Seismic Retrofit Philosophy & Process for Steel Truss Highway Bridges

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Contents

🔹 General

🔹 Seismic Classification of Truss Bridges
  − Seismically Classifying Truss Bridges
  − Classification of SC Truss Bridges
  − Identification of SC Truss Bridges

🔹 Seismic Performance Levels

🔹 Seismic Hazard Levels

🔹 Bridge Importance
Contents (cont’d)

Service Life Categories

Selection of Performance Levels

Seismic Retrofit Strategies

Seismic Retrofitting Design Process

General (cont’d)

Basis for Seismic Retrofit Philosophy

- Performance expectations per AASHTO Standard Specifications
  - Essentially elastic under small to moderate EQ loading
  - Realistic ground motion intensity
  - No-Collapse under strong shaking, inspectable damage

Performance expectations (for new designs)

- Minimize life hazard
- Low probability of collapse
- Function of Essential bridges maintained
- High NEP for ground motions
Components of Earthquake Hazard

❖ Hazard
  - Consequences of Physical Effects of Earthquakes
    • Ground Shaking
    • Landslides
    • Tsunamis

❖ Risk
  - Probability of loss of life & property, in a region, within a given time interval

❖ Vulnerability
  - Permissible damage (public policy, engineering, cost, ...)

NON-EXCEDANCE PROBABILITY OF MOTIONS

\( A_{\text{max}} \)
\( f_i \), \( \zeta \)

\( t_1 \), \( t_2 \)

PSD

\( \text{Time (sec)} \)

\( \text{NEP} \)
General (cont’d)

**Retrofit Philosophy Provisions**
- Performance acceptable by public (minimize life hazard)
- Uniformly applicable nationwide
- No restrictions on innovation

General (cont’d)

**Basis for Retrofit Concepts**
- Enhance ductility
- Reduce inertial loading using RMDs
- Strengthening supports, members, connections
- Weight reduction of deck structures
- Improving superstructure redundancy
- Combination of above
Seismically Classifying Truss Bridges

◆ Ordinary Bridge Categories *(Bridge Retrofitting Manual)*
  - Essential Bridges
    • Expected to maintain functionality after EQ
  - Standard Bridges
    • All other bridges

◆ Truss Bridge Classification
  - Seismically Complex (SC)
    • Essential bridges that happen to be truss bridges
    • Unusual truss bridges
  - Seismically Standard (SS)
    • All other trusses

Classification of SC Trusses

◆ SC Classification Criteria
  - Single truss span > 500 feet
  - Deck trusses or double-deck trusses
  - Multi-span w/ 7 spans or more
  - Series of spans w/ total length > 1,600 feet
  - Unusual geometry, mass or stiffness distribution, skew > 20 deg
  - Moveable trusses: swing, lift, or tilt open
Classification of SC Trusses

SC Classification Criteria (cont’d)

- Truss supported on tall / slender concrete piers
- Truss supported on braced steel towers
- Truss supported on unreinforced masonry
- Truss on concrete piers or steel braced towers with height variability of over 25%
- Historic

Classification of SC Trusses (cont’d)

SC Truss Bridge Seismic Response Attributes

- High inertial forces due to mass of long-span
- Large lateral forces due to double deck or deck truss
- Support-specific seismic excitation
- P-Delta effects: slender columns and towers
- Large base shears in short columns of bridge frames
- Brittle unreinforced masonry
Identification of SC Truss Bridges

Seismic Performance Levels

<table>
<thead>
<tr>
<th>Performance Level</th>
<th>Damage Level</th>
</tr>
</thead>
</table>
| 1. **PL1: Life Safety** | • Significant damage after a large EQ  
• Function is significantly disrupted  
• Life safety assured  
• Bridge may need to be replaced |
| 2. **PL2: Operational** | • Minimal or repairable damage  
• Limited function for emergency vehicles  
• Repairable w/ or w/o traffic flow restrictions |
| 3. **PL3: Fully Operational** | • Negligible damage  
• Full function for all traffic  
• No repair required |
Seismic Hazard Levels

