International Bridge Conference 2006  
MCEER-Seismic Design and Retrofit of Bridges  
“Recommended AASHTO LRFD Guidelines for the Seismic Design of New Highway Bridges”  
(NCHRP 20-7/Task 193)

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Tuesday, June 13, 2006

Presentation Topics

♦ Background leading up to the work completed to date on the Guidelines  
♦ Excerpts selected from the Guidelines  
♦ Planned AASHTO T-3 Committee activities for adoption in 2007 as a Guideline  
♦ Current status  
♦ Planned activities post-adoption  
♦ Observations  
♦ Conclusions
Stakeholders Table

<table>
<thead>
<tr>
<th>IAI Team (as needed)</th>
<th>T-3 Working Group</th>
<th>Technical Review Panel (to be invited)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roy Imbsen, IAI</td>
<td>Rick Land, CA Chair</td>
<td>George Lee, MCEER, Chair</td>
</tr>
<tr>
<td>Roger Borcherdt, USGS</td>
<td>Harry Capers, NJ, Co-chair</td>
<td>Rick Land, T-3 Chair</td>
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<tr>
<td>Po Lam, EMI</td>
<td>Ralph Anderson, IL</td>
<td>Geoff Martin, MCEER</td>
</tr>
<tr>
<td>E. V. Leyendecker, USGS</td>
<td>Jerry Weigel, WA</td>
<td>Joe Penzien, HSRC, EQ V-team</td>
</tr>
<tr>
<td>Lee Marsh, Berger/Abam</td>
<td>Ed Wasserman, TN</td>
<td>John Kulicki, HSRC</td>
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<tr>
<td>Randy Cannon, formerlySCDOT</td>
<td>Paul Liles, GA</td>
<td>Les Youd, BYU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Joe Wang, Parsons, EQ V-team</td>
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<tr>
<td></td>
<td></td>
<td>Lucero Mesa, SCDOT V-team</td>
</tr>
</tbody>
</table>

Current T-3 Working Group

- Rick Land, CA (Past chair)
- Harry Capers, NJ (Co-chair)
- Richard Pratt, AK (Current chair)
- Ralph Anderson, IL
- Jerry Weigel, WA
- Ed Wasserman, TN
- Paul Liles, GA
- Kevin Thompson, CA
Overall T-3 Project Objectives

♦ Assist T-3 Committee in developing a LRFD Seismic Design Specification using available specifications and current research findings
♦ Develop a specification that is user friendly and implemental into production design
♦ Complete six tasks specifically defined by the AASHTO T-3 Committee, which were based on the NCHRP 12-49 review comments

Background-Task 6 Report

♦ Review Reference Documents
♦ Finalize Seismic Hazard Level
♦ Expand the Extent of the No-Analysis Zone
♦ Select the Most Appropriate Design Procedure for Steel
♦ Recommend Liquefaction Design Procedure
Table of Contents

♦ 1. Introduction
♦ 2. Symbols and Definitions
♦ 3. General Requirements
♦ 4. Analysis and Design Requirements
♦ 5. Analytical Models and Procedures
♦ 6. Foundation and Abutment Design Requirements
♦ 7. Structural Steel Components
♦ 8. Reinforced Concrete Components

Appendices

♦ Appendix A – Acceleration Time Histories
♦ Appendix B – Provisions for Site Characterizations
♦ Appendix C – Guideline for Modeling of Footings
♦ Appendix D – Provisions for Collateral Seismic Hazards
♦ Appendix E – Liquefaction Effects and Associated Hazards
♦ Appendix F – Load and Resistance Factor Design for Single-Angle Members
Table of Contents

♦ 1. Introduction
♦ 2. Symbols and Definitions
♦ 3. General Requirements
♦ 4. Analysis and Design Requirements
♦ 5. Analytical Models and Procedures
♦ 6. Foundation and Abutment Design Requirements
♦ 7. Structural Steel Components
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LRFD Guidelines(1.1)-Background

