Drilled Shaft Testing

Pile Dynamics, Inc. Representative Days
September 27 – 29, 2017
For driven piles we usually have a dynamic loading system.
Dynamic Testing of cast-in-situ piles

- need large drop weight
  - Approx 2% or more of ultimate capacity
    - e.g. 20 ton weight to assess 1000 tons capacity
    - GRLWEAP to assess weight and cushion
- prepare pile top
  - top transducer
  - excavate or build up pile top - 4 strains
  - flat top protected by cushion
- analysis method (CAPWAP®)
CAPWAP must also model non-uniform pile

- **Know the area at sensor location**
  - measure circumference
  - Consider casing (composite), if applicable
- **Know the total concrete volume!**
  - Shape from calipers or TIP – recommended
- **Use soil profile information**
- **Add impedance increases or shaft plug**
DLT on Drilled Shafts and CFA Piles

Can assess “system” with wave equation for given pile geometry, soil condition, and req’d ult capacity.
Drop Weight

Typically between 1% and 2% of required test load

1% rock socket

1.5% friction pile

2% end bearing in granular soils

(test to 1000 ton by 20 ton ram)

More is generally better (up to 5%)
DLT on Drilled Shafts and CFA Piles

Standard procedure:

*Blows of increasing drop height*, until either:

1. Permanent set > 3 ~ 4 mm
   
   (0.12 ~ 0.16 inches)
   
   stop if > 5 mm (0.2 inch) or more set, or

2. Stresses reach the limit, or

3. Capacity prediction > Required test load
Pile Set

Measured Independently by

1. laser
2. piano wire / mirror setup
3. survey equipment
4. PDM

Set ideally between 1/4” and 1/8”
(6 to 3 mm)
Increase drop heights until either stresses too large, or until achieve at least 3 mm (0.12”) set.
Stop test if 5 mm (0.2”) or more set.
**DLT on Drilled Shafts and CFA Piles**

**Preparation of the top**

*System generally used in the USA*

*Build up pile top with steel casing*

- Reduces excavation
- Protects reinforcing

4 strain transducers recommended

(2 or 4 accelerometers)
**DLT on Drilled Shafts and CFA Piles**

**Preparation of the top**

Another system

Reinforced cap executed after casting and cut-off

Sensors preferably installed on pile shaft surface smoothened with an electric grinder

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*Photos provided by PDI Engenharia, RJ, Brazil*
Las Truchas Mexico – June 1974

Testing barrette
Arbor Housing
Charleston WV
1977 CFA tests
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Tampa, Florida
(early 1982)
“Sunshine Skyway”
Melbourne, Australia
1982
Westgate Freeway

**Tested 100 shafts**
(1.5 m dia - 60 m long)

**Socketed in Claystone**

$R_u = 2000$ tons

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Correlation of Static and Dynamic Pile Tests on Large Diameter Drilled Shafts; by: Seidel, J., Rausche, F.

Traditional

\[ F = ma \]

Top transducer

**Force**

**Pile Velocity**

- Single mass only

- Accelerometer

- Strain / Force
Use 4 strains

Force Transducer

F = ma

Accelerometer always on pile
Traditional - Pile Top Preparation

Remove steel casing for small diameter shafts
Tampa
$120 million repair cost
1 year delay
Tampa
APE 750 hammer
60 ton ram
4.5 ft drop
6 ft dia. Shafts (under pier)
DRILLED SHAFT DESIGN

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Tampa Results for two 72” dia shafts

Large-scale Dynamic High-Strain Load Testing of a Bridge Pier Foundations.
Hussein, M.H., Bullock, P.J., Rausche, F., McGillivray, R., Eighth Int’l Conf. on Application of Stress Wave Theory to Piles
Lisbon, Portugal 2008
Attach accelerometer to ram; instead of strain for force. Attach accelerometers to the pile for velocity.
F=ma or Top Transducer - Preparation
TOP TRANSDUCER
Drilled Shaft Tests

Shaft Diameter
1.68 m

Transducer diameter
600 mm

Thin cushion
Testing bored piles

“APPLE” drop weight with 28 tons

20 – 80 tons available
FORCE TRANSDUCER

- Force is more accurate
- No “windows” in casing
- Area and Modulus known
- Less pile preparation
- Eliminate excavations
- 8 strains (4 pairs: in/out)
- Accelerometer on pile
Alternate Analysis

Transducer Force = Pile Top Force

\[ \varepsilon_{\text{trans}} \times EA_{\text{trans}} = \varepsilon_{\text{pile}} \times EA_{\text{pile}} \]

\[ \varepsilon_{\text{pile}} = \frac{\varepsilon_{\text{trans}} \times EA_{\text{trans}}}{EA_{\text{pile}}} \]

\( \frac{EA_{\text{trans}}}{EA_{\text{pile}}} \) \( \leftrightarrow \) input as “replay factor”

input \( \rightarrow \) E and A of the pile
Testing Pile Through Slab
The PDA is, and has been designed for the Driven Pile Market

<table>
<thead>
<tr>
<th>Driven Piles</th>
<th>Bore Piles</th>
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<tbody>
<tr>
<td>• Continuous monitoring of hundreds if not thousands of blows</td>
<td>• Require as few blows as possible</td>
</tr>
<tr>
<td>• Entry of driving resistance often entered in #blows / m (ft)</td>
<td>• Set measured after each blow</td>
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<tr>
<td>• Force measurement taken from the pile top</td>
<td>• Force measurement may be taken various ways</td>
</tr>
<tr>
<td></td>
<td>• By load cell / Dolly</td>
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<tr>
<td></td>
<td>• Traditionally</td>
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<tr>
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<td>• From ram measurements</td>
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Designed for the Bored Pile Industry
Allows for multiple configurations of force measurement

Where are you measuring force?

- Load Cell
- Pile
- Ram
Proceeding to Data Collection

PDA-DLT

Creating Wired data collection subsystem...
Waiting on snapshot received event...
Setting snapshot received event...
Creating form for project definition...
Standard configuration where measurements are made on the pile

Hammer is custom defined for the user’s drop weight

Display confirms Measurement location
F=ma Configuration

%Ram Mass below the sensors allows for inertial correction

Helmet Mass allows for inertial correction
Load Cell Instrumentation

Load Cell Appears when activated

User fabricated load cell may be recalled
Stress values on the pile can be calculated from measurements made on the Load Cell.

Helmet Mass allows for inertial correction.
Users often require load cells of various sizes to appropriately match the Load Cell to the pile size and required load.
Enter Properties of your own Load Cell

Calculated FMX valued is based on the entered area and the yield strength of the load cell. This can be used to verify the appropriate size of the Load cell for the Loads required.
Cal Pulse will Display the Active Channels
Force vs. Displacement Plot
Total Resistance (Case) vs. Displacement
Static Resistance (Case) vs. Displacement
Set and Drop Height Entry
Auto Populated Summary Graph