Structural Health Monitoring System at the I-10 Twin Span Bridge over Lake Pontchartrain

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and

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Outline of Presentation

- Motivation
- Objectives
- Overview of the Project
- View of Instrumentation Plan
- Design of Lateral Load Test
- Some Results
- Conclusions
The existing I-10 Twin Span Bridge over Lake Pontchartrain sustained serious damage from the storm surge associated with hurricane Katrina, in August of 2005.

A new (higher and stronger) bridge is being constructed to replace the old Bridge. Part of the bridge is supported by a group of battered pile foundations.

To address certain concerns raised during the design of the new I-10 Twin Span Bridge, LA DOTD decided to install a structure health monitoring system on a selected pier.

The system includes instrumenting both the substructure and superstructure of the selected pier for short- and long-term monitoring of the bridge.
Objectives

Short-term Monitoring:

- Perform lateral load test on M19 eastbound pier,
- Validate the FB-MultiPier analysis for predicting the performance of battered pile group foundation systems under lateral loading,
- Develop (or back-calculate) p-y curves and multipliers for use in the analysis and design of battered pile group foundations for bridges build in similar soil conditions,
Objectives

**Long-term Monitoring:**

- Develop a data acquisition smart monitoring system for long-term monitoring the structural health of the new I-10 Twin Span Bridge,
- Evaluate the behavior of pile group structure under dynamic loads caused by selected events (winds, waves, and vessel collision),
- This includes monitoring both substructure and superstructure
Overview of the Project

- The construction of a new replacement bridge is almost completed,
- The new bridge is located 300 ft east of the current bridge,
- The bridge is supported by group of battered pile foundations,
- It consists of two parallel structures, with 3-12 ft travel lanes and 2-12ft shoulders on each side (60 ft wide).
Location of I-10 Twin Span Bridge
Location of I-10 Twin Span Bridge

- 5.4 mile long
- 300 ft east of the old bridge

- Source: Volkert Construction, LA DOTD
Overview of Twin Span Bridge

- **Old Bridge**
  - Normal Stretch: 8 feet high
  - High-Rise Stretch: 65 feet high

- **New Bridge**
  - Normal Stretch: 30 feet high
  - High-Rise Stretch: 80 feet high
  - Expected Completion Dates:
    - Westbound span: 2009
    - Eastbound span: 2011
  - Marine Traffic: 135', 200', 250', 200'

*Source: Volkert Construction, LA DOTD*
Overview of Twin Span Bridge

M19 Pier
Overview of M19 Pier (Eastbound)

- **Footing size:** 44 ft x 42.5 ft x 7 ft
- **Total:** 24 battered pile (batter angle of 1:6)
- **Size:** 36” square PPC piles. 110 ft long
- **Embedded pile length:** ~87 ft
- **Water depth:** 11 ft
Medium to stiff gray and tan silty clay to clay soil with silt and sand pockets and seams

Medium dense light gray sand was noted between 46 ft to 58 ft

Piles tip on stiff silty clay layer
Instrumentation of M19 Eastbound Pier

Substructure:

• MEMS In-Place inclinometers (IPI) for 8 selected piles
• Sister bar strain gauges for 12 selected piles,
• 4 Uniaxial MEMS tiltmeters,
• 2 Triaxial accelerometers,
• 8 Water pressure cells.

Superstructure:

• Strain gauges: columns, bent cap, 3 steel girders, 3 concrete girders, and one diaphragm,
• Corrosion meters: footing, columns, & bridge deck,
• OSMOS Weigh In Motion: concrete bridge deck.
In-place Inclinometers
Installation of IPI Casing: Casting Phase

- Casing length = 100 ft
- To install 6 MEMS IPI sensors at depths of 5, 15, 25, 35, 45, and 65 ft from bottom of pile cap.
Instrumentation of M19 Eastbound Pier

Sister Bar Strain Gauges
Installation of Sister Bar Strain Gauges: Casting Phase

- For selected 12 piles
- At 16 ft and 21 ft from the top of pile (total 4 strain gauges / pile)
Monitoring Pile Strain Change during Strand Cutting, Casting, and Relocation

Pile# 4
Monitoring of Piles’ Strain Change

Pile #1 was instrumented with data logger and battery for further monitoring during storage, relocation, and delivery.
Pile Driving & Footing Construction