Task 2 - Seismic Hazard Level

Recommended approach to addressing the seismic hazard:

♦ Design against the Effects Ground Shaking Hazard
♦ Selection of a Return Period for Design less than 2500 Years
♦ Inclusion of the USGS 2002 Update of the National Seismic Hazard Maps
♦ Effects of Near Field and Fault Rupture to be addressed in a following Task
♦ Displacement Based Approach with both Design Spectral Acceleration and corresponding Displacement Spectra provided
♦ Hazard Map under the control of AASHTO with each State having the option to Modify or Update their own State Hazard using the most recent Seismological Studies
LRFD Guidelines (1.1)-Background
Task 2-Seismic Hazard

Seismic Hazard Practice can be best illustrated in looking at the following sources:

♦ NEHRP 1997 Seismic Hazard Practice
♦ Caltrans Seismic Hazard Practice
♦ NYCDOT and NYSDOT Seismic Hazard Practice
♦ NCHRP 12-49 Seismic Hazard Practice
♦ SCDOT Seismic Hazard Practice
♦ Site-Specific Hazard Analyses Conducted for Critical Bridges

LRFD Guidelines(1.1)-Background
Seismic Hazard for Normal Bridges

♦ Selection of a lower return period for Design is made such that Collapse Prevention is not compromised when considering large historical earthquakes.
♦ A reduction can be achieved by taking advantage of sources of conservatism not explicitly taken into account in current design procedures.
♦ The sources of conservatism are becoming more obvious based on recent findings from both observations of earthquake damage and experimental data.
LRFD Guidelines (1.1) - Background

Task 2 - Sources of Conservatism

<table>
<thead>
<tr>
<th>Source of Conservatism</th>
<th>Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational vs. Experimental Displacement Capacity of Components</td>
<td>1.3</td>
</tr>
<tr>
<td>Effective Damping</td>
<td>1.2 to 1.5</td>
</tr>
<tr>
<td>Dynamic Effect (i.e., strain rate effect)</td>
<td>1.2</td>
</tr>
<tr>
<td>Pushover Techniques Governed by First Plastic Hinge to Reach Ultimate Capacity</td>
<td>1.2 to 1.5</td>
</tr>
<tr>
<td>Out of Phase Displacement at Hinge Seat Addressed in Task 3</td>
<td></td>
</tr>
</tbody>
</table>

Idealized Load – Deflection Curve

Considered in Design
LRFD Guidelines (1.1)-Background
Seismic Hazard-Normal Bridges

Two distinctly different aspects of the design process need to be provided:

- An appropriate method to design adequate seat width(s) considering out of phase motion.
- An appropriate method to design the ductile substructure components without undue conservatism.

These two aspects are embedded with different levels of conservatism that need to be calibrated against the single level of hazard considered in the design process.
LRFD Guidelines(1.1)-Background
Task 3-Expand the No-Analysis Zone

♦ At a minimum, maintain the number of bridges under the “Seismic Demand Analysis” by comparing Proposed Guidelines to AASHTO Division I-A.

♦ Develop implicit procedures that can be used reduce the number of bridges where “Seismic Capacity Analysis” needs to be performed. This objective is accomplished by identifying a threshold where an implicit procedures can be used (Drift Criteria, Column Shear Criteria).

♦ Identify threshold where “Capacity Design” shall be used. This objective is achieved in conjunction with the “Seismic Capacity Analysis” requirements.

