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ARCHITECTS & ENGINEERS LLC
Since 1959

# Rehabilitation of Historical Steel Bridge No. 321

## over Rio Grande de Manatí

***ACT Contract No. 668504***

*Puente Mata de Plátano / Ing. Juan José Jiménez*

March 31, 2017

Alvin Rodríguez, PE
Elvin Pérez, PE

Ciales, PR

# OBJECTIVES

- ❑ Team Information
- ❑ Location
- ❑ Historical Relevance
- ❑ Bridge Description
- ❑ Analysis of Alternatives
- ❑ Rehabilitation Considerations
  - Design guidelines exceptions
  - Bridge capacity
  - Rehabilitation schemes
- ❑ Highlights

# TEAM INFORMATION

- Owner

  **Puerto Rico Highway & Transportation Authority (PRHTA)**

- Planning, Design & Services During Construction

  **CMA Architects & Engineers LLC**, PR
  **Sparks Engineering Consultant**, TX

- Inspection & Safety

  **Puerto Rico Highway & Transportation Authority (PRHTA)**

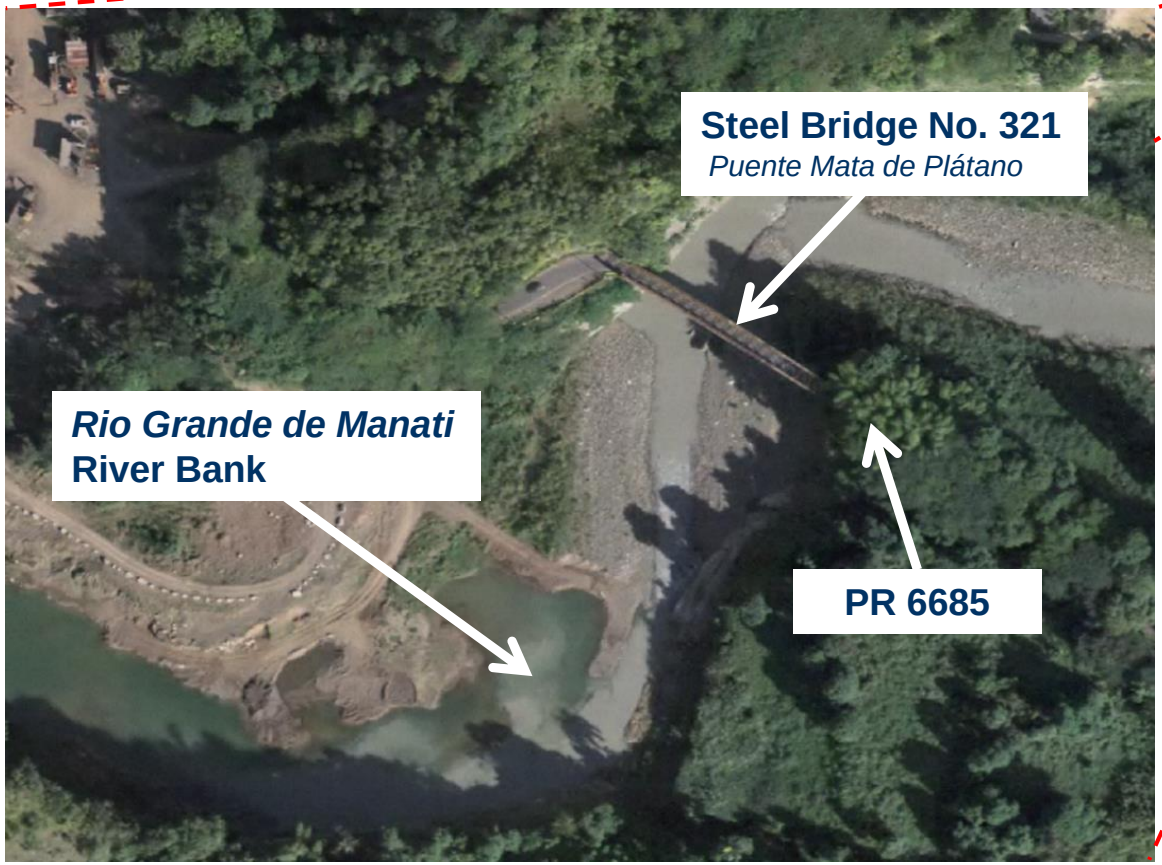
- Contractor

  **CD Builders** - General Contractor
  **Cholo Onsite** - Structural Steel Contractor

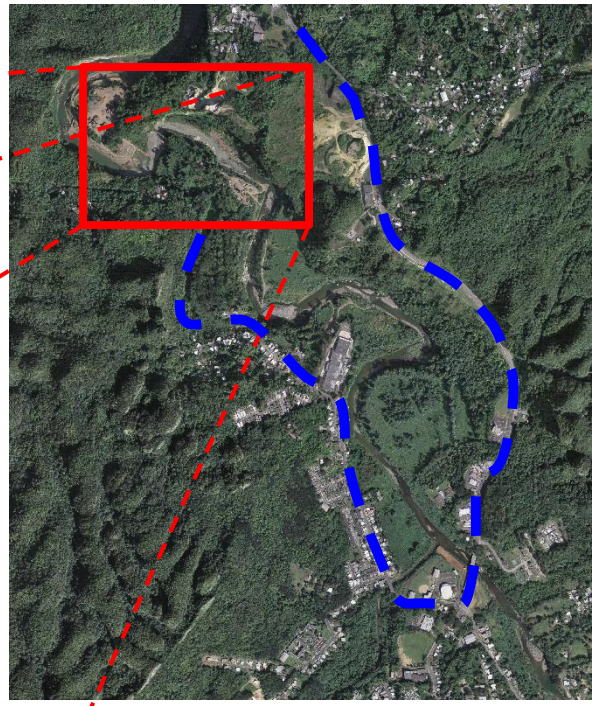
# REHABILITATION OF HISTORICAL STEEL BRIDGE NO. 321

## LOCATION

- **PR-6685 Km. 9.7** over *Rio Grande de Manati*
  **Municipality of Ciales-Manati**




Manati, PR



Ciales, PR

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# HISTORICAL RELEVANCE

- **Centenary Bridge**
  - Erected in 1905 by Eng. Luis Ninlliat
  - Erected during the American Military Government
  - **112** year-old bridge

- **Historic Bridge Registry**
  - State Historic Preservation Office **(SHPO)** National Registry Nomination (1995)

