LATERAL PILE LOAD TEST RESULTS WITHIN A SOFT COHESIVE FOUNDATION

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West Bank & Vicinity, New Orleans, LA, Hurricane Protection Project Facts

- **WRDA 1986**
  - Authorized Westwego to Harvey Canal

- **WRDA 1996**
  - Modified project to add Lake Cataouatche
  - Also authorized East of Harvey Canal

- **WRDA 1999**
  - Combined the 3 projects into one

- **Cost shared**
  - 65% Federal / 35% Non-federal

- **Sponsor**
  - LADOTD for construction & WJLD for O&M

- **Current estimated total project cost:** $308M
Project construction began in 1991

Will protect approximately 250,000 citizens

When complete, will cover over 65 miles of levees, floodwalls and floodgates in Orleans, Plaquemines and Jefferson

Will protect over 65,000 homes and businesses in tri-parish area

By the end of 2005, federal & local sources will have spent over $100 million

B/C = 5.1
CONCRETE GRAVITY FLOODGATE
WITH
BUOYANT STEEL SECTOR GATES
DESIGN ALTERNATIVES

- CASE Pile Group Analysis (CPGA)
  - Rigid Base Analysis
  - Single “Average” value of $E_s$

- G-Pile
  - Utilization of multiple p-y curves
  - Development of Pile Head Deflection curves
  - Develop Moment vs Deflection curves
# G-PILE / CPGA COMPARISON

(Normal Operating Case)

<table>
<thead>
<tr>
<th>G-PILE RESULTS</th>
<th>CPGA RESULTS</th>
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<tbody>
<tr>
<td>Average $E_s = 0.44 \text{ k/in}^2$</td>
<td>Average $E_s = 0.17 \text{ k/in}^2$</td>
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<td>CBF = 0.31</td>
<td>CBF = 0.59</td>
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<td>$\delta_{\text{max}} = 0.125 \text{ in}$</td>
<td>$\delta_{\text{max}} = 0.258 \text{ in}$</td>
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Structure was designed as a Float-In Structure

- 91 Piles (56 vertical – 35 battered)
- 48" Dia. Pipe piles

Solicited as a Best Value Contract - Contractor elected to construct in place

Resulted in new pile foundation

- 180 Piles (72 vertical – 108 battered)
- 24” Dia. Pipe piles
LATERAL PILE LOAD TEST

REQUIREMENTS

• Apply/Record Lateral Load
  – Horizontal Jack
  – Load Cell

• Record Pile Head Deflections vs Load
  – Scales
  – Wire Lines

• Acquire p-y Data
  – Inclinometers
  – Strain Gages
PILE INSTRUMENTATION

48” DIA PIPE PILE

- Strain Gages
- Grout
- Inclinometer
- Steel Pipe Pile

[Diagram showing a cross-section of a 48” diameter pipe pile with labeled components: Strain Gages, Grout, Inclinometer, Steel Pipe Pile]
Concerns with Additional Steel:
- Increase pile stiffness
- Alter/Widen pressure bulb
PILE INSTRUMENTATION

24” DIA PIPE PILE
PILE INSTRUMENTATION
24” DIA PIPE PILE
Welded Steel Diaphragm – Detail and actual location will be supplied by District.

- S1
- S2
- S3
- S4
- S5
- S6
- S7
- S8
- S9
- S10
- S11
- S12
- S13
- S14

0°  30°  60°  90°  180°  270°  360°

- Inclinometer Casing
- Cut
- A-Strain Gages
- B-Strain Gages
- C-Strain Gages (Pile 2 Only)
10 ft (5 PILE DIAS)

Casing

Grout

Inclinometer

Strain Gages

24” Dia Pipe Pile
LOAD APPLICATION

• Service Load = 30 Tons

• Load Increments:
  12.5%, 25%, 37.5%, 50%, 62.5%, 75%,
  87.5%, 100%, 125%, 150%, 160%, 170%,
  180%, 190%, 200%

• Load Decrements:
  150%, 100%, 50%

• Repeat Loading Procedure
STATIC VS CYCLIC LOADING

Graph showing the relationship between Applied Lateral Load (lbs) and Pile Head Deflection (in) for static and cyclic loading.
\[ \sigma = E \varepsilon = \frac{P}{A} + \frac{M}{S} \]

\[ \sigma_A - \sigma_B = \frac{P_A}{A} + \frac{M_A}{S} - \frac{P_B}{A} - \frac{M_B}{S} \]

\[ \Delta \sigma = \frac{2M}{S} \]

\[ M = \frac{\Delta \sigma \cdot S}{2} \]
Figure 4. Form of the results obtained from a laterally loaded pile (Reese and Cox 1968)

\[ p = \frac{d^2M}{dx^2} \]
Consider the Taylor series expansion of $f(x)$ near a point $x$.

$$f(x+h) = f(x) + hf'(x) + \frac{h^2}{2!} f''(x) + \frac{h^3}{3!} f'''(x) + \cdots$$

$$f''(x) \approx \frac{f_{(i+1)} - f_{(i)}}{h}$$

$$f'''(x) \approx \frac{f_{(i+1)} - 2f_{(i)} + f_{(i-1)}}{h^2}$$
P-Y CURVE COMPARISON
(Upper Clay and Sand Strata)

SOIL REACTION, p (lb/in)
DEFLECTION, y (in)

- Sand L-PILE
- Sand 1
- Sand 2
- Sand 3
- Sand Average
- Clay 1
- Clay 2
- Clay 3
- Clay Average
- Clay L-Pile
BENEFITS OF LATERAL PILE LOAD TEST

• Establish Pile Head Deflections
  – Identify Plastic Limit of Soil
  – Verify Group Effects

• Develop Moment vs Depth Curves
  – Structural Analyses
  – Determine Pile Tip

• Develop p-y Curves
  – Pile Stresses & Deflections
  – G-Pile or CPGA
RESULTING PILE HEAD DEFLECTIONS
ALTERING SOILS FACTORS OF SAFETY

L-pile FS = 1.0
L-pile FS = 1.3 on soil
L-pile FS = 1.5 on soil
L-pile FS = 2.0 on soil
LESSONS LEARNED

- Strain gage/inclinometer system well suited for p-y data development
- Allow adequate time for inclinometer readings
- Mark piles and ground fully for alignment
- Cycle load during test before 200%
- Secure jacking device
- Two pile system effective/redundant
LESSONS LEARNED

- p-y development/utilization less conservative
- Apply adequate load to pile to develop full p-y data
- Outside gage coating successful
- Relatively inexpensive
- Utilize F.S. = 1.0 on soils when developing soil reaction data
- Update EM with design and F.S. criteria
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