Range of Applicability of “Seismic Demand Analysis”
Range of Applicability of “Seismic Demand Analysis”

Region of Required for the Target Design Hazard, Site Class B

Region of Required for the Target Design Hazard, Site Class D
Region of Required Maximum for the Target Design Hazard, Site Class B

Region of Required Maximum for the Target Design Hazard, Site Class D
LRFD Guidelines(1.1)-Backround
Task 3-Proposed Range of Analysis

Based on Spectral Acceleration at 1.0 second period, $S_{D1}$, considering:

- $S_{D1}$ is a good representation of the difference in regional demands (i.e., $S_{D1}$ is considerably lower in the Eastern U.S.)
- The choice of high frequency spectral indicator as recommended in NCHRP 12-49 penalizes the Eastern U.S. for no credible justification considering that damage to bridges is associated with low frequency range of bridge period.
- The choice of $S_{D1}$ fits well with the adopted displacement approach for bridges considering that ductility is taken into account when assessing the capacity.

\[
S_{a0} = F_a S
\]
\[
S_{a1} = F_{a1} S
\]

$S_f$ = Rock spectral acceleration @ $T=1.0$ Sec
$F_{a1}$ = Soil Amplification Factor

Site Class Spectrum
Rock Spectrum

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24
The objective of this task is to select the most appropriate design procedure (i.e., displacement or force based) for a bridge with a steel superstructure and to examine both the NCHRP 12-49 and SCDOT using a trial design.

Two design examples were selected from the work done by Itani and Sedarat in 2000 entitled “Seismic Analysis and Design of the AISI LRFD Design Examples of Steel Highway Bridges”.

This effort was a continuation to the 1996 AISI published Vol. II Chapter 1B of the Highway Structures, Design Handbook, “Four LRFD Design Examples of Steel Highway Bridges”.
The main two purposes in examining this report are to:

♦ Identify the performance objective for seismic design of steel girder structures.
♦ Identify the specifications utilized for proper completion of the design process.

Example 1 is a Simple-Span Composite I Girder. The design process shown in the report includes:

♦ Calculation of lateral load at the end cross-frame.
♦ The design of the top strut.
♦ The design of the diagonal member.
♦ The design of the bottom strut.
Bridge Cross Section of Example 1

Example 1 Girder Layout
Example 1 (con’t)

Two important aspects of the design process are identified:

♦ The end cross-frame is designed for the full seismic force with no reduction of this force assuming a restrained condition of the bridge (i.e., shear keys capable of sustaining the full seismic force).
♦ A single angle bracing is used for the diagonal member of the end-cross-frame. As this practice is typical and favored for ease of construction, the design process for a single angle bracing needs to be referenced or included for clarity of use by the bridge engineer.
♦ AISC has a stand alone document on “LRFD Design Specification for Single-Angle Members” that can be included or referenced in the Specifications.

Example 2 is a Two-Span Cont. Composite I Girder. The design process shown in the report includes:

♦ Calculation of the lateral load at the bent cross-frame.
♦ The design of the plate girder connections to the R/C Deck.
♦ Design of the top strut.
♦ Design of the diagonal member.
♦ Design of the bottom strut.
♦ Calculation of superstructure lateral capacity.
Elevation Details of Example 2
Example 2 (con’t)

Three important aspects of the design process are identified:

♦ The bent cross-frame is designed to ensure column hinging mechanism assuming a restrained condition of the superstructure to the bent.
♦ The load path from the deck to the girders or the top strut is checked.
♦ Double angles with stitches are used for the top strut and the diagonal member due to the higher seismic demand on this bridge location in seismic zone 4.
♦ AISC LRFD Specifications Chapter E applies to compact and non-compact prismatic members subject to axial compression through the centroidal axis. The design process for members with stitches is also included.

LRFD Guidelines(1.1)-Background; Task 4-Load Path and Performance Criteria

♦ Specifications regarding the load path for a slab-on-girder bridge are examined using SCDOT and NCHRP 12-49 documents.
♦ SCDOT specifications has a general section on load path while NCHRP 12-49 has a section only on “Ductile End-Diaphragm in Slab-on-Girder Bridge.”
The AISC provisions limit the force reduction factor $R$ to 3 for ordinary bracing that is a part of a seismic resisting system not satisfying the special seismic provisions.

It is proposed to adopt the AISC limit for an $R$ reduction factor of 3.