    ✓ **Design integrity**

    **Minor rehabilitation on structural elements**

    ✓ **Original Elements**

    **Workmanship and materials**

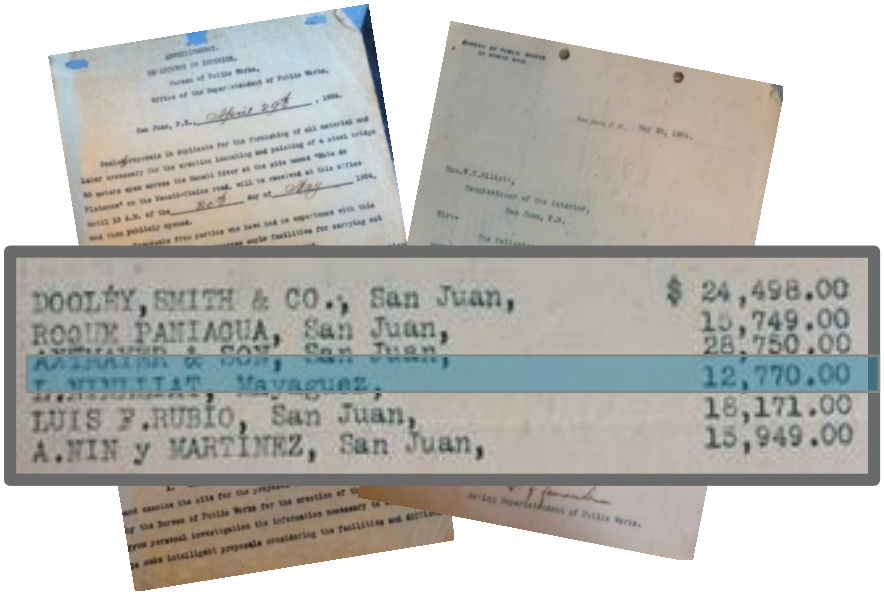
    ✓ **Locality**

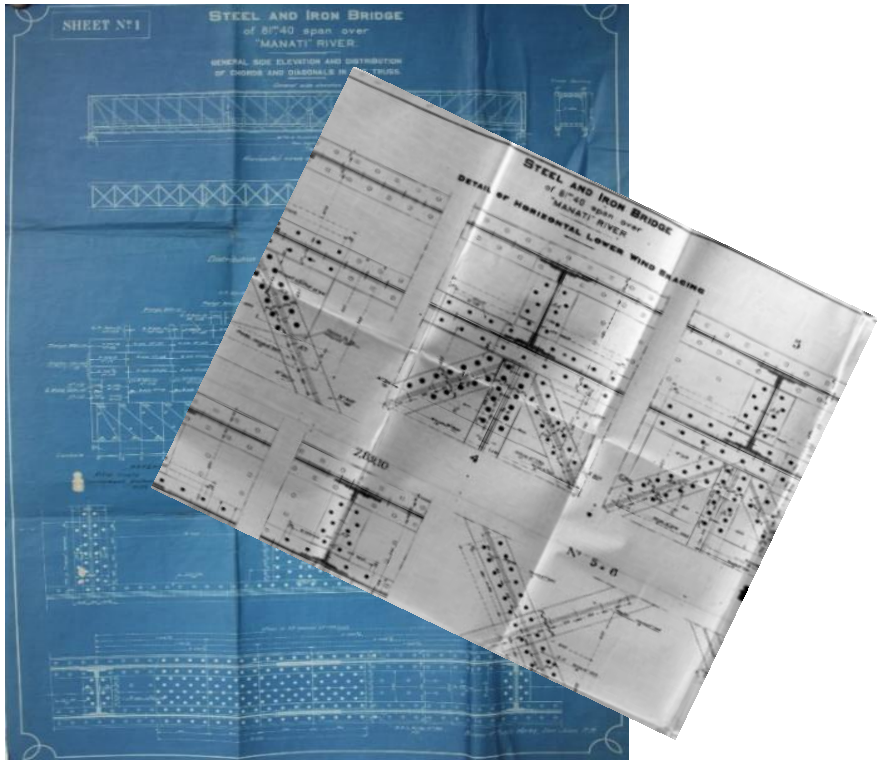
    **Importance to the community**

- **One of a Kind**
  - Only **Double Whipple Riveted Truss** in PR

# HISTORICAL RELEVANCE

- **Bid Documents**
  - Erection & Painting
  - Bid / Due Date: April 29th 1904 / May 20th 1904
  - Lowest Bidder: $12,770.00 [ **Approx. $750k in 2017** ]




*Reference: Archivo Histórico General de Puerto Rico - Puerta de Tierra, Archivo Histórico - Carolina PR*

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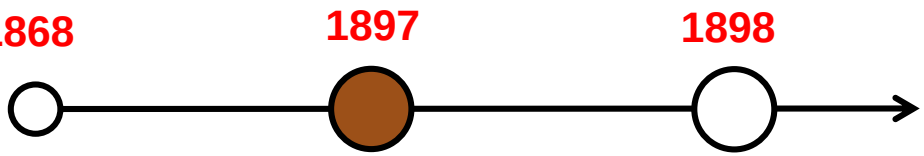
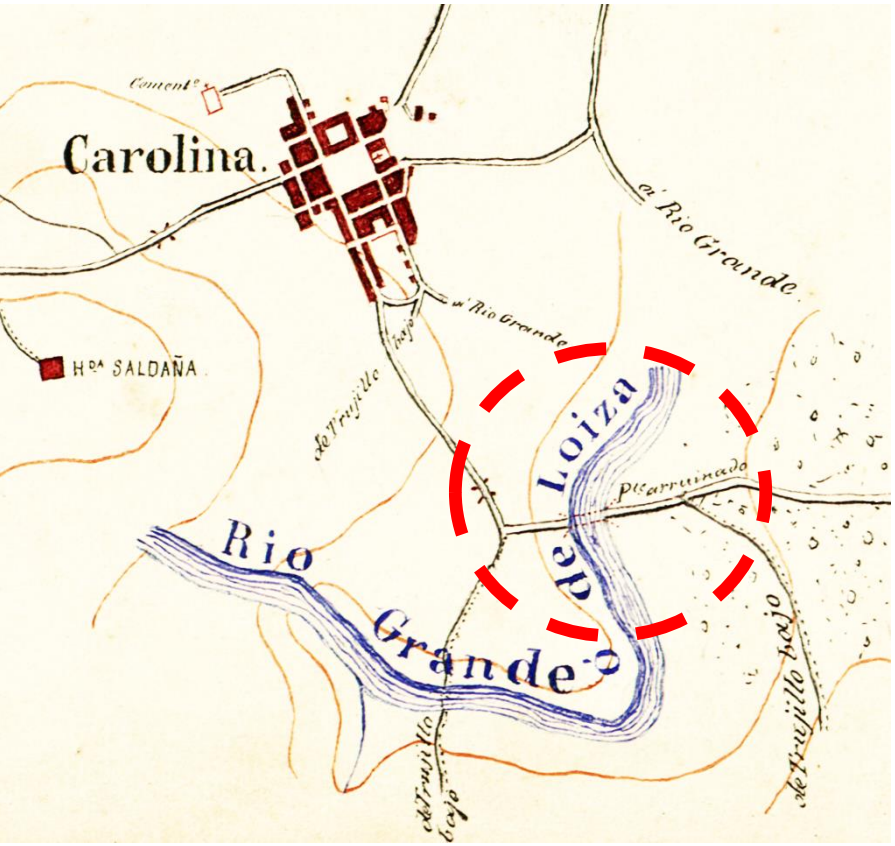
# HISTORICAL RELEVANCE




- **June 1868**
  - Existing bridge in San Fernando de Carolina **swept away** during high floods
- **May 1897**
  - Municipality of Carolina requests to Spanish Government funds for a **new bridge**
- **November 1897**
  - Spanish Government **approves** a bridge over Rio Grande de Loiza **[Puente Principe de Asturias]**
- **March 1898**
  - **Foundation construction** commences in Carolina.

*Reference: Archivo Histórico - Carolina PR*

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# HISTORICAL RELEVANCE

**1905** — **1995** — **2003-2010** — **2011-2013** — **2013**

- **April 1905**
  - American Military Government **determines to relocate Bridge** from Carolina to Ciales
- **June 1995**
  - Bridge is **included** in the **National Historical Registry**
- **January 2003-2010**
  - Evidence of **significant deterioration**
  - Capacity Limited to 9 tons
  - PRHTA recommended **Bridge Closure**
- **February 2011 - 2013**
  - Detailed bridge inspections & evaluations
  - **Alternative evaluations**
  - Community Meetings Coordination


**Dedicated to Juan Jose Jimenez (1945) DTOP Superintendent**

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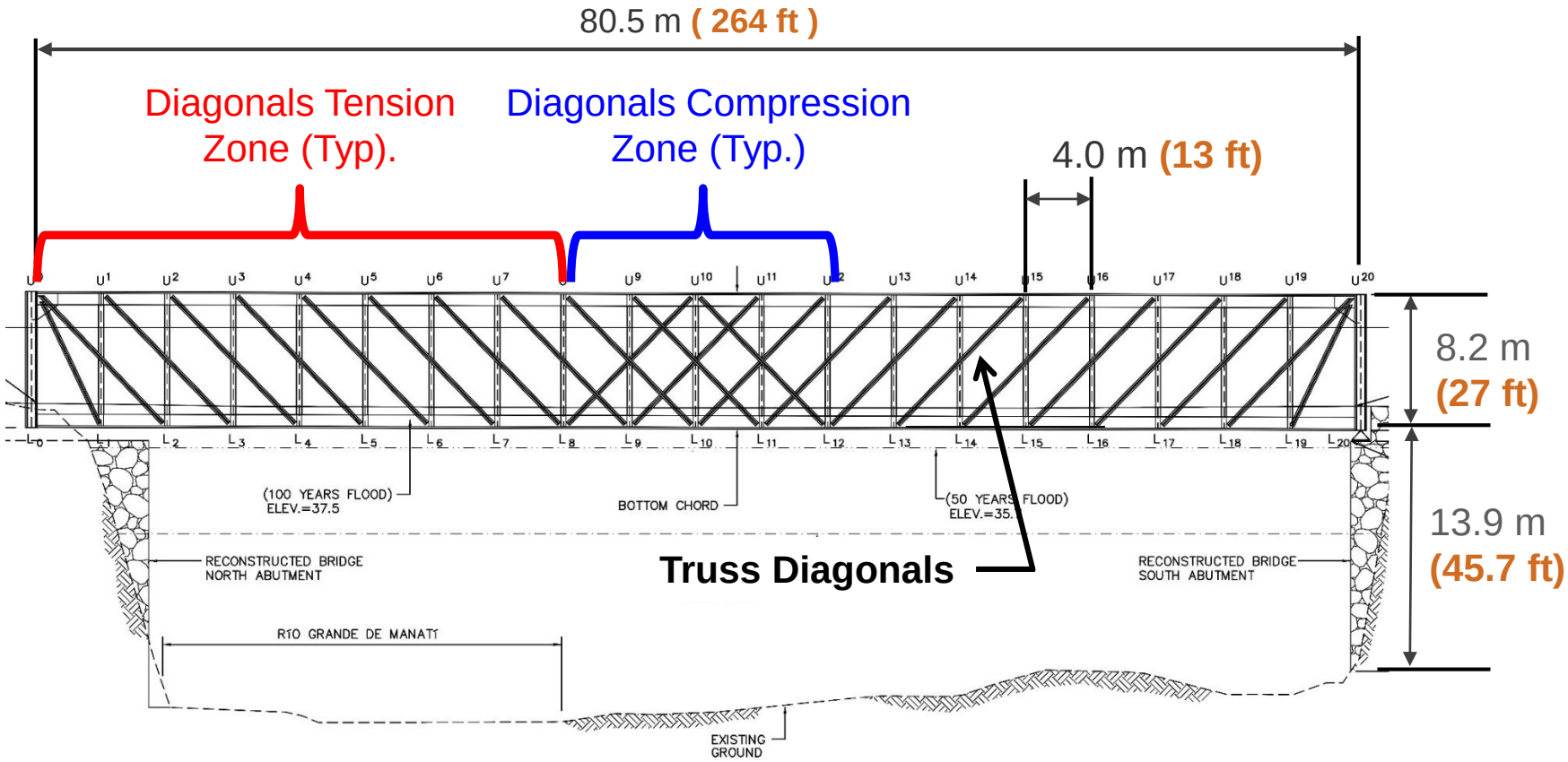
# BRIDGE DESCRIPTION




