Seismic Retrofit and Rehabilitation of the Million Dollar Bridge

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Million Dollar Bridge
Located near Cordova, AK

Span Layout (Existing)
Million Dollar Bridge

Million Dollar Bridge
Bridge History

◆ 1909-1910: Bridge was built by the Copper River and Northwestern Railway to serve the Bonanza copper mines
  - 1570' long Pratt truss
  - Spans are 400', 300', 450', & 400'

◆ 1938: Railway & mine closed

◆ 1958: Bridge was converted to a road bridge
  - New concrete deck
  - Injection of cracks in Piers 2 & 3

◆ 1964: Bridge was badly damaged in the Good Friday earthquake
  - Span 4 fell into the river
  - Pier 3 badly damaged
Bridge History

- 1973: Ramp installed from Pier 3 to Span 4
- 1975: Pier 3 strengthened with internal PT and a false bent placed under Span 4
- 1995: False bent destroyed in flood
- 1996: Pilasters added to strengthen Pier 3

Original Construction

- Built by the Katalla Corporation
  - For the Copper River and Northwestern Railway
  - From Cordova to the Kennecott/Bonanza copper mine
- Built in the winter of 1909-1910
  - Caisson for Pier 1 sunk in May, 1909
  - Span 4 completed June, 1910, thirteen months later
  - Built on falsework driven through the ice
  - Wind chill temperature frequently approached -60°F
- Cost $1,424,774
Sinking Caisson No. 1, May, 1909

Piers 1 and 3, August 12, 1909
Construction, February 11, 1910

Span 1, April 22, 1910
1964 Earthquake

1964 Earthquake Damage
1964 Earthquake Damage (Span 4)

1964 Earthquake Damage (Pier 3)
1964 Earthquake Damage

Goal of Project

- **Rehabilitation**
  - To prevent further degradation of bridge
  - Restore capacity to carry full legal live loads

- **Seismic retrofit**
  - Design for earthquake comparable to 1964
  - Prevent future collapse or irreparable damage

- **Preserve historic integrity of bridge**
Scope of Rehabilitation

- Raise Span 4 (Phase 1)
- Replace missing or damaged members (Phase 1)
- Restore spans to original or reasonable geometry (Phase 2)
- Other general rehabilitation measures (Phase 2)
  - Deck joints
  - Concrete

Scope of Seismic Retrofit

- Seismic Isolation of Superstructure (Phase 2)
- Strengthening of
  - Superstructure (Phase 1)
  - Piers (Phase 1 & 2)
  - Abutments (Phase 1 & 2)
  - Foundations (caissons) (Phase 2)
Span Layout (Retrofit)

Historic Design Criteria

- Bridge is on the National Register of Historic Places
  - On the basis of its original construction
- “The Secretary of the Interior’s Standards…”
  - Protect and maintain
  - Repair
  - Replace
  - …
Historic Issues

- Replacement of members in Spans 3 and 4
- Retrofit of Piers 1 & 2
  - With reinforced concrete jackets, or
  - With high-strength rods
- Replacement of Pier 3 with a new pier and foundation

Seismic Design Criteria

- Design to 475 year hazard
- Significant damage allowed
- Collapse not allowed
- Full-ductility structure
  - Clearly defined plastic mechanism
  - Inelastic behavior restricted to properly detailed piers, piles, etc.
Environmental Issues

- ADF&G Permit
- Temporary access roads & work pads
  - Provided an opening in the access road, to minimize blockage of the river
  - Remove each summer

Construction Site Factors

- Remoteness of the bridge from Cordova
- Remoteness of Cordova from major metropolitan centers
- High water in summer
- Cold weather and high winds in winter
- Access to north shore difficult for heavy equipment
Hydrologic Conditions

- **Copper River**
  - Currents reach 12 mph
  - Average discharge is 57,400 cubic feet / second
  - Transports a great deal of sediment
    - 1 gram / liter
    - 1,000,000 tons per day during peak flows

- **Water surface elevation varies greatly during summer**

- **River freezes in winter**
  - Ice is 2-3 feet thick on average

- **Icebergs are commonplace when the river is flowing**

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**Peak Yearly Discharge, 1950-1995**

![Graph showing peak yearly discharge from 1950 to 1995 with occurrences and probability distribution.]
Water Surface Elevation

[Bar chart showing water surface elevation with occurrences and probabilities]

Winter Conditions

[Image of snowy landscape]
Winter Conditions

Contractor Camp
Contractor Yard

Span 4 Lift and Temporary Support
Span 4 Lift

Span 4 Lift
Span 4 Lift

Span 4 Lift
Temporary Strengthening

Span 4 Lift
Span 4 Temporary Support

Span 3 Lift and Temporary Support
Span 3 Temporary Support

Span 4 Rehabilitation

New end post member
New strut member
New hanger member
New L14 Pin
New diagonal member
New bottom chord member
Structural Steel Fabrication

- Fabricate members per original shop drawings

- But
  - Use single, rather than multiple plates
  - Use modern shapes
  - Use bolts, rather than rivets

- Maintain external dimensions & appearance

- Bolt heads to outside

Tension Control Bolt
Span 4 Rehabilitation

Span 4 Rehabilitation
Span 4 Rehabilitation

Completed Span 4
Pier 3 Demolition and Replacement

Pier 3 Shafts
Pier 3 Shafts

Pier 3 Demolition
Pier 3 Demolition

Pier 3 Footing
Pier 3 Footing

New Pier 3
Conclusion of Phase 1

Phase 2

- Strengthen Piers 1 & 2
- Reposition spans
- Replace bearings with friction pendulum bearings
Pier 1 and 2 Retrofit

Transverse high strength rods
Longitudinal high strength rod, typ (not all shown)
### Truss Repositioning Plan

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### Friction Pendulum Bearing Retrofit
Bearing Retrofit

Friction Pendulum Bearings
Temporary Support
Temporary Strengthening

Friction Pendulum Bearings

- Mechanically simple
- Mathematically complex
Force-Deformation Relationship

- **One-dimensional behavior**
  \[ F = \frac{N}{R} D + \mu N \text{sgn} \ddot{D} \quad \text{where} \quad N = \text{vertical force} \]

- **Common simplification**
  \[ F = \frac{W}{R} D + \mu W \text{sgn} \ddot{D} \quad \text{where} \quad W = \text{dead weight} \]

Contact Surface Model

- Slider - Contact Surface
- Slider - Contact Point
- Dish - Contact Surface
- Solid Element
- Rigid Link, typ.
Period of Vibration Test

- Give the slider an initial velocity
  - Radius = 20 feet
  - Coefficient of friction = 1%

Period of Vibration Result

\[ T = 2\pi \sqrt{\frac{R}{g}} = 2\pi \sqrt{\frac{20\text{ ft}}{32.2\text{ ft/sec}^2}} = 4.96\text{ sec} \]
Friction Test

- Analyze slider on a flat, frictional surface
- Apply both horizontal and vertical motions

Motions

Horizontal Motion

Vertical Motion

μ = 0.05
Comparison

Model Comparison
ADINA Model

Truss Database
New Pier 3

Friction Pendulum Bearings

Friction Pendulum Bearing Form
Ground Motion

475-year return period

Bearing Response

Video Clip

Friction Pendulum Bearings
Reduction of Superstructure Forces

Current Status

**Phase 1**
- Drive piles
- Lift Spans 3 & 4
- Replace structural steel
- Build new Pier 3 & footing
- Done!

**Phase 2**
- Reposition spans
- Replace bearings with friction pendulum bearings
- Strengthen Piers 1 & 2