Special end-diaphragm addressed in NCHRP 12-49 will be considered for bracing system with a reduction factor, $R$, greater than 3 as stipulated in the AISC provisions.

- Adopt AISC LRFD Specifications for design of single angle members and members with stitches.
- Allow for three types of a bridge structural system as adopted in SCDOT Specifications and stipulated in NCHRP 12-49.
- Adopt a force reduction factor of 3 for design of normal end cross-frame (No Special Detailing).
- Adopt NCHRP 12-49 for design of “Ductile End-Diaphragm” where a force reduction factor greater than 3 is desired.
LRFD Guidelines(1.1)-Background
Task 5 Recommend Liquefaction Design Procedure

The objective of this task is to review applicable recent research and information currently available on liquefaction and to recommend design procedures consistent with the “Displacement Approach” adopted for the proposed specifications.

LRFD Guidelines(1.1)-Proposed Liquefaction Design Requirements

The following list highlights the main proposed liquefaction design requirements:

- Liquefaction design requirements are applicable to SPC “D”.
- Liquefaction design requirements are dependent on the mean magnitude for the 5% PE in 50-year event and the normalized Standard Penetration Test (SPT) blow count \([N_{1,60}]\).
- If liquefaction occurs, then the bridge shall be designed and analyzed for the Liquefied and Non-Liquefied configurations.

Design requirements for lateral flow are still debatable and have not reached a consensus worth comfortably adopting.
LRFD Guidelines (1.3) Flow Chart A

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LRFD Guidelines (1.3)
Flow Chart B

Table of Contents

- 1. Introduction
- 2. Symbols and Definitions
- 3. General Requirements
- 4. Analysis and Design Requirements
- 5. Analytical Models and Procedures
- 6. Foundation and Abutment Design Requirements
- 7. Structural Steel Components
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LRFD Guidelines (3.1)-Applicability

- Design and Construction of New Bridges
- Bridges having Superstructures Consisting of:
  - Slab
  - Beam
  - Girder
  - Box Girder
- Spans less than 500 feet

LRFD Guidelines (3.2)-Performance Criteria

- One design level for life safety
- Seismic hazard level for 5% probability of exceedance in 50 years (i.e., 1000 year return period)
- Low probability of collapse
- May have significant damage and disruption to service
LRFD Guidelines (3.3) - Earthquake Resisting Systems (ERS)

- Required for SDC C and D
- Must be identifiable within the bridge system
- Shall provide a reliable and uninterrupted load path
- Shall have energy dissipation and/or restraint to control seismically induced displacements
- Composed of acceptable Earthquake Resisting Elements (ERE)

Permissible Earthquake Resisting Systems (ERS)

- Abutment resistance not required as part of ERS
  - Plastic hinges in acceptable locations or elastic design of columns.
  - Knuckle-off saddles permissible

- Abutment not required in ERS, breakaway abutments permissible
  - Plastic hinges in acceptable locations or elastic design of columns.

- Abutment resistance required, but abutment
  - Allowable resistance not to exceed 3% in 75-year earthquake elastically
  - and resistant to seismic forces in longitudinal direction is less than 0.30 x
    - prescriptive value given in 7.5.2
LRFD Guidelines (3.3)

Permissible Earthquake Resisting Elements

Permissible Earthquake Resisting Elements that Require Owner's Approval
LRFD Guidelines (3.4) - Seismic Hazard

- 5% Probability of Exceedence in 50 Years
- AASHTO-USGS Technical Assistance Agreement to:
  - Provide paper maps
  - Develop ground motion software
- Hazard maps for 50 States and Puerto Rico
  - Conterminous 48 States-USGS 2002 maps
  - Hawaii-USGS 1998 maps
  - Puerto Rico-USGS 2003 maps
  - Alaska-USGS 2006 maps
- Maps for Spectral Accelerations Site Class B
  - Short period (0.2 sec.)
  - Long period (1.0 sec.)
Figure 3.4.1-1
Design Response Spectrum, Constructed Using Two-Point Method