ELEVATION

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# BRIDGE DESCRIPTION

*Photo 2010*

- **Steel**
  - Built-up Sections
  - Rivet connections
  - Fy Min. 26ksi
- **Roadway**
  - Asphalt
  - Compacted soil base

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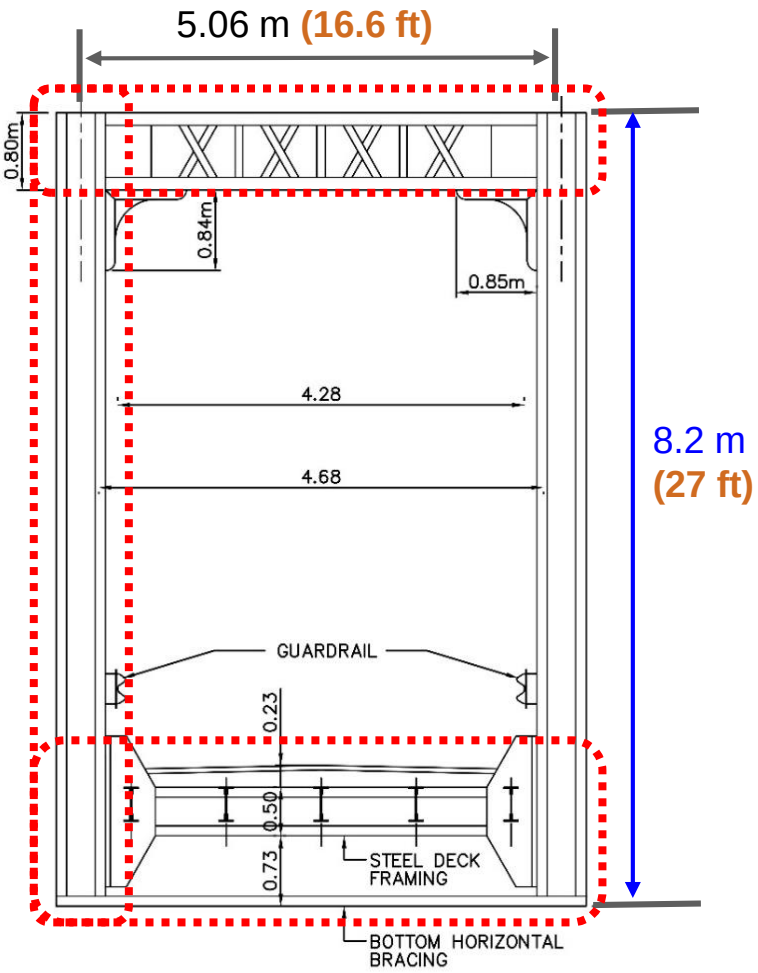
# BRIDGE DESCRIPTION

Top. Horizontal Bracing & Header

Verticals/Columns

Bottom Horizontal Bracing & Beam Support



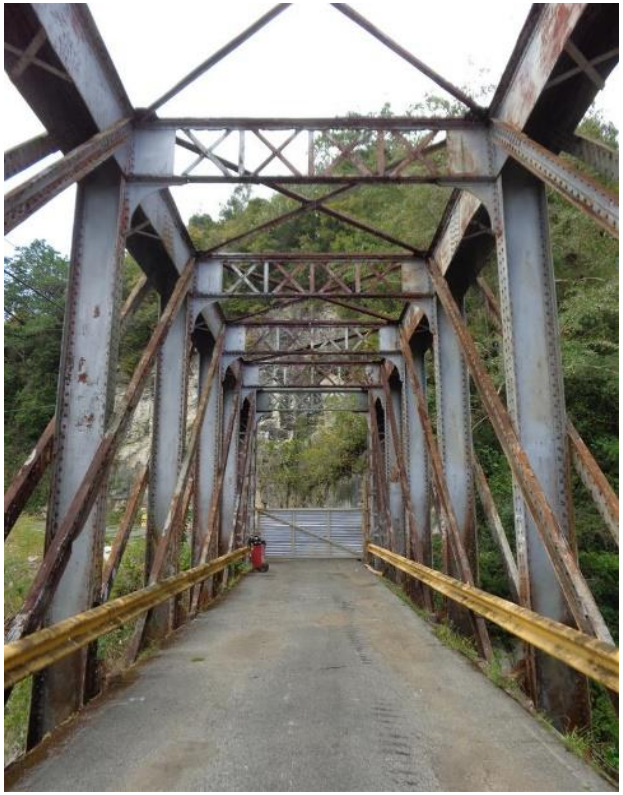



*Photo 2012*

TYPICAL INTERMEDIATE FRAMES

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# ANALYSIS OF ALTERNATIVES

## ❑ Alternate No. 1:

**No action** | Permanent Bridge Closing

- Increases traffic on PR-149
- Increase in travel time from local commuters of nearby sector
- Increase in travel distance from point-of-origin to destination

## ❑ Alternate No. 2:

**Replacement** | In-kind Bridge $3.8MM

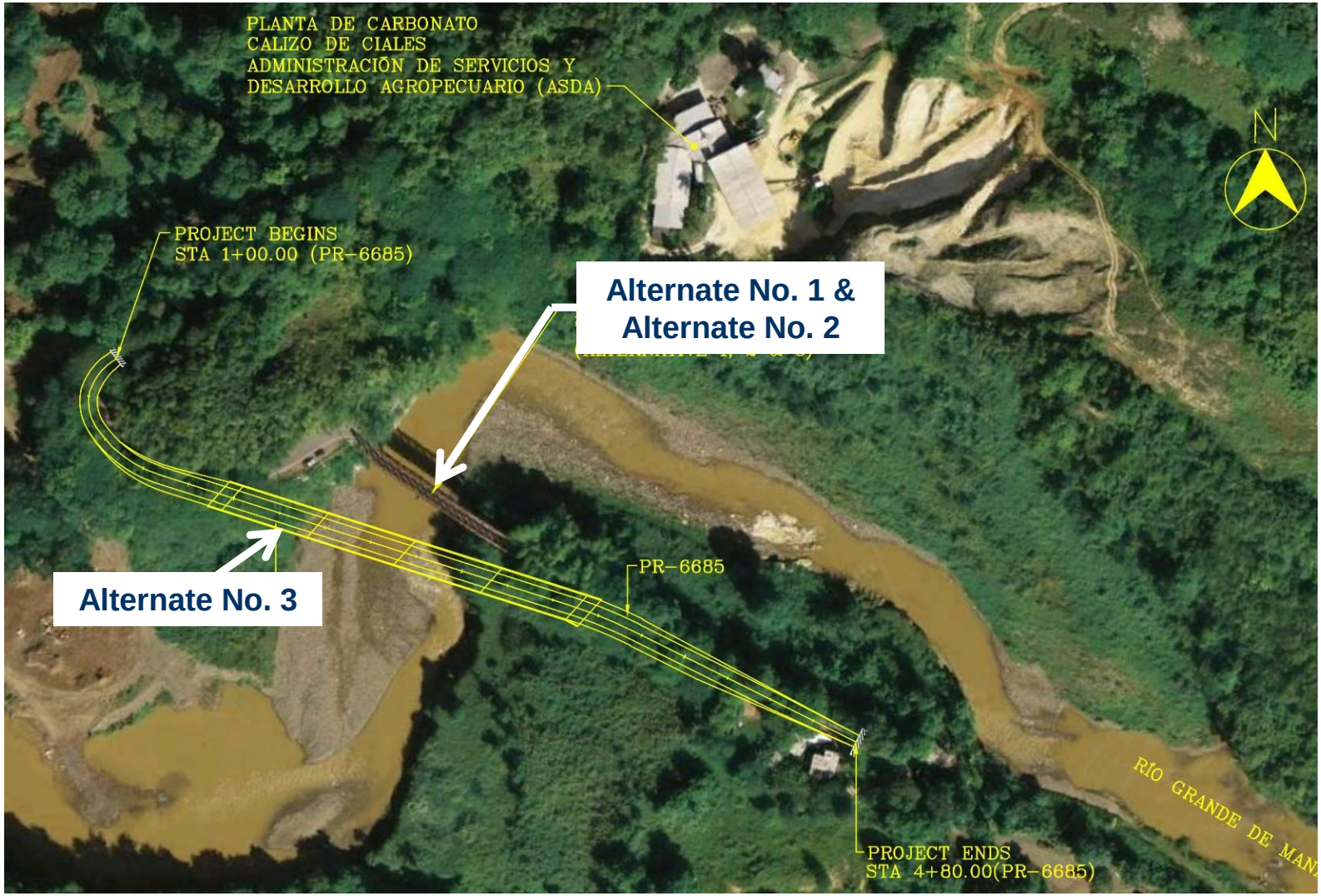
- Single lane
- Slightly higher in elevation to be above 100yr flood level
- Adverse effect to the historical concept

