Guidelines for the Seismic Retrofitting of Steel Truss Highway Bridges

Retrofit Measures, Approaches and Strategy

A Retrofit Measure is the physical modification of a component in a bridge for the purpose of correcting seismic deficiencies of components or of improving the seismic performance of the bridge.

Examples:
- Replacing lacing bars with perforated cover plates on a truss member to strengthen the member
- Replacing a truss bearing with a more robust bearing that can transmit seismic lateral loads to the substructure

Many retrofit measures may be employed in the seismic retrofit of a bridge.
Retrofit Measures, Approaches and Strategy

A Retrofit Approach is a method of improving the response of the bridge or correcting its seismic deficiencies.

Examples:
- Strengthening members
- Base Isolation

One or more retrofit approaches may be employed in the seismic retrofit of a bridge.

Retrofit Measures, Approaches and Strategy

A Retrofit Strategy is the overall plan for the seismic retrofit of a bridge
- The plan can employ more than one retrofit approach and several different retrofit measures

For Example, the Seismic Retrofit Strategy of the North Viaduct of the Golden Gate Bridge used eight different types of retrofit measures:
- Replacing expansion joints and restrainers
- Replacing the existing support towers with new towers,
- Replacing existing bearings with new isolation bearings
- Modification/strengthening of some connections and framings.

The Adopted Approach was:
- Use of isolation bearings to reduce the seismic input to the superstructure
  And some deficient members were also strengthened.
Retrofit Measures, Approaches and Strategy

**Retrofit Strategy**

- Enhance ductility
- Reduce inertial loading using RMDs
- Strengthening supports, members, connections
- Weight reduction of deck structures
- Improving superstructure redundancy
- Combination of above

**Constructability**

- Provide at least one feasible construction method
- Watch out for changed load path
- Be careful whether remove member(s) will cause buckling
Retrofit Measures, Approaches and Strategy

Do Nothing Strategy vs. Full Replacement Strategy

<table>
<thead>
<tr>
<th>Seismic Hazard Level</th>
<th>Service Life Category (SLC)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>SLC1 (ASL = 5-25 y)</td>
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<td></td>
<td>SLC2 (ASL = 26-50 y)</td>
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<td></td>
<td>SLC3 (ASL &gt; 50 y)</td>
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<td><strong>Lower Level Earthquake</strong></td>
<td><strong>PL3 (Full / ND)</strong></td>
</tr>
<tr>
<td><strong>Upper Level Earthquake</strong></td>
<td><strong>PL1 (Life / SD)</strong></td>
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<tr>
<td><strong>Site Hazard</strong></td>
<td><strong>PL1 (Life / SD)</strong></td>
</tr>
</tbody>
</table>

Retrofit Measures, Approaches and Strategy

![Flowchart Diagram]
Retrofit Measures, Approaches and Strategy

[Map of the United States with color-coded hazard levels]

Retrofit Measures, Approaches and Strategy

[Image of a bridge with a TYLin International logo]
Retrofit Measures, Approaches and Strategy

Truss members

General
- Add stiffeners to decrease slenderness – Drill holes - use A325 bolts
- Add cover plates to increase strength – Use bolts as above

Chords - Primary Members
- Usually built-up from rolled sections and plates or forged eyebars for all-tension members
- Resist longitudinal seismic forces as added tension or compression

Seismic Vulnerabilities
- Compression members – Non-ductile, buckling
- Eyebar members – No reserve capacity, non-ductile, buckling

Retrofit Measures, Approaches and Strategy

Truss members

Retrofit Measures
- Compression members – Increase buckling resistance
  • Add stiffeners, replace lacing bars or plates with thicker plates, A325
- Compression members – Increase strength
  • Add stiffeners, add plates, end connections, A325
- Tension Eyebars thrown into compression
  • Brace against compression buckling
- Tension Eyebars Increase strength
  • Replace with adequate section, strengthening shear locks
  • Isolation and / or damping
Connections

- General
  - Rivets were used from 1800s to about 1965 ±
  - High strength bolts, A325 and A490 (limited ductility?)
  - Field-welding rarely used, shop-welded members sometimes used
  - Connections for members with D/C ratios greater than 1 shall be strengthened to nominal capacity of 25 percent of member for both existing and new connections

- Seismic Vulnerabilities - Pinned Connections
  - Pins Usually OK, framing in members may fracture or buckle

- Seismic Vulnerabilities - Gusset Plates
  - Gusset plate edges: $l/t$ slenderness limits, stiffener $l/r$ limits
  - Stiffener Moment of Inertia Limits
Retrofit Measures, Approaches and Strategy

Deck System

- **General**
  - Reinforced concrete, steel grids, concrete-filled grids
  - Supported by longitudinal steel stringers spaced 4 to 8 feet and transversely by floor beams spaced at panel points 15 to 25 feet
  - Lightly fastened (if at all) to Steel Stringers and floor beams

- **Seismic vulnerabilities**
  - Fillets can fracture, concrete deck slabs can float freely, can crack, can be displaced, can collide with truss members, and can destroy deck joints
  - Concrete-filled grids float freely as a unit

- **Retrofit Measures**
  - Connect deck to floor beams and stringers with shear studs
  - Replace steel lateral bracing, replace deck with composites
  - Isolation and / or damping

Lateral Bracing System

- **General**
  - Primary longitudinal lateral load-resisting element
  - Carries lateral loads to portal frames, then to the bearings
  - Placed in plane of upper and lower chords (sometimes only one)
  - Usually in the form of cross frames or chevron frames