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LRFD Guidelines(3.5)-SDC

Range of Applicable of Analysis

Four categories SDC A, B, C and D encompassing requirements for:

- Seismic Demand Analysis requirement
- Seismic Capacity Analysis requirement
- Capacity Design requirement
- Level of seismic detailing requirement including four tiers corresponding to SDC A, B, C and D
- Earthquake Resistant System
### Table 3-1: Seismic Design Categories

<table>
<thead>
<tr>
<th>Value of $S_{za}$</th>
<th>Seismic Design Category (SDC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{za} &lt; 0.15g$</td>
<td>A</td>
</tr>
<tr>
<td>$0.15g \leq S_{za} &lt; 0.30g$</td>
<td>B</td>
</tr>
<tr>
<td>$0.30g \leq S_{za} &lt; 0.50g$</td>
<td>C</td>
</tr>
<tr>
<td>$0.50g \leq S_{za}$</td>
<td>D</td>
</tr>
</tbody>
</table>

**LRFD Guidelines (3.5)**

**Seismic Design Category (SDC)**

- SDC "A":
  - Yes: Complete
  - No

- SDC "B":
  - Yes:
    - Demand Analysis: Implicit Capacity
    - If 1% <= $\%_{cr}$, Yes
    - Tier III: Designing
    - Complete
  - No

- SDC "C":
  - Yes:
    - Demand Analysis: Implicit Capacity
    - If 1% <= $\%_{cr}$, Yes
    - Capacity Design
    - Yes: Tier II Designing
    - Complete
  - No

- SDC "D":
  - Yes:
    - Demand Analysis: Pushover Capacity Analysis
    - If 1% <= $\%_{cr}$, Yes
    - Capacity Design
    - Yes: Tier II Designing
    - Complete
  - No

*International Bridge Conference 2006  Roy Imbsen 63*
Table of Contents

- 1. Introduction
- 2. Symbols and Definitions
- 3. General Requirements
- 4. Analysis and Design Requirements
- 5. Analytical Models and Procedures
- 6. Foundation and Abutment Design Requirements
- 7. Structural Steel Components
- 8. Reinforced Concrete Components
LRFD Guidelines (1.3)
Flow Chart C

LRFD Guidelines (1.3)
Flow Chart C (cont.)
LRFD Guidelines (1.3) Flow Chart D

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### LRFD Guidelines (4.2) - Analysis Procedures to Determine Seismic Demands

<table>
<thead>
<tr>
<th>Seismic Design Category</th>
<th>Regular Bridges with 2 through 6 Spans</th>
<th>Not Regular Bridges with 2 or more Spans</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Not required</td>
<td>Not required</td>
</tr>
<tr>
<td>B, C, or D</td>
<td>Use Procedure 1 or 2</td>
<td>Use Procedure 2</td>
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<table>
<thead>
<tr>
<th>Procedure Number</th>
<th>Description</th>
<th>Section</th>
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<tbody>
<tr>
<td>1</td>
<td>Equivalent Static</td>
<td>5.4.2</td>
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<tr>
<td>2</td>
<td>Multimodal Spectral</td>
<td>5.4.3</td>
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<td>3</td>
<td>Non-linear Time History</td>
<td>5.4.4</td>
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### LRFD Guidelines (4.8.3) Drift Capacity for SDC B and C

<table>
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<tr>
<th>Fb/L</th>
<th>Yield (C1)</th>
<th>Spalling (C2)</th>
<th>Ductility 4 (C3)</th>
<th>Experimental (C4)</th>
<th>SPC B (C5)</th>
<th>SPC C (C6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td></td>
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<td></td>
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</tbody>
</table>
End of Test

Essentially Elastic

Moderate Damage
LRFD Guidelines (4.11) - Capacity Design Requirement for SDC C and D
Longitudinal Response of a Concrete Bridge