## ❑ Alternate No. 3:

Construction of **New Bridge** $5.5MM

- Four spans: 38 m each / 152 m total span
- Overall dimension: Two 3.65m wide lanes / 2.40m shoulders
- No truck capacity limitations
- Removal of existing bridge due to potential collapse during 100yr flood level

# ANALYSIS OF ALTERNATIVES

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# ANALYSIS OF ALTERNATIVES

***Let's think out of the box….***

*How about* ***rehabilitating the existing bridge?***

❑ Alternate No. 4:

**Rehabilitation $3.3MM**

- Maintain **historical aspect** of the bridge
- Minimize traffic impact on PR-149 due to continuity of local commuters
- Reduce **travel distance** for nearby sectors
- Minimize **complexity of construction** in an environmental sensitive area

❑ Rehabilitation Considerations

- ✓ **PRHTA Design guidelines exceptions**
- ✓ **Determine bridge capacity**
- ✓ **Establish rehabilitation schemes**

# REHABILITATION CONSIDERATIONS

| Description | Design Guidelines | | Exceptions |
|---|---|---|---|
| **Design Speed** | 1979 PRHDM:<br>AASHTO 2004: | 25 mph<br>40 mph | **15 mph**<br>posted at bridge crossing. |
| **Bridge Width** | 1979 PRHDM:<br><br><br><br>AASHTO 2004: | 6.10 m (Travel way)<br><br><br>10.90m (Face-to-Face Railings)<br><br>Full width of roadway approach | **3.80 m** Single Lane with Traffic Controller.<br><br>**4.00 m** face-to-face |
| **Vertical Clearance** | 1979 PRHDM:<br>AASHTO 2004: | 4.40 m<br>4.30 m | **Actual Height: 5.97m**<br>Limited to 2.40m at approach. |
| **Structural Capacity** | AASHTO 2004 | HS-30 | **HS-15**<br>Based on Existing Condition Assessment |

- **No exception taken:**
  - Horizontal alignment, super-elevation, vertical alignment, grade, stopping sight distance, cross-slope, lateral offset to obstruction

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# REHABILITATION CONSIDERATIONS

## ❑ Bridge Capacity | Design Guidelines

- The Manual for Bridge Evaluation 2nd Edition **(2013 Interims)**
  - ✓ **Allowable Stress Methodology (LRFD optional, no preference)**
  - ✓ **Tension Elements**
- American Institute of Steel Construction **(AISC 360-05)**
  - ✓ **Compression Elements**

**Elements Evaluated**

**Bottom Chord, Top Chord, Verticals, Diagonals, Beams, Rivets**

| | |
|---|---|
| Limiting Mechanisms Evaluated: | Tension<br>Compression **(Local & Flexural Buckling)** |
| Live load (HS-15 & HS-20): | Truck Load **(Point Load)**<br>Lane Load **(Uniform & Point Load)** |

# REHABILITATION CONSIDERATIONS

- **Fracture Critical Members** (FCM) - Tension elements whose failure would be expected to result in **collapse** of the bridge.

- **Load-redistribution** thru an all-riveted construction
- **Crack propagation** is not possible across adjacent elements
- **Redundancy** for the **pair of diagonal** truss elements

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# REHABILITATION CONSIDERATIONS

❑ **Load Rating Analysis** (LRA) - Calculations to determine the safe live load capacity of the bridge

$$\textbf{Rating Factor (RF)} = \frac{\text{Capacity} - \text{Dead Load}}{\text{Live Load Demand x Impact Factor}}$$

**RF < 1.0** → Capacity **Deficiency** → Element will need to be reinforced to **Add Capacity**

**RF > 1.0** → Capacity **Adequate** → Element will need to be **Repair/Rehabilitated**

❑ **Inventory Rating (IR)**

- ✓ Safe Live Load
- ✓ Indefinite vehicle use
- ✓ Minimum Maintenance

❑ **Operating Rating (OR)**

- ✓ Maximum live load permitted
- ✓ Limiting vehicle use
- ✓ Frequent Maintenance

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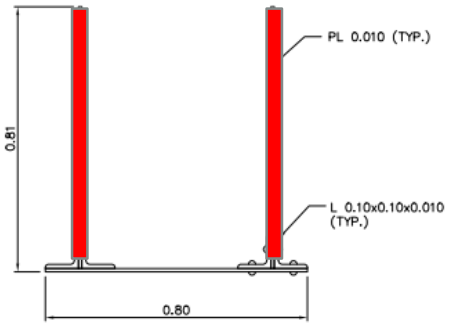
# REHABILITATION CONSIDERATIONS

❑ **Bottom Chords** (Tension Element) - HS-15

- Perforation at bottom flange plate (Approx. 35% corrosion)
- Missing rivets
- Bottom chord to Vertical flange plate corrosion




**RF = 0.50** (Inventory)
***RF = 2.90*** *(Operating)*

Element will need to be reinforced to **Add Capacity**

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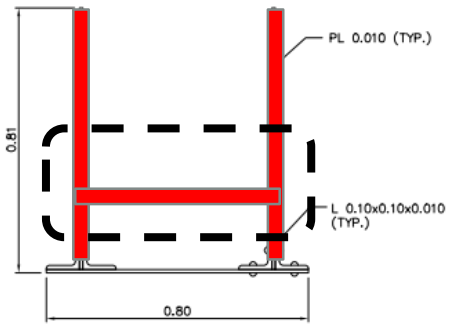
# REHABILITATION CONSIDERATIONS

- **Bottom Chords** (Tension Element) – HS-15

- Additional plate added for Capacity
- Concrete added to provide drainage slopes

