ASCE 61 Updates and New ASCE Guidelines for Seismic Design of Bulkheads

G. S. Johnson
P. Jain

1Senior Principal, Simpson Gumpertz & Heger Inc.
2Senior Project Manager/Structural Engineer, Moffatt & Nichol

Tuesday, June 26, 2018
Standard ASCE 61
Seismic Design of Piers and Wharves

Started development in 2005
First Edition published 2014
Second Edition scheduled for 2019
First ever COPRI Standard
Why We Needed This

Recognizes differences between marine construction and buildings

- Most “failures” from lateral deformations
- “Failure” ≠ Collapse
- Historically “failure” means unrepairable due to cost
- Standardizes performance-based design already industry practice
- Geotech not decoupled from structural
- Displacement-based design, not force-based
What Does it Cover

Pile-supported piers and wharves
- Bulkheads to be added to ASCE 61-19

Without public access
- Separation from ASCE 7

Performance-based design criteria
- Repairability
- Life-safety

Encourages displacement-based design

Allows force-based design
- Low seismicity
- Governed by other loads, such as mooring and berthing
- Conservatively designed
Other Unique Marine Topics

Consideration of vessels at berth during earthquakes

Multiple earthquakes
  ◦ Aftershocks

Load combinations including wave, current, mooring, and berthing

Treatment of topsides facilities
  ◦ Especially important for new use of existing structures
Typical Marginal Wharf – Structural System

**Embankment**

- Retains weak and/or liquefiable soils
- Steep, mostly submerged
- Not rigid. May deform several feet.
**Typical Marginal Wharf – Structural System**

**Piles**

Embedded in foundation soils

Forced to follow embankment deformations

Hinges may occur at deck level or deep in soil

Transfer inertia load from deck into foundation soils
Typical Marginal Wharf – Structural System

**Deck**

Very strong and stiff

Designed as strong beam / weak column

More similar to bridges than buildings
What Happens at Building Code “Failure”

First hinge hits “collapse prevention limit state”

Structure remains standing

May have displaced several feet

Damage localized at deck connections and in-ground
What Really Happens in Earthquakes

• 1999 Turkey Earthquake M7.4
2016 Ecuador Earthquake (M7.8)
Piers and wharves may move several feet

2010 Chile Earthquake (M8.1)
Full Scale Testing Data – U.C. San Diego

Sponsored by Ports of Los Angeles, Long Beach, and Oakland
Tests at University of Washington

1.75 % Drift

9% Drift
## Damage Levels Used in ASCE 61-14

<table>
<thead>
<tr>
<th>Minimal Damage OLE</th>
<th>Controlled and Repairable Damage CLE</th>
<th>Life Safety Protection DE</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="initial_cracking_and_spalling.png" alt="Image" /></td>
<td><img src="substantial_spalling.png" alt="Image" /></td>
<td><img src="broken_connection.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Initial cracking and spalling of the pile and/or deck</strong></td>
<td><strong>Substantial spalling of the pile exposing the spiral or substantial spalling in the deck to the depth of the embedded pile or that exposed the deck</strong></td>
<td><strong>Broken connection from either spalling into the core, fractured dowel bars or buckled strand.</strong></td>
</tr>
</tbody>
</table>
Reasons for Historic Performance

Piles have large reserves between “Repairability” and “No Collapse” performance criteria

High redundancy
Changes Coming to ASCE 61-19

Adding bulkheads

Revised strain limits for piles
  ◦ Steel pipe piles

Updated earthquake levels consistent with AASHTO
  ◦ More closely linked to transportation systems than buildings in function and configuration
  ◦ 975 year return period
  ◦ Risk-based criteria in ASCE 7 not applicable
  ◦ Inherent factor of safety of 1.5 for buildings in ASCE 7 not applicable

More extensive treatment of nonstructural components and supported facilities
Use and Adoption of ASCE 61

U.S. Navy
California Building Code Chapter 31F (Marine Oil Terminals)

Port Authorities
◦ Port of Anchorage

Note: Some Port Authorities Using Their Own Similar Standards
◦ Port of Los Angeles
◦ Port of Long Beach
◦ Port of Oakland
ASCE Guidelines for Seismic Design of Bulkheads
An Overview

Pooja Jain, P. Eng, PE, SE
Senior Project Manager/Structural Engineer, Moffatt & Nichol
• Range of performance
• What are seismically induced deformations?
• Soil-structure interaction is critical
### Need?

<table>
<thead>
<tr>
<th>Number of Documents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30+</td>
<td>24 w/ bulkhead design guidance</td>
</tr>
<tr>
<td></td>
<td>13 w/ seismic design</td>
</tr>
<tr>
<td></td>
<td>3 w/ performance-based design</td>
</tr>
</tbody>
</table>

- Limited guidance on performance criteria/levels
- Lack of consistency between various codes/standard/references
- Limited guidance on liquefiable soils
Guideline Chapter 1 - Purpose and Scope

Practice-oriented guidelines for force- and performance-based seismic design of bulkheads

- Yielding, planar sheet pile bulkheads
- Cantilever/anchored including lateral force resisting system
- Quay wall or cut-off wall for pile-supported pier/wharf system
- Specific to marine engineering industry
Guidelines Chapter 2 – Literature Review

Literature Review

- Pertinent references
- Limitations and observations
Guideline Chapter 3 – Failure Modes

Chapter 3: Bulkheads Types and Failure Modes
Guidelines Chapter 4 – Performance Levels

Seismic Performance Levels
- Life Safety Protection
- Controlled/Repairable Damage
- Minimal Damage

Seismic hazard definition
- From governing local codes
Guideline Chapter 5: Geotechnical Considerations

Active Earth Pressures
- Current Practice: Mononobe-Okabe (M-O) Method
- Proposed: General Limit Equilibrium (GLE) Method

Groundwater considerations

Soil strength reduction (liquefiable or sensitive soils)

Uncertainty in Soil Parameters & Analysis Methods

Seismic Passive Earth Pressures
- Current Practice: Mononobe-Okabe (M-O) Method
- Proposed: (1) NCHRP Method (Modified p-y curves)
- Proposed: (2) Simplified Method
Guidelines Chapter 6
Structural Considerations

- Water Level (Tidal and Piezometric)
- Allowable Stresses
- Plastic Design
- Material Considerations
- Design Considerations
  - Embedment Depth
  - P-Delta/Secondary Stresses on sheet piles
  - Capacity Protection
  - Corrosion Protection
  - Detailing for Articulated Connections
  - Additional Design Consideration
Guidelines Chapter 7 - Methodologies

Analysis and Design Methodologies

- Limit Equilibrium Method
- P-Y Method
- Numerical Modeling (with tools such as FLAC/PLAXIS) – verification only
Appendix - Example Problems

Worked Examples for two differing subsurface conditions for Level 1, Level 2 and Level 3 earthquakes.
Timeline

2019

• Finalize draft
• Technical editing & copyright approvals
• Prepare final documents for publication
• Final publication