Additional strength to be provided by the bridge deck.

\[ M_{po} \]

\[ L_r \]

\[ \kappa_p = \frac{2M_p}{L} \]

Plastic hinge zone

M_{po} = plastic overstrength moment

Transverse Response of a Concrete Bridge

\[ M_{fr} \]

\[ L_r \]

\[ \kappa_r = \frac{2M}{L} \]

Plastic hinge zone

M_{po}
LRFD Guidelines (4.12)

Hinge Seat Requirement

The calculation for a hinge seat width involves four components:

♦ Minimum edge distance
♦ Other movement attributed to prestress shortening, creep, shrinkage, and thermal expansion or contraction
♦ Skew effect
♦ Relative hinge displacement

LRFD Guidelines (4.12) Relative Seismic Displacement vs. Period Ratio

♦ Deq for a target ductility of 2 shown as Curve 1
♦ Deq for a target ductility of 4 shown as Curve 2
♦ Caltrans SDC shown as Curve 3
♦ Relative hinge displacement based on (Trocholak is et. Al. 1997) shown as Curve 4
LRFD Guidelines (4.12)
Seat Width Requirements Compared to NCHRP 12-49 and DIV I-A (H=20ft)

LRFD Guidelines (4.12)
Seat Width Requirements Compared to NCHRP 12-49 and DIV I-A (H=30ft)
Table of Contents

♦ 1. Introduction
♦ 2. Symbols and Definitions
♦ 3. General Requirements
♦ 4. Analysis and Design Requirements
♦ 5. Analytical Models and Procedures
♦ 6. Foundation and Abutment Design Requirements
♦ 7. Structural Steel Components
♦ 8. Reinforced Concrete Components
LRFD Guidelines (1.3)
Flow Chart E

1. Determine Seismic Displacement Demands for SDC B, C, D
2. Define Bridges
   - Sections 1.1, Section 3
3. Select Analysis Procedure 1
   - Sections 4.2
4. Select Analysis Procedure 2
   - Sections 4.3
5. Select Analysis Procedure 3
   - Sections 4.4
6. Satisfy Modeling Requirements
   - Sections 5

Flow Chart E (cont.)

1. Satisfy Mathematical Modeling Requirements for Procedure 2
   - Sections 5
2. Abutment Modeling
   - Sections 2
3. Foundation Modeling
   - Sections 3
4. Effective Section Properties
   - Sections 6
5. Conduct Demand Analysis
   - Sections 1.2
6. Determine Displacement Demands Along Member Local Axis
7. Return to Combine Orthogonal Displacements
   - See Figure 1.3C

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LRFD Guidelines (5.2) - Abutments

Design Passive Pressure Zone

Characterization of Capacity and Stiffness

Seat Abutments

Diaphragm Abutments
# Table of Contents

- 1. Introduction
- 2. Symbols and Definitions
- 3. General Requirements
- 4. Analysis and Design Requirements
- 5. Analytical Models and Procedures
- 6. Foundation and Abutment Design Requirements
- 7. Structural Steel Components
- 8. Reinforced Concrete Components

**Flow Chart D (cont.)**

1. Satisfy Support Requirements
   - Seat Width
     - Sections 12
     - Shear Key
     - Sections 14
2. Foundation Investigation
   - Sections 2
3. Spread Footing Design
   - Sections 3
4. Pile Cap Foundation Design
   - Sections 4
5. Drilled Shaft
   - Sections 5
6. Abutment Design
   - Sections 7
7. Design Complete
LRFD Guidelines(6.3)-Spread Footing Rocking Analysis

\[ L_f = \text{Footing Length} \]
\[ B_f = \text{Footing Width} \]
\[ \delta_r = \delta_s + \delta_{ro} \]
\[ W_f = W_r + W_{col} + W_{con} + W_{cover} \]

\[ C = R_s N_c P_c \]