**RF = 3.84** (Inventory)
***RF = 7.46*** *(Operating)*

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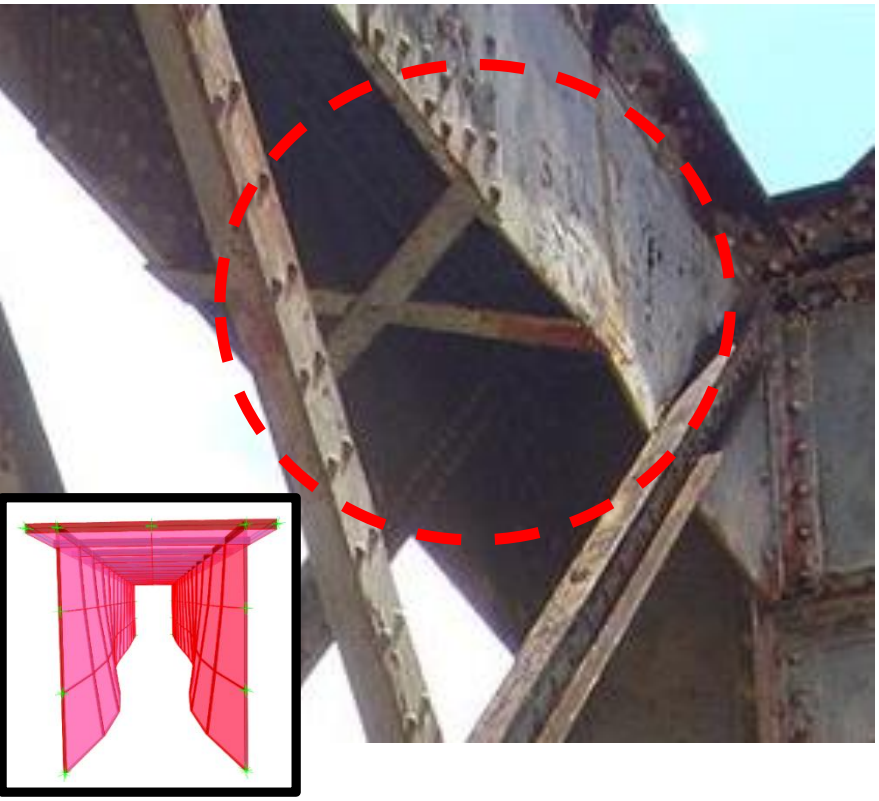
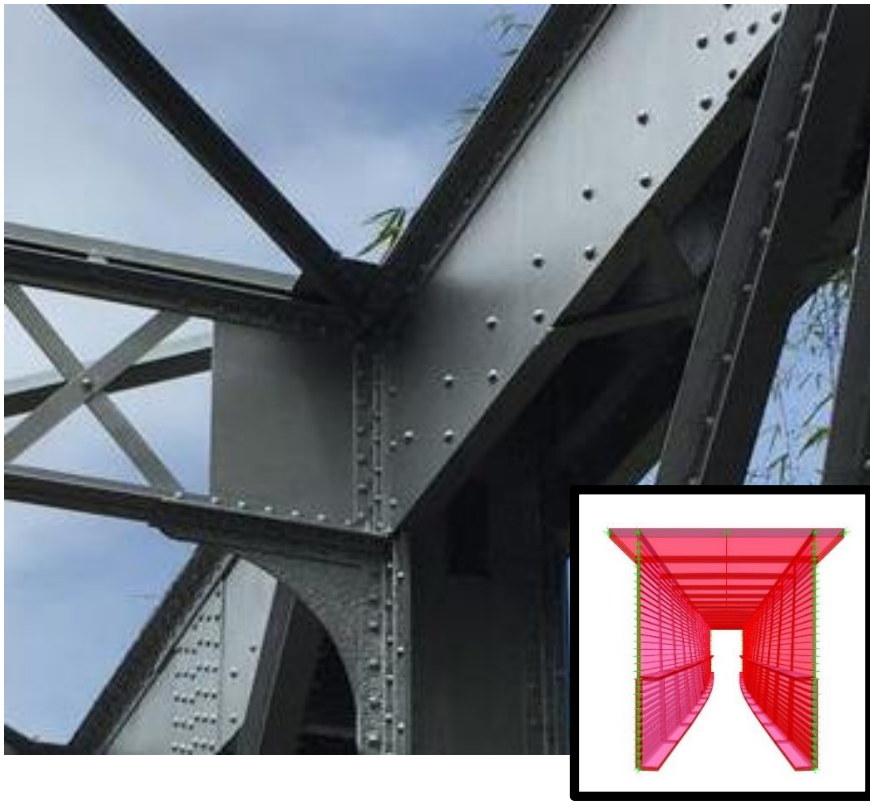
# REHABILITATION CONSIDERATIONS

❑ **Top Chords** (Compression Element) – HS-15



- Top chord flange buckling
- Loss of section observed

**RF = 0.57** (Inventory)
***RF = 0.59*** *(Operating)*



- Added new C12x30 channels each side for stiffness

**RF = 7.50** (Inventory)
***RF = 6.94*** *(Operating)*

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# REHABILITATION CONSIDERATIONS

❑ **East & West Truss Verticals** – HS-15

- Severe Corrosion at bottom chord
- Missing rivets
- Deformation/bends at column flanges

**RF = 7.07** (Inventory)
***RF = 9.92*** *(Operating)*

Element will need to be
**Repair/Rehabilitated**

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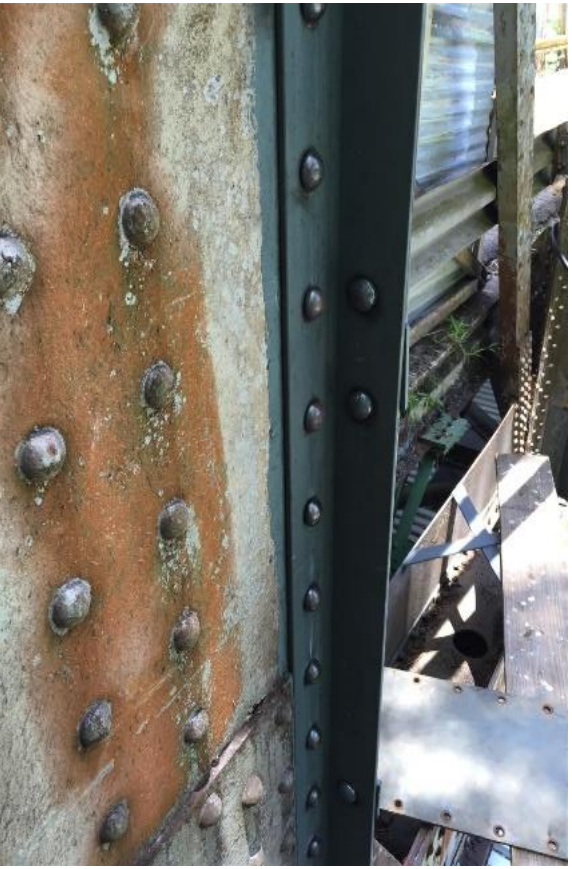
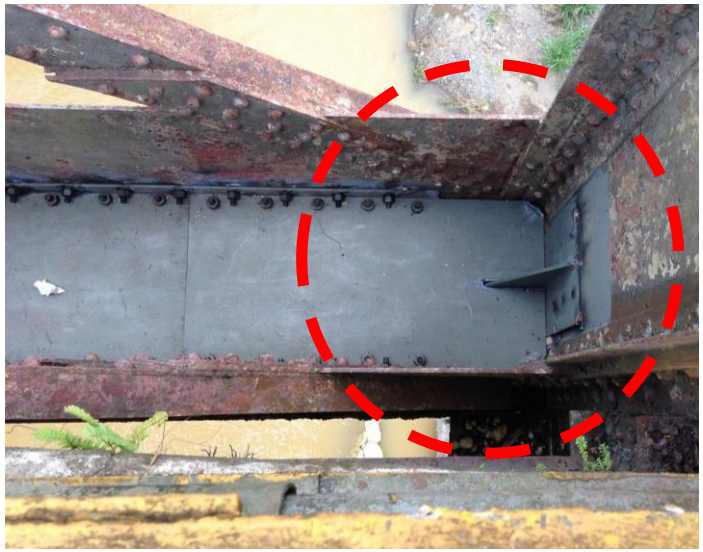
# REHABILITATION CONSIDERATIONS

❑ **East & West Truss Vertical** – HS-15





- Added new angles/plate bars & rivets replacement
- Added new transfer plates for lateral load transfer

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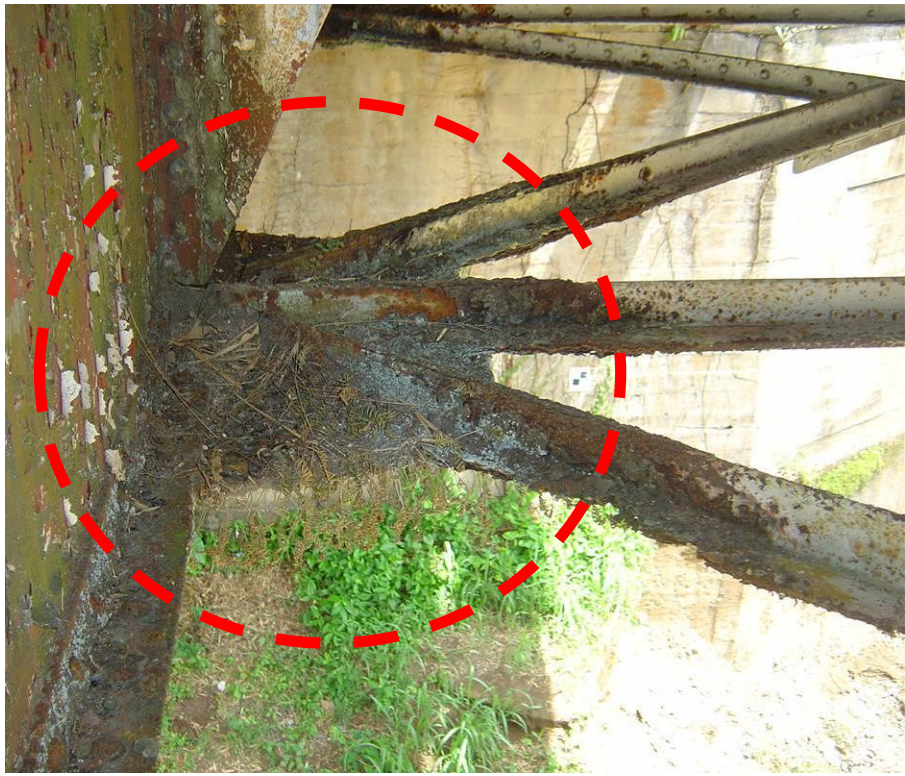
# REHABILITATION CONSIDERATIONS

