New Performance-Based Standards for Seismic Design of Piers and Wharves

Presented by:

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Agenda

- Background / history of standards
- Why we had to go this route
- What to expect
- Technical issues / political drama
ASCE Standards Committee

- Formed in 2005
- National committee of > 40 professionals
- Owners, consultants, and academics
- Geographically diverse
- Heavy geotechnical emphasis
- Funding by US Navy
What will these new standards do?

- Codify current practice of performance-based seismic design
  - National consensus document
- Build on work done by others specifically for the marine industry
  - Port of Los Angeles
  - California State Land Commission (MOTEMS)
  - PIANC
Why is this necessary?

- Billions of dollars of construction in seismic regions
  - Performance-based design being used routinely on a project basis
- Existing marine codes have limited standing
- Conventional building codes still often take precedence
  - Enforcement by local building officials
- Conventional code development controlled by building designers
  - Major changes to those codes
Code History

- Through 1997:
  - Three model building codes adopted by building officials in US
    - Note: Not all ports subject to local building official jurisdiction
  - Dominated by UBC / SEAOC “Blue Book”
  - “Nonbuilding structures” added in 1988
  - No specific reference to piers and wharves
“World domination” by building designers

- **Post 1997:**
  - Consolidation of 3 US Model Building Codes into IBC
  - FEMA Sponsored National Earthquake Hazards Reduction Program (NEHRP)
  - ASCE 7
  - Different sponsoring organizations
  - Similar, but not identical, documents
  - Many of the same authors
Major changes to codes – not benign

- Some due to “lessons learned”, many change for the sake of change
- Huge expansion of “nonbuilding structures”
  - Conflicts with existing industry practices and standards (not just piers and wharves)
- Major changes to ground motion definitions
  - Biggest effect outside of California
14.6.6 Piers and Wharves:

14.6.6.1 General: Piers and wharves are structures located in waterfront areas that project into a body of water or parallel the shore line.

14.6.6.2 Design Basis: Piers and wharves shall be designed to comply with the Provisions and approved standards. Seismic forces on elements below the water level shall include the inertial force of the mass of the displaced water. The additional seismic mass equal to the mass of the displaced water shall be included as a lumped mass on the submerged element, and shall be added to the calculated seismic forces of the pier or wharf structure. Seismic dynamic forces from the soil shall be determined by the registered design professional.

The design shall account for the effects of liquefaction on piers and wharfs as required.
2003 NEHRP

- Task Committee of industry engineers
- Attempt to add performance-based design
- Crashed and burned
14.3.3 Piers and wharves. Piers and wharves are structures located in waterfront areas that project into a body of water. Two categories of these structures are:

a. Piers and wharves with general public occupancy, such as cruise ship terminals, retail or commercial offices, restaurants, fishing piers and other tourist attractions.

b. Piers and wharves where occupancy by the general public is not a consideration and economic considerations (on a regional basis, or for the owner) are a major design consideration, such as container wharves, marine oil terminals, bulk terminals, etc., or other structures whose primary function is to moor vessels and barges.

These structures shall conform to the building or building-like structural requirements of the Provisions or other rational criteria and methods of design and analysis. Any methods used for design of these structures should recognize the unique importance of liquefaction and soil failure collapse mechanisms, as well as consider all applicable marine loading combinations, such as mooring, berthing, wave and current. Structural detailing shall be carefully considered for the marine environment.

14.3.3.1 Additional seismic mass. Seismic forces on elements below the water level shall include the inertial force of the mass of the displaced water. The additional seismic mass equal to the mass of the displaced water shall be included as a lumped mass on the submerged element, and shall be added to the calculated seismic forces of the pier or wharf structure.

14.3.3.2 Soil effects. Seismic dynamic forces from the soil shall be determined by the registered design professional. The design shall account for the effects of liquefaction on piers and wharves, as appropriate.
15.5.6 Piers and Wharves.

15.5.6.1 General. Piers and wharves are structures located in waterfront areas that project into a body of water or parallel the shoreline.

15.5.6.2 Design Basis. In addition to the requirements of Section 15.5.1, piers and wharves that are accessible to the general public, such as cruise ship terminals and piers with retail or commercial offices or restaurants, shall be designed to comply with this standard.

The design shall account for the effects of liquefaction and soil failure collapse mechanisms, as well as consider all applicable marine loading combinations, such as mooring, berthing, wave, and current on piers and wharves as required. Structural detailing shall consider the effects of the marine environment.
Why was performance-based design rejected?

- Two level performance criteria
- Levels of shaking / return periods viewed as “unconservative”
  - Consistent risk vs. life-safety
- Displacement based design not understood
UBC / IBC / ASCE Performance Criteria

- Historically was single earthquake
  - 475 year return period
  - Life safety only

- Now Maximum Considered Earthquake (MCE)
  - 2,500 year RP with deterministic cap
  - Collapse Prevention

- Design Earthquake
  - 2/3 MCE
    - (800-1000 year)
  - Life Safety

- Really a single-level earthquake design for 2/3 MCE

- Performance at higher level is presumed due to implied factors of safety for buildings
Why change the 475 year return period?