Cutoff: 6’ – 7’
Substructure Instrumentation

- IPI Sensor
- Triaxial Accelerometer
- Water pressure cell
- Tiltmeter
- Corrosion meter
- Data loggers
Superstructure Instrumentation

- Extensometers For OSMOS WIM
- Omega Strain Gauge
- Corrosion meter

Extensometers For OSMOS WIM
PVC Conduits to Data Loggers & DAQ Computer
Design/Setup of Lateral Load Test at M19 Pier

- Target maximum lateral load: 2000 kips
- Load applied using high strength low relaxation two 19-strand tendons (0.62 in² each strand) run through the westbound and eastbound footings,
- Installed the dead-end anchorages at M19 eastbound pier, and installed the live-end two 600-ton jack system at M19 westbound pier,
- Temporary assembled the data acquisition system,
Design/Setup of Lateral Load Test at M19 Pier

- Recorded all initial readings,
- Strand tendons were preloaded to 300 kips each,
- The eastbound footing and westbound footing were pulled towards each other using the two 600-ton hydraulic jacks,
- Load was applied in increments of 100 kips (50k/tendon),
Measurements from strain gauges and MEMS IPI sensors were recorded after each load increment,

Deformations of east and west bound footings and columns of M19 were monitored using laser survey,
Design of Lateral Load Test at M19 Pier

Westbound

Eastbound

44’

68’ 6”

Live End

Dead End

Jacking Anchorage

Westbound

Eastbound

42’ 6”

7’ 6”

44’

68’ 6”

44’

DEAD END WITH 19C15 EMBEDDED ANCHORAGE

FOOTING

19X0.62” TENDON

19X0.62” TENDON THRU 4” PVC

LIVE (STRESSING) END WITH 600 TON CYLINDER

PLAN
Setup of Lateral Load Test at M19
Setup of Lateral Load Test at M19

Westbound

600-ton Jack

19-strand tendon (0.62 in$^2$ each)

Water Pressure Cells

Dead End Anchorage

Eastbound

Data loggers

Monitoring

Live End Jacking Systems
Setup of Lateral Load Test at M19 Pier

Survey Prism

Survey Station At M18 Eastbound

Automated Laser Survey System
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Profiles of Lateral Deformation with Load

Pile # 4
Lateral Deformation (in)

Pile # 10
Lateral Deformation (in)

Lateral Load = 1870 kips
Pile 4 (boring)
Pile 7 (boring)
Pile 4 (CPT, Nk=15)
Pile 7 (CPT, Nk=15)
Load – Footing Displacement

![Graph showing deformation vs load for different categories like Soil Boring, CPT (Nk=15), Pile cap (measured E1), and Pile cap (measured E2).]
Load versus Strains

Load vs. Strain - M19 Pile #4

Load vs. Strain - M19 Pile #9
Load versus Tension Strains

![Graph showing load versus micro-strain for different conditions.](image)

- Pile 8 (Soil Boring)
- Pile 10 (Soil Boring)
- Pile 8 (CPT, Nk=15)
- Pile 10 (CPT, Nk=15)
- Pile 8 (Measurement)
- Pile 10 (Measurement)

*160 micro-strain (750 k-ft)*
Analysis of Lateral Load Test

\[ P_z = a z^4 + b z^3 + c z^2 + d z \]

\[ \theta_z = \sum_{z_i = z_o}^z \left( \frac{a z^6}{30} + \frac{b z^5}{20} + \frac{c z^4}{12} + \frac{d z^3}{6} + F_o z + M_o \right) \times \frac{d z}{E I} \]
Back-Calculated P-Y Curves

P-Y curve, 5ft depth

P-Y curve 10, ft

P-Y curve 15 ft
Calculated Moment Profile

Pile 11
Moment (kips-ft)

Cal Vs Predicted pile 11
Mom (kips-ft)
Conclusions

- The substructure instrumentation system was successfully installed.
- The system was used to monitor the M19 pier during the lateral load test. A maximum load of 1870 kips was applied.
- The success rate of installing the strain gauges and IPI sensors were about 65 percent.
- The maximum lateral deformations measured at M19 pile cap ranged from 0.58 to 0.72 in., which are ≈50% of the value predicted using the FB-MultiPier analysis.
- The installation of the superstructure monitoring system is on-going.
- The DAQ monitoring system will be used for long-term monitoring of the M19 eastbound pier.
THANK YOU
Questions