## ❑ Horizontal Bottom Truss Diagonals



- Bottom truss with severe corrosion at angles and gusset plates
- Areas with significant loss of section
- Connection to column is compromised

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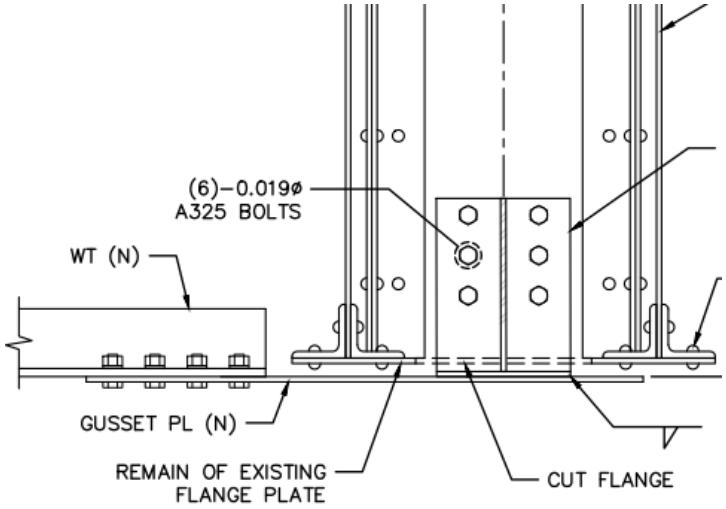
# REHABILITATION CONSIDERATIONS

## ❑ Horizontal Bottom Truss Diagonals




- Steel angle replacement
- Steel plate connection to column replaced

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# REHABILITATION CONSIDERATIONS

## ❑ Horizontal Top Truss Diagonals

- Top truss with severe corrosion at angles & gusset plates
- Local areas with significant loss of section

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# REHABILITATION CONSIDERATIONS

## ❑ Cross-Beams & Horizontal Truss Diagonals

- Replace top cross-beam
- Replace horizontal truss diagonals

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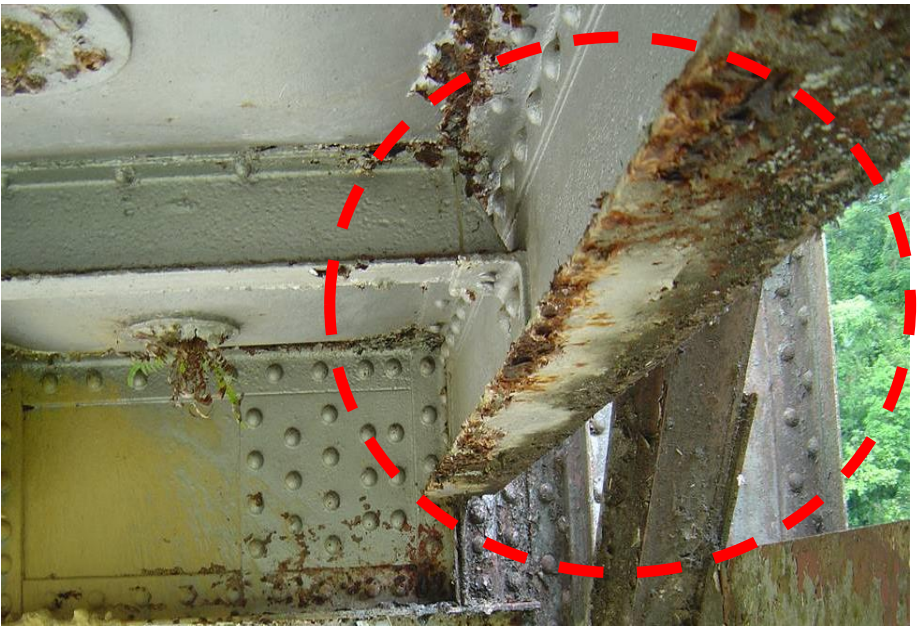
# REHABILITATION CONSIDERATIONS

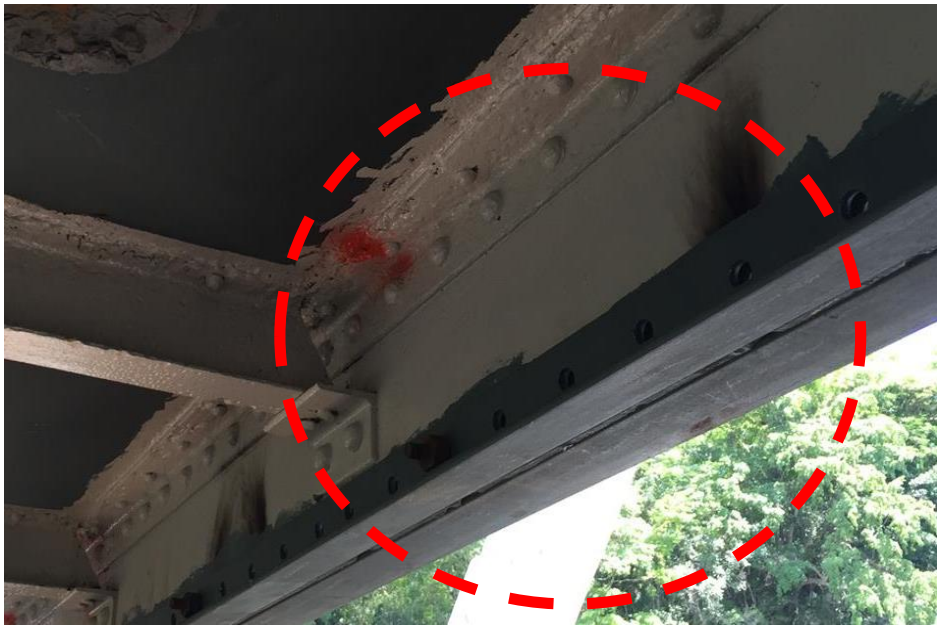
- Horizontal Top Truss Diagonals

# REHABILITATION CONSIDERATIONS

❑ **Deck & Supporting Beam -** (HS-15)



- Moderate underside corrosion
- Local areas with significant loss of section



- Replacement of angles

**RF = 1.40** (Inventory)
***RF = 2.30*** *(Operating)*

Element will need to be
**Repair/Rehabilitated**

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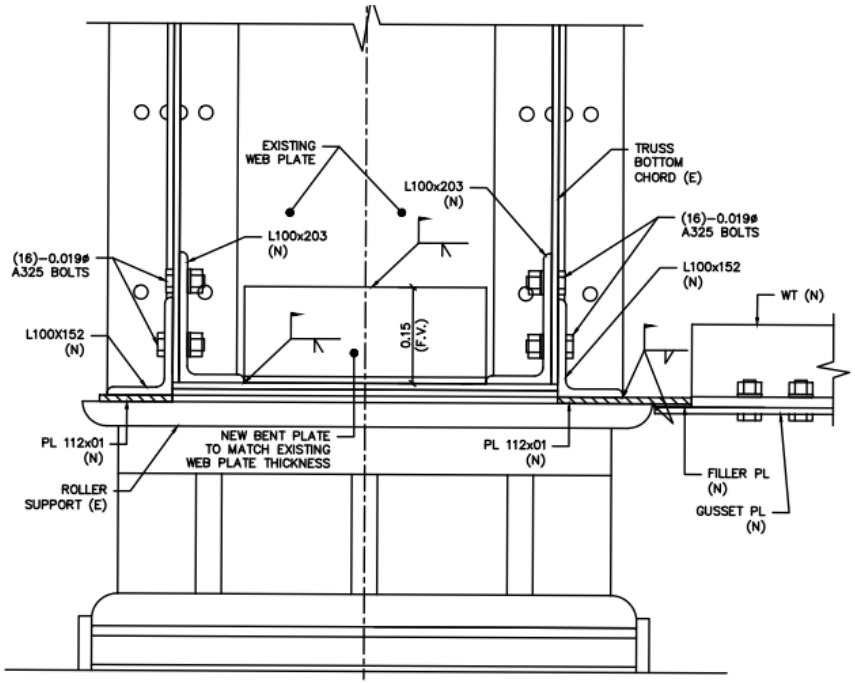
# REHABILITATION CONSIDERATIONS

## ❑ Abutment




- Moderate corrosion at beam connection to roller
- Free sliding inhibited due to rust

