Luling Bridge Stay Cable Replacement

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Stay Cables
Lower Anchorage
Upper Anchorage
Statement of Problem

- Rusting and water leakage in anchorage zones
- Cracking/splitting of cable cover pipes
- Signs of compromise in cables safety
- In 2002, LADOTD initiated a project for Structural Evaluation of the Stay Cables
Three Phases of Investigation

Phase I: Assessing extent of problems and the overall integrity

Phase II: Hands-on inspection of the suspect locations and critical elements

Phase III: Detailed design of repairs, and monitoring
Phase I
Cable Force and Damping Measurement

[Graph showing measured and design forces for different cables, including NE I - TE, NE I - TW, NE I - BE, NE I - BW, NE II - T, NE II - B, NE III - T, NE III - B, NE IV - TE, NE IV - TW, NE IV - BE, NE IV - BW, NE V - TE, NE V - TW, NE V - BE, NE V - BW, NE VI - T, NE VI - B.]

- Measured Force
- Design Force

[Additional graphs and charts illustrating force measurements and comparisons, along with a wave form and Scruton Number = 10 for different cable types.]
Phase II - Inspection
Inspection of Deck Anchorage Boxes

[Images of deck anchorage boxes with signs of wear and corrosion]
Source of Problem
NDE Method for Free Length Inspection

Impulse Radar

Thermal Imaging
Cable Inspection Vehicle
Cable Free Length Inspection
Cable Free Length Inspection

Hands-on inspection and Tap Testing
Cable Free Length Inspection

Thermography
# Inspection findings

## Damage Severity Levels

<table>
<thead>
<tr>
<th>Severity Level</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Satisfactory</td>
<td>Minor deterioration and anomalies noted</td>
</tr>
<tr>
<td>2</td>
<td>Poor</td>
<td>Deterioration of the protective elements and potential for degradation. Cables with this level of damages need to be routinely monitored and corrective action needs to be planned.</td>
</tr>
<tr>
<td>3</td>
<td>Critical</td>
<td>Deterioration or potential for deterioration of the main tension elements (steel wires) exists. Action (repair) is necessary. Cables with this level of damages shall be closely monitored until repairs are applied.</td>
</tr>
</tbody>
</table>
Severity Level 1, Epoxy and Weld Repair
Severity Level 2, Tape Damages, Wrinkle, Void, Moderate Rust
Severity Level 3, Exposed Grout and Steel Wires, Heavy Rust
Summary

- All cables have at least damage Level 2
- 39 out of 72 cables are rated critical
- Damage causes still present
- Increasing rate of deterioration is evident
- Damages need to be monitored closely
- Timely corrective action is needed
- Alarming similarity with Zarate-Brazo Largo
Decision Making
Life Cycle Cost Analysis

- Define planning horizon
- Define repair/replacement strategies
- Estimate costs
- Calculate present values for strategies
- Select preferred strategy
Repair/Replacement Strategies

- Base Case
- Repair all
- Repair-Replace 1
- Repair-Replace 2
- Replace all
Cost Structure

- **Initial Costs**
  - Initial repair and replacement
  - Monitoring system

- **Distributed Annual Costs**
  - Inspection and force measurement
  - Maintenance of monitoring system

- **Periodic Repair Costs**
  - Re-repair old repairs and new repairs

- **Vulnerability Costs** (also distributed annually)
  - Replacement of fatigued cables
  - Storm related repairs
Cost Structure

Agency Costs
- External costs-contracts, estimated based on past experience and industry input
- Internal costs ignored

Users’ Costs
- Delays due to lane closures
  - 3 minutes per vehicle per lane
  - 2/3 of vehicles affected
  - $7/hr for cars and 18/hr for trucks
- Detours due to load limits and bridge closure
  - One hour detour time
Present Value Estimation
Agency and Users’ Costs Comparison

### Initial Costs
- **Repair all:** 6.4
- **Repair-Replace 1:** 10.1
- **Repair-Replace 2:** 14.0
- **Replace all:** 19.0

### Initial, Distributed Costs
- **Repair all:** 14.7
- **Repair-Replace 1:** 17.1
- **Repair-Replace 2:** 19.2
- **Replace all:** 19.9

### Initial, Distributed, Periodic Costs
- **Repair all:** 20.2
- **Repair-Replace 1:** 19.8
- **Repair-Replace 2:** 20.5
- **Replace all:** 19.9

### Initial, Distributed, Periodic, Vulnerability Costs
- **Repair all:** 25.5
- **Repair-Replace 1:** 17.1
- **Repair-Replace 2:** 19.9
- **Replace all:** 19.9
Phase III

- Additional Inspection
  - Critical cables
  - Superstructure

- Monitoring System for potential wire breaks

- Cable Replacement Design
Cable Replacement Design
Cable Replacement Design

Objectives:

- Develop a cost effective cable replacement design that requires minimal engineering by contractors.
- Minimize impact to traffic and Maintenance of Traffic (MOT).
- Analyze for live load, wind force, and construction load effects.
Scope

- Assess current conditions
- Replacement cable design
- Temporary cable design
- Construction sequence & Structural analysis
- Design for peripherals
- Maintenance of traffic design
- Cost Estimate and Plan Preparation
Assess current conditions

- Existing Cable Forces
- Geometry Survey
Replacement Cable Design

Available cable systems

- Parallel strand system
- Parallel wire system
Replacement cable design

- Parallel strand, preferred system
- Availability, 3 US manufacturers
- Used in most new bridge constructions
- Ease of inspection and replacement
- Corrosion protection system

- No failures documented in bridges using this system
Replacement cable design

Parallel strand, preferred system
- Larger anchorages may require modifications to structure
- Larger cables increase wind load
- Effects vary with available systems
- Installation method
- Qualification testing
- Equivalent stiffness (27,55,61,75 strand)
Temporary cable design

Need for Temporary cables
- Uncertainty in cable condition
- Large cable group spacing
- Need to maintain traffic w/o load limits
Construction Sequence

Highlights:

- Use of “Highline” or “Cableway” as a means of supporting and lifting cables
- Limiting operation to one side of bridge
- Need for minimal space on deck for construction
- Most of operation at deck level
  - Use of saddle as top support
  - Lower ends as live ends
Construction Sequence
Construction Sequence
Construction Sequence
Construction Sequence
Modeling & Structural Analysis

- CAD model to determine geometry conflicts
- Finite Element Model for structural analysis
Finite Element Model
Finite Element Analysis

- Analyze each stage of construction
- Generate member action envelopes for all load combinations
- Analyze Live load and wind load effects
- Finalize design of permanent elements
- Finalize design of temporary elements
Design for Peripherals

- Cable damper design
- Anti-vandalism and security
- Anchorage drainage design
Maintenance of Traffic
Questions?