume Driving
Stop To Remove Template
Stop to Change Cushion
Resume Driving
End of Drive

Embedded Data Collector  PDI PDA
I-95 @ Moncrief Creek
Bent 1 Pile 2
Maximum CASE Capacity (Jc=0.4) Comparison

Maximum CASE Method Capacity (kips) vs Pile Depth (feet)

- Embedded Data Collector
- PDI PDA
I-95 at Edgewood
Static Pile Load Test
Strain Measurement Comparison

Time (seconds)

Strain (ue)

Level 1 B Average Level 2 Average Level 5 EDC Top Strain EDC Toe Strain

Pile Top

Pile Tip
I-95 at Edgewood
Load Test Pile
Load versus Displacement

AVERAGE DISPLACEMENT  FDOT Failure Criteria  FDOT Failure Criteria 2

O Ring Failure, Test Stopped
I-95 @ Edgewood
Load Test Pile
Capacity Comparison

Ultimate Pile Capacity (kips) vs. Time

- UF Total Capacity
- Static Test Failure Load
End Bearing Comparison

(Predicted Tip - Measured Tip) / (Measured Tip) x 100

Over-prediction

Under-prediction

LA 1 Results
Costs

• The overall goal is to achieve the lowest unit cost possible while maximizing the number of piles that can be tested

• By testing more piles:
  – lower safety factors or higher LRFD $\phi$ factors can be utilized
  – overall foundation costs can be reduced
  – project safety and confidence are moved to a higher level
Costs

- Expect typical electronics economies of scale: Higher performance at Lower cost over time.
- Expect continued innovations in wireless and sensors further driving costs down.
- Have an initial chicken-egg challenge at the introduction of this capability (e.g. CD players initially cost $1K at their introduction.)
FDOT Costs Of Testing

Jan 2003 – Jan 2005 Test Piling Average Bid Prices

Pile Size – 24” Prestressed Concrete

Test Pile $174 per LF
Production Pile $43 per LF

$110 increase per foot

$11,000 for Test Pile

Dynamic Load Test $1,654 Each

$12,654 per 100 LF Test Pile
Summary and Conclusions

- **Embedded Strain and Acceleration Measurements** - Compare favorably with current External Attachment Method at pile top – *In Addition Embedded Provide Real Time Tip Measurements*

- **Static Testing** - Embedded Strain Measurements Taken During The Static Load Test At The Pile Top And Pile Tip Compared Favorably With The Strain Measurements Made With The Sister Bar Strain Gages Used During The Static Load Test

- **Reliable** - The System Has Been Demonstrated To Reliably Collect Data Before (on site), During (whole drive) and After (e.g. load test) Pile Installation Process

- **Better Capacity Estimates** - Total And Tip Resistance are Computed Individually For Every Hammer Blow *In Real Time*

- **Advanced Capabilities** - Additional Information Can Be Uploaded And Stored On The Pile In The Casting Yard And Downloaded By The System Operator At The Project Site

- **Safety** - Safety Is Improved Dramatically By Removing The Need To Climb The Pile Leads To Attach Gages

- **Time Savings** - Dramatic Time Savings (Contractor, CEI, & Owner) At The Project Site Can Be Realized By Eliminating The Need To Prepare The Pile In The Field, Attach And Detach The Gages, As well as Climbing The Pile Leads
Future Growth

Continuous Remote Structural Monitoring

- Multi-user with access control
- Web accessible
- Mobile user accessible (PDA, smart phone, etc.)

Finished Structures

Structures with 100’s of embedded sensors

Wireless Telemetry

Monitoring System

Information Services
- Remote Monitoring
- Data management
- Reporting/Query
- Analysis

Contractors
Civil Engineers

Internet

- FHWA
- FEMA
- State DOTs
- Other

Government Agencies