<table>
<thead>
<tr>
<th>Hazard Category</th>
<th>Hazard Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Level (LL)</strong></td>
<td>• Ground motions <em>reasonable</em> Probability of Exceedance (in lifetime)</td>
</tr>
<tr>
<td></td>
<td>• 100 year mean return period</td>
</tr>
<tr>
<td><strong>Upper Level (UL)</strong></td>
<td>• Ground motions <em>low</em> Probability of Exceedance (in lifetime)</td>
</tr>
<tr>
<td></td>
<td>• 1,000 year mean return period</td>
</tr>
<tr>
<td><strong>Site Hazard</strong></td>
<td>• Known active faults</td>
</tr>
<tr>
<td></td>
<td>• Unstable local geology</td>
</tr>
<tr>
<td></td>
<td>• Alignment crossing over fault</td>
</tr>
</tbody>
</table>

NEP and Mean Return Period

**Probability of exceedance in** $n$-**years**

\[
P(n) = 1 - (1-p_a)^n
\]

where: $p_a =$ Annual Frequency

\[
N = 1 / p_a = \text{Mean Return Period}
\]

<table>
<thead>
<tr>
<th>N</th>
<th>n</th>
<th>$p_a$</th>
<th>P(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>25</td>
<td>0.01</td>
<td>22%</td>
</tr>
<tr>
<td>1,000</td>
<td>25</td>
<td>0.001</td>
<td>2%</td>
</tr>
</tbody>
</table>
USGS/NEHRP Hazard Map
Horizontal PGA 90% NEP in 50 years

Bridge Importance

- Important Bridge
  - Essential Bridge (Bridge Retrofitting Manual)
    - SC Truss Bridge
### Service Life Categories

<table>
<thead>
<tr>
<th>Service Life Category (SLC)</th>
<th>Anticipated Service Life (ASL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Replacement scheduled within 5 years</td>
</tr>
<tr>
<td>SLC1</td>
<td>5 – 25 years</td>
</tr>
<tr>
<td>SLC2</td>
<td>26 – 50 years</td>
</tr>
<tr>
<td>SLC3</td>
<td>&gt; 50 years</td>
</tr>
</tbody>
</table>

### Selection of Performance Levels

<table>
<thead>
<tr>
<th>Seismic Hazard Level</th>
<th>Service Life Category (SLC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SLC1 (ASL = 5-25 y)</td>
</tr>
<tr>
<td>Lower Level (LL) Earthquake</td>
<td>PL3 (Full / ND)</td>
</tr>
<tr>
<td>Upper Level (UL) Earthquake</td>
<td>PL1 (Life / SD)</td>
</tr>
<tr>
<td>Site Hazard</td>
<td>PL1 (Life / SD)</td>
</tr>
</tbody>
</table>
10-Step Process

**SEISMIC RETROFITTING DESIGN PROCESS**

**STEP 1 (Chapter 3)**
Screen inventory of bridges for SC Trusses

**STEP 2**
Conduct a detailed structural inspection of the selected truss and a review of maintenance records

**STEP 3**
Develop a Condition Assessment Report

**10-Step Process (cont’d)**

**STEP 4 (Chapter 4)**
Perform an analytical evaluation of the existing bridge

**STEP 5 (Chapter 5)**
Develop conceptual seismic retrofit measures

**STEP 6 (Chapter 6)**
Evaluate alternative seismic retrofit approaches

**STEP 7 (Chapter 7)**
Evaluate constructability and cost of retrofit alternatives
10-Step Process (cont’d)

**STEP 8**
Conduct retrofit strategy meetings & Peer Review process

**STEP 9**
Document retrofit strategy selection process

**STEP 10**
Prepare construction Plans, Specifications, & Estimates