- **Seismic vulnerabilities**
  - Usually framed from non-ductile, slender members acting in tension only (elastic buckling)

- **Retrofit Measures**
  - Brace or strengthen members against buckling
  - Replace rivets with A325 bolts
Retrofit Measures, Approaches and Strategy
Portal Bracing System

General

- Primary members for portals placed at ends of through trusses, take compression loads from chords and lateral loads from lateral bracing system and carry them to support bearings
- Performs two structural functions:
  - Acts as a chord member in axial compression from chord loads
  - Acts as a flexure system from lateral bracing system loads
- Two-component framing system:
  - Main member usually a box section carrying compression
  - Cross bracing framing into chords carries shear from lateral bracing system
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Portal Bracing System

- Portal framing systems positioned internally in the truss and sloped to the support bearings perform only the one function of carrying shear from lateral bracing system

- Portal framing systems positioned internally in the truss and sloped to the support bearings are often lost to view by other truss members

- Portal framing systems positioned at truss ends are visually prominent – appearance is important
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Portal Bracing System

**Seismic Vulnerabilities**
- Designed for wind loads only
- Chord members can buckle and displace laterally
- Bracing members are usually non-ductile members that can buckle
- Inadequate connections

**Retrofit Measures**
- Replace rivets with A325 bolts
- Replace lattice bars with perforated plates
- Add section by bolting on plates or rolled sections (appearance?)
- Strengthen chord-to-floor beam connections
- Use isolation and / or damping
- Install energy dissipating frames in deck trusses
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Sway Frames

◆ General
  - Placed at panel points
  - Function to resist side-sway distortions
  - Warren trusses usually used for shallow frames for added head room
  - Chevron truss pattern for deeper trusses

◆ Seismic Vulnerabilities
  - Bracing members usually non-ductile members that can buckle
  - Inadequate connections

◆ Retrofit Measures
  - Brace or strengthen members against buckling
  - Replace rivets with A325 bolts
Concrete Pier Shafts, Cellular Steel Shafts & Steel Braced Towers

General
- Concrete pier shafts usually fixed to concrete foundations with spliced rebars
  - Designed for wind loads, lightly reinforced and confined, and thin concrete cover
- Occasionally Steel pier shafts and braced towers are usually fixed to concrete foundations with steel anchor bolts
  - On older bridges (pre 1960s), braced towers are usually used
  - On newer bridges, cellular steel shafts are generally used
  - Designed for wind loads

Seismic Vulnerabilities
- Concrete shafts non-ductile, lightly reinforced, subject to corrosion
  - Pre 1950s, low bond & 40 ksi yield rebars
  - Lap splices at base can pull out (bond lost from concrete cracking
  - Footing dowels can pull out (bond failure)
- Steel shafts and braced towers anchor bolts inadequate in number and embedment
  - Panels in steel shafts can buckle in shear or compression
  - Braced frame legs inadequate in compression
  - Braced frames bracing members can buckle or connection tear out in tension
Retrofit Measures, Approaches and Strategy

Concrete Pier Shafts, Cellular Steel Shafts & Steel Braced Towers

◆ Retrofit Measures
  - For concrete shafts, see *Bridge Retrofitting Manual*
  - For steel cellular shafts:
    - A325 bolt on steel stiffeners or plates for plate buckling
    - Add anchor bolts in new cored holes in footing
  - For braced steel towers:
    - A325 bolt on stiffeners or rolled sections on legs
    - Replace rivets with A325 bolts at end connections
    - Replace bracing members
    - Add anchor bolts in new cored holes in footing
    - Isolation and/or damping (RMD)
Retrofit Measures, Approaches and Strategy

Shear Locks

- **General**
  - Transfer lateral loads in the lateral bracing system from one truss to another or to support bearing system
  - As an example: transferring loads from the suspended span to the tips of the cantilever arms in a cantilever truss

- **Seismic Vulnerabilities**
  - Inadequate connections of shear lock to the structure
  - Shear locks too fragile to transfer loads
  - Inadequate internal clearance in shear lock for seismic movements

- **Retrofit Measures**
  - Rebuild or replace shear locks to function under seismic loads
Retrofit Measures, Approaches and Strategy

Support Bearings

◆ General
  - Older bearings are usually fabricated of structural steel
  - Designed as either a fixed bearing longitudinally or as a rolling bearing longitudinally to accommodate thermal movements
  - Designed to accommodate structural rotations

◆ Seismic vulnerabilities
  - Can be unstable and topple-over
  - Inadequate connection of truss-to-bearing or bearing-to-pier
  - Bearing inadequate to transmit seismic shear loads

◆ Retrofit Measures
  - Strengthen bearings and connections or replace all
Retrofit Measures, Approaches and Strategy

Expansion Joint Devices

◆ General
  - “Bridges” gaps between trusses and truss and abutment
  - Older bridges usually used finger joints, new bridges usually modular steel and rubber joints

◆ Seismic Vulnerabilities
  - Usually will be the most vulnerable element in the truss
  - Joints can displace and fracture

◆ Retrofit Measures
  - Do nothing as truss will not collapse
  - Replace with new 3-D proprietary joints
  - Replace with non-proprietary sacrificial joints
Retrofit Measures, Approaches and Strategy

Seismic Isolation (AND Damping)

- See Isolation Manual
- install RMD
Retrofit Measures, Approaches and Strategy
Cost Considerations

General
- Major consideration in seismic retrofitting
- Seismic retrofitting engineering and construction costs are many time higher than for new construction
- Life of retrofitted components need not exceed remaining life of the truss
- Consider replacement cost to retrofitting cost