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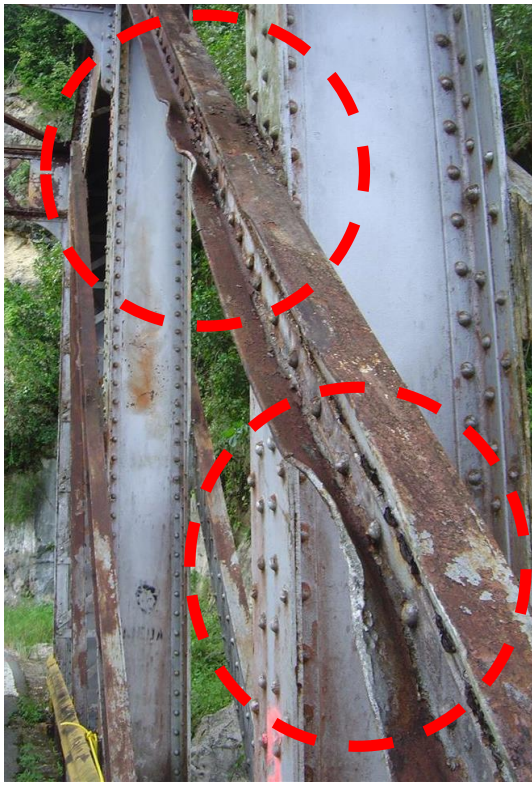
# REHABILITATION CONSIDERATIONS

❑ **East & West Truss Diagonals** - (HS-15)



- Flange deformation/bends
- Significant corrosion

**RF = 3.29** (Inventory)
***RF = 6.88*** *(Operating)*

Element will need to be
**Repair/Rehabilitated**

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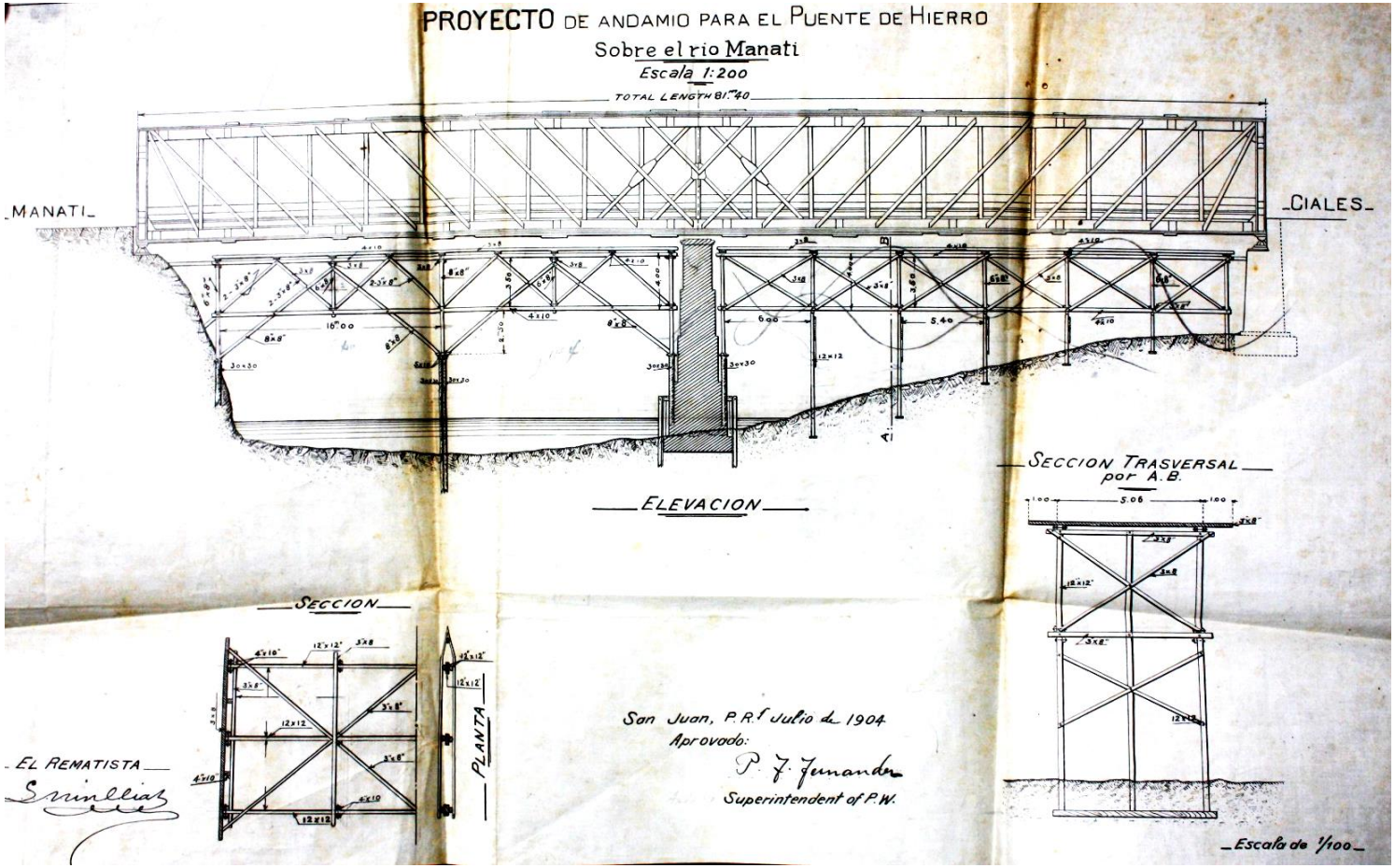
# REHABILITATION CONSIDERATIONS

- East & West Truss Diagonals




Let's do it the original way…

**...temporary support from below?**

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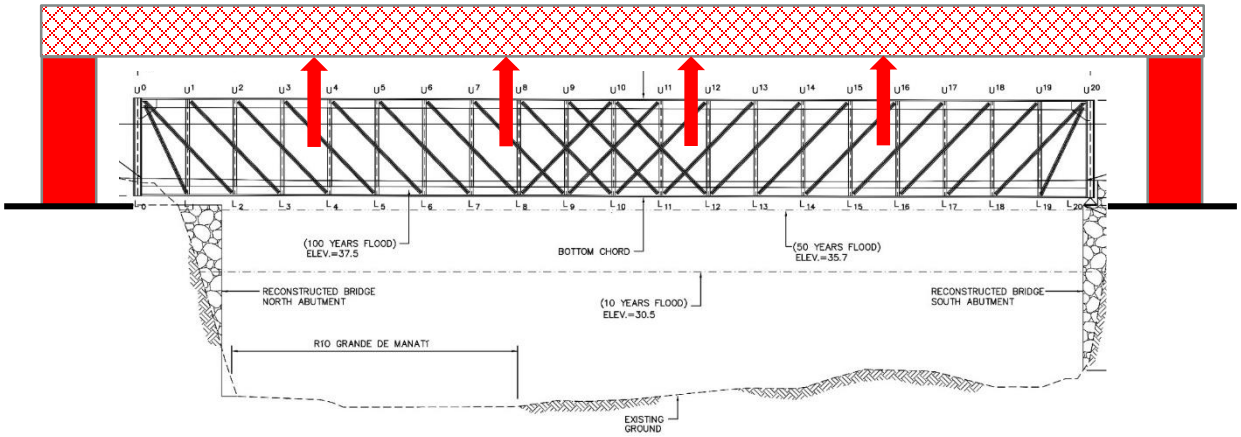
# REHABILITATION CONSIDERATIONS

- East & West Truss Diagonals




…construction gangway from above?