Flow Chart

START

1. Establish footing dimensions based on service loading
   OR
   A minimum footing width of 3 times column diameter

2. Calculate \( \Delta \)
3. Calculate \( \mu = \Delta / \Delta_{min} \)
   - If \( \mu \leq \beta \)
     - Yes: Check Shear Strength of Footing
     - No: Proceed
   - If \( \mu > \beta \)
     - Yes: Proceed
     - No: Check Flexure in the direction of rocking

4. Calculate \( M_f = 1.5 M_s \)
5. Calculate \( \beta = \text{Shear of } M_f \) and \( M_s \)

END
LRFD Guidelines(6.8)-Proposed Liquefaction Design Requirements

The following list highlights the main proposed liquefaction design requirements:

- Liquefaction design requirements are applicable to SPC “D”.
- Liquefaction design requirements are dependent on the mean magnitude for the 5% PE in 50-year event and the normalized Standard Penetration Test (SPT) blow count \([N_{160}]\).
- If Liquefaction occurs, then the bridge shall be designed and analyzed for the Liquefied and Non-Liquefied configurations.

Design requirements for lateral flow are still debatable and have not reached a consensus worth comfortably adopting. The IAI geotechnical team is preparing a task to address this topic and complement the effort produced in the NCHRP 12-49 document.

LRFD Guidelines(6.8) Liquefaction Design Requirements

An evaluation of the potential for and consequences of liquefaction within near surface soil shall be made in accordance with the following requirements:

Liquefaction is required for a bridge in SDC D unless one of the following conditions is met:

- The mean magnitude for the 5% PE in 50-year event is less than 6.5.
- The mean magnitude for the 5% PE in 50-year event is less than 6.7 and the normalized Standard Penetration Test (SPT) blow count \([N_{160}]\) is greater than 20.

Procedures given in Appendix D of NCHRP 12-49 and adopted from California DMG Special Publication 117 shall be used to evaluate the potential for liquefaction.
LRFE Guidelines (6.8)

Typical Example of Two Column Bent Supported On Shafts

LRFD Guidelines (6.8)

Moment-Demand vs. Capacity for Shaft with:
(i) no liquefaction
(ii) with liquefaction

• Note: moment demand distribution is dependent on the geotechnical properties of the surrounding soil
LRFD Guidelines(6.8)
Liquefaction Design Requirements

♦ The Designer shall cover explicit detailing of plastic hinging zones for both cases mentioned above since it is likely that locations of plastic hinges for the Liquefied Configuration are different than locations of plastic hinges for the Non-Liquefied Configuration.

♦ Design requirements of SPC “D” including shear reinforcement shall be met for the Liquefied and Non-Liquefied Configuration.

Table of Contents

♦ 1. Introduction
♦ 2. Symbols and Definitions
♦ 3. General Requirements
♦ 4. Analysis and Design Requirements
♦ 5. Analytical Models and Procedures
♦ 6. Foundation and Abutment Design Requirements
♦ 7. Structural Steel Components
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Flow Chart F

Note:
1) Type 1 considers concrete substructure
2) Type 1* considers steel substructure
3) Type 1** considers concrete filled steel pipes substructure

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**LRFD Guidelines (1.3)**

**Flow Chart G**

- **Type 2 & 3**
  - **Essentially Elastic Substructure**
  - **Ductile Steel Superstructure**
  - **Use Reduction Factors Table 7.2**
  - **Satisfy Member Requirements for SDC C and D Section 7.4**
  - **Satisfy Connection Requirements for SDC C and D Section 7.7**
  - **Satisfy Bearing Requirements Section 7.9**
  - **Satisfy Support Seat Width Requirements See Figure 1.3D**

- **Type 3**
  - **Elastically Substructure**
  - **Fusing Mechanism at Interface Between Superstructure and Substructure Section 7.2**
  - **Isolation Devices Section 7.8 Fixed and Expansion Bearings**

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**LRFD Guidelines (7.1)-General Load Path and Performance Criteria**