- Increase ground shaking in Eastern US
  - 2% in 50 years
- Keep actual design values for California about the same
  - 2/3 factor
  - Justified by inherent 1.5 factor of safety
Charleston, SC
Site Class D

Period (sec)
Spectral Acceleration (g)

2/3 NEHRP
USGS-10% in 50 Years
Oakland Outer Harbor Wharf, CA
Site Class D

Period (sec)

Spectral Acceleration (g)

2/3 NEHRP
USGS-10% in 50 Years
Port industry issues with changes

- Hard to distinguish between damage states for life-safety and collapse prevention
  - Inherent 1.5 FS is only for buildings – doesn’t make sense for ports
- Accelerations / forces can be scaled, displacements are not linear
- Massive ground failures occur in 2,500 year event that don’t occur at 500 years
  - Can’t just scale those events by 2/3
- Life safety hasn’t been an issue
1989 Loma Prieta Earthquake
1989 Loma Prieta Earthquake
1995 Kobe Earthquake
1995 Kobe Earthquake
1995 Manzanillo, Mexico Earthquake
1995 Manzanillo, Mexico Earthquake
1999 Turkey Earthquake
1999 Turkey Earthquake
2004 Indonesia Earthquake / Tsunami

02/03/2005
## New Standards

### Seismic Hazard Level and Performance Level

<table>
<thead>
<tr>
<th>Design Classification</th>
<th>Operating Level Earthquake (OLE)*</th>
<th>Contingency Level Earthquake (CLE)*</th>
<th>Design Earthquake (DE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ground Motion Probability of Exceedance</td>
<td>Performance Level</td>
<td>Ground Motion Probability of Exceedance</td>
</tr>
<tr>
<td>High</td>
<td>50% in 50 years (72 year RP)</td>
<td>Minimal Damage</td>
<td>10% in 50 years (475 year RP)</td>
</tr>
<tr>
<td>Moderate</td>
<td>n/a</td>
<td>n/a</td>
<td>20% in 50 years (225 year RP)</td>
</tr>
<tr>
<td>Low</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Does higher RP = more conservative?

- **ASCE 7**
  - 2,500 year return period
  - Non-collapse / life-safety

- **ASCE Piers and Wharves**
  - Lower return periods
  - Controlled and repairable damage
  - “Failure” is more functional and economical
  - Life-safety and collapse not such a big issue
Why is displacement based design an issue?

- Displacement based not done for buildings
  - Force based
  - R factors to reduce the load accounting for ductility and inelastic deformations

- Force based doesn’t work well for piers and wharves
  - Judgment needed
  - Assign a building system or non-building structure
<table>
<thead>
<tr>
<th>Pile Type</th>
<th>Top of pile</th>
<th>In-ground</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid Concrete Piles - Dowelled</strong></td>
<td>$0.005 \leq \varepsilon_c \leq 0.020^c$</td>
<td>$0.005 \leq \varepsilon_c \leq 0.008^{c,d}$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{sd} = 0.050 ? 0.6\varepsilon_{smd}$</td>
<td>$\varepsilon_p = 0.015^b$</td>
</tr>
<tr>
<td><strong>Hollow Concrete Piles$^a$ - Dowelled</strong></td>
<td>$\varepsilon_c = 0.004$</td>
<td>$\varepsilon_c = 0.006$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{sd} = 0.025$</td>
<td>$\varepsilon_p = 0.015$</td>
</tr>
<tr>
<td><strong>Solid Concrete Piles - Fully Embedded</strong></td>
<td>$0.005 \leq \varepsilon_c \leq 0.020^c$</td>
<td>$0.005 \leq \varepsilon_c \leq 0.008^{c,d}$</td>
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<tr>
<td></td>
<td>$\varepsilon_p = 0.015$</td>
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</tr>
<tr>
<td><strong>Steel Pipe Piles (concrete plug doweled connection)</strong></td>
<td>$\varepsilon_c = 0.025$</td>
<td>See Fully Embedded</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{sd} = 0.050 \leq 0.6\varepsilon_{smd}$</td>
<td>?</td>
</tr>
<tr>
<td><strong>Steel Pipe Piles (hollow steel section) - Fully Embedded</strong></td>
<td>$\varepsilon_{s,c} = 0.025$</td>
<td>$\varepsilon_s = 0.025$</td>
</tr>
<tr>
<td><strong>Steel Pipe Piles (concrete filled) - Fully Embedded</strong></td>
<td>$\varepsilon_s = 0.035$</td>
<td>$\varepsilon_s = 0.035$</td>
</tr>
</tbody>
</table>
Final Semi-cycle from 7 to 8 in. Displacement

non-seismic Pile Test Unit
Tests at University of Washington

1.75 % Drift

- 9% Drift
Advantages to industry specific standards

- Structural configurations
  - "Irregularities"
  - Sloping foundations
  - Battered piles
  - Strong beam / weak column
- Loading
  - Kinematic
  - Mooring and berthing
- Code developers who work in the industry
  - Building guys won’t listen to us
- Standing as “ASCE Mandatory Standard”
What’s next?

- Standard to be balloted in 2008
- Hopefully published 2009
- Over time – gain national standing and acceptance by building officials
- Continued application by marine industry
Acknowledgements

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Questions ?