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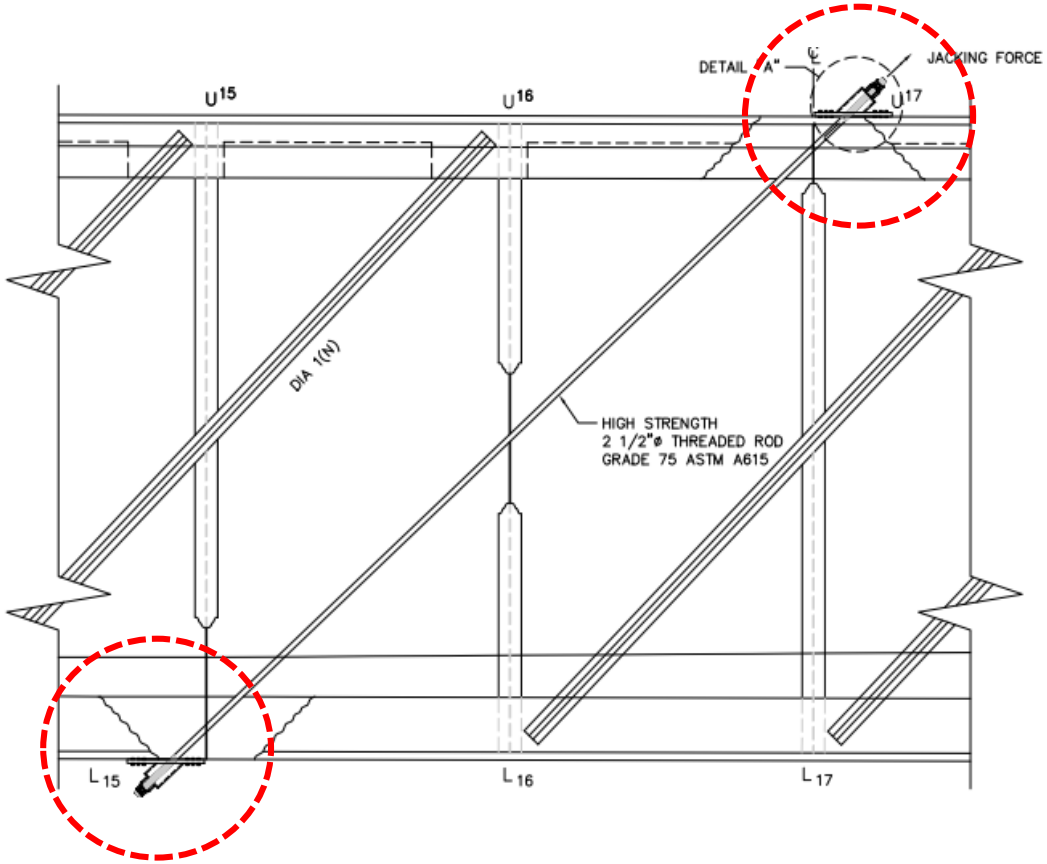
# REHABILITATION CONSIDERATIONS

## ❑ East & West Truss Diagonals

…how about a **temporary load transfer mechanism?**




**Dead-End Jacking Force System**

- Readily available equipment (Hydraulic jack, electric pump)
- Area accessibility

Forces will need to be determined with precision

- ✓ 3D State-of-the-Art modeling
- ✓ Knowledge of Const. Live Load

| | |
|---|---|
| U-11 - L-9 | 3.35 kips |
| U-13 - L-11 | 58.52 kips |
| U-17 - L-15 | 142.96 kips |
| U-19 - L-17 | 177.90 kips |
| U-20 - L-18 | 251.12 kips |

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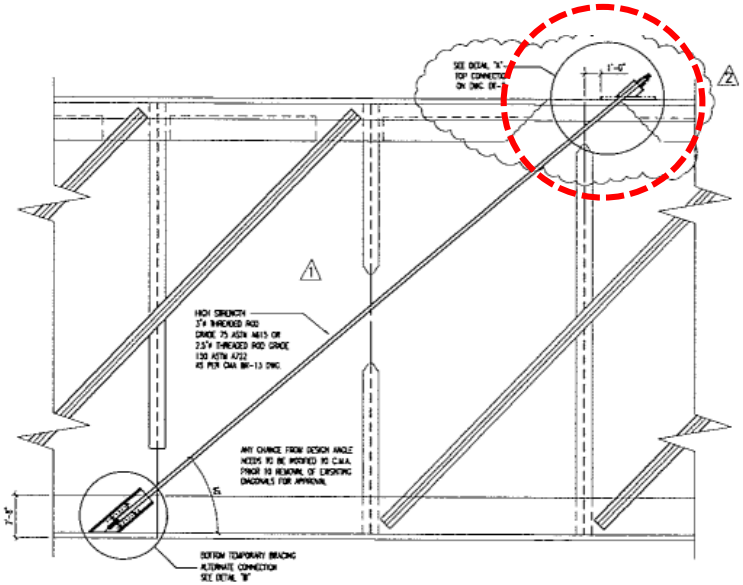
# REHABILITATION CONSIDERATIONS

## ❑ East & West Truss Diagonals



Top Chord **Active** End Jack

**Weight = 1400 lbs.**

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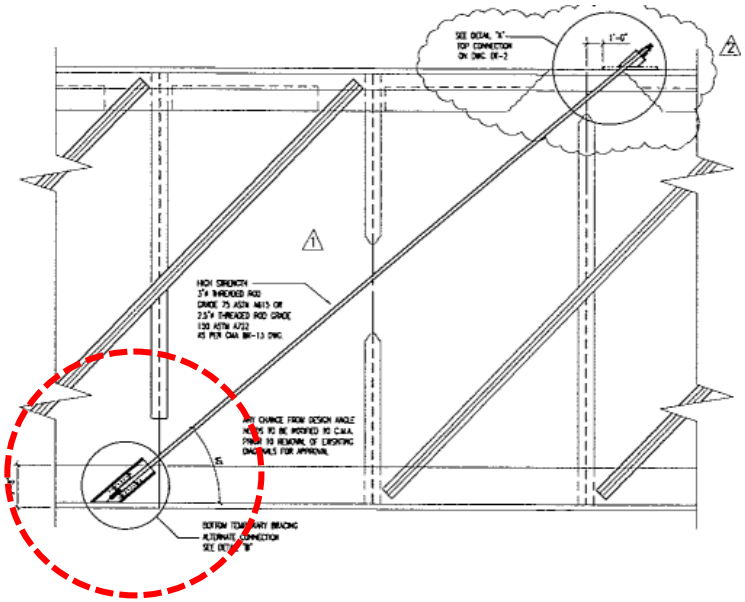
# REHABILITATION CONSIDERATIONS

- ❑ East & West Truss Diagonals

Bottom Chord
**Dead** End Jack

**Weight = 400 lbs.**



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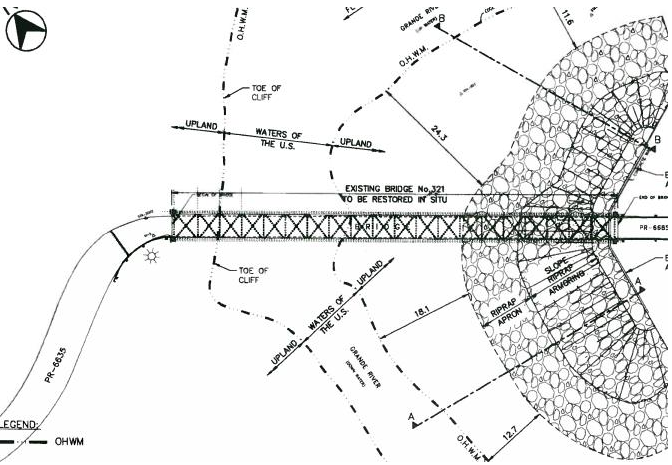
# REHABILITATION CONSIDERATIONS

- East & West Truss Diagonals

## REHABILITATION CONSIDERATIONS

# VIDEO

# REHABILITATION CONSIDERATIONS

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# REHABILITATION CONSIDERATIONS

# REHABILITATION CONSIDERATIONS

## ❑ Rehabilitation Schemes


- Take all superimposed dead weight off the bridge

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# REHABILITATION CONSIDERATIONS

## ❑ Rehabilitation Schemes

- **Limit maximum** platform dead load restricted to **10psf**
- **Limit maximum** construction load to **115psf**

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# REHABILITATION OF HISTORICAL STEEL BRIDGE NO. 321

## HIGHLIGHTS

| | | |
|---|---|---|
| **❑ Structural Steel** | | |
| ▪ Existing Steel | **613,000 lbs.** | |
| ▪ Replacement Steel | **122,500 lbs.** | (20% Existing Steel) |
| ▪ Added Steel (Capacity Increase) | **46,400 lbs.** | (8% Existing Steel) |
| **❑ Roadway** | | |
| ▪ Existing Pavement & Soil | **334,000 lbs.** | |
| ▪ New Conc. Slab | **417,000 lbs.** | (25% Increment) |
| **❑ Diagonal Bracings** | | |
| ▪ Bracing Replacement Execution Time | **16 days** | @ Initial stages |
| ▪ Bracing Replacement Execution Time | **5 days** | @ later stages |
| ▪ Steel Plates | **A36 (36ksi)** | |
| ▪ Tension Rod (DYWIDAG) | **2 ½" diam. Grade 150** | Safety Factor = 3.0 |
| ▪ Hydraulic Pump (ENERPAC) | **150 tons** | |
| **❑ Start / Expected Comp.** | **Oct. 2013 / Oct. 2017** | |
| **❑ Awarded Cost** | **3.3MM** | |
| **❑ Construction Cost** | **3.8MM** | |

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# HIGHLIGHTS

## ❑ Key Elements of Success:

- **Collaboration**
  - Between the Owner, Contractor, Inspection and Design Team
  - Proved to be effective in the execution and minimization of environmental risks.

- **Detailed execution strategy plan and protocols**
  - At selective demolition, material selection and rehabilitation work was critical

- **Fabricated materials on-site**

- **Proven execution methodology**
  - for potential rehabilitation work at other bridges with similar structural configurations.

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**Rehabilitation of Historical Steel Bridge No. 321** over Rio Grande de Manatí