Unless a more refined analysis is made, an approximate load path shall be assumed as follows:

The following requirements apply to bridges with either:

- A concrete deck that can provide horizontal diaphragm action, or
- A horizontal bracing system in the plane of the top flange

The seismic loads in the deck shall be assumed to be transmitted directly to the bearings through end diaphragms or cross-frame.
LRFD Guidelines(7.1)-General
Seismic Load Path and Affected Components

LRFD Guidelines(7.2)
Performance Criteria

♦ Type 1 – Design a ductile substructure with an essentially elastic superstructure.
♦ Type 2 – Design an essentially elastic substructure with a ductile superstructure.
♦ Type 3 – Design an elastic superstructure and substructure with a fusing mechanism at the interface between the superstructure and the substructure.
LRFD Guidelines(7.2)
Performance Criteria

♦ For Type 3 choice, the designer shall assess the overstrength capacity for the fusing interface including shear keys and bearings, then design for an essentially elastic superstructure and substructure.
♦ The minimum overstrength lateral design force shall be calculated using an acceleration of 0.4 g or the elastic seismic force whichever is smaller.
♦ If isolation devices are used, the superstructure shall be designed as essentially elastic.

Table of Contents

♦ 1. Introduction
♦ 2. Symbols and Definitions
♦ 3. General Requirements
♦ 4. Analysis and Design Requirements
♦ 5. Analytical Models and Procedures
♦ 6. Foundation and Abutment Design Requirements
♦ 7. Structural Steel Components
♦ 8. Reinforced Concrete Components
LRFD Guidelines (1.3) Flow Chart F

1. Type 1 considers concrete substructure
2. Type 1* considers steel substructure
3. Type 1** considers concrete filled steel pipes substructure

**Flow Chart F**

**International Bridge Conference 2006  Roy Imbsen**
Assist T-3 to Develop a LRFD Seismic Design Specification

♦ Current LRFD Specification is a Performance Based Specification
♦ Proposed Seismic Design Guideline uses a Displacement Based Approach which is a Performance Based Approach
♦ A Force Based Approach (i.e., Division 1-A) is a Prescriptive Specification and not consistent with the LRFD Specification

Observations-Seismic Design of Bridges for Global Deformability

♦ A bridge should deform in a manner that will not lead to collapse or result in any element going beyond its limit state (i.e., be a weak link).
♦ Select a seismic design strategy consisting of:
  – Ductile components
  – Capacity protected components
  – Isolation, etc
♦ Confirm the selected seismic design strategy and the global deformability by evaluating the demands and capacities.
Overall T-3 Project Objectives

♦ Assist T-3 Committee in developing a LRFD Seismic Design Specification using available specifications and current research findings
♦ Develop a specification that is user friendly and implemental into production design
♦ Complete six tasks specifically defined by the AASHTO T-3 Committee, which were based on the NCHRP 12-49 review comments

Observations

♦ Similar specifications are being used for both new design and retrofitting
♦ State and local agencies are using similar specifications
♦ This approach is transparent and easy to apply to other performance levels
♦ Higher level of confidence that performance objectives are verified
♦ Innovative and promotes “informed intuition”
Conclusions & Planned Activities

♦ Guidelines are User Friendly & can be Implemented
♦ Specifications and Commentary should be Tested with Example Bridges
♦ Develop Workshop Materials
♦ Present Pilot workshops
♦ Add Sections as recommended in the Comments

LRFD Guidelines(8.6) Column
Shear Requirement for SDC B, C, and D

The shear demand for a column, $V_d$, in SDC B shall be determined based on the lesser of:

♦ The force obtained from an elastic linear analysis
♦ The force, $V_o$, corresponding to plastic hinging of the column including an overstrength factor

The shear demand for a column, $V_d$, in SDC C or D shall be determined based on the force, $V_o$, corresponding to plastic hinging of the column including an overstrength factor.