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

Presented by:

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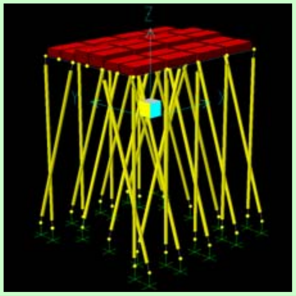
November 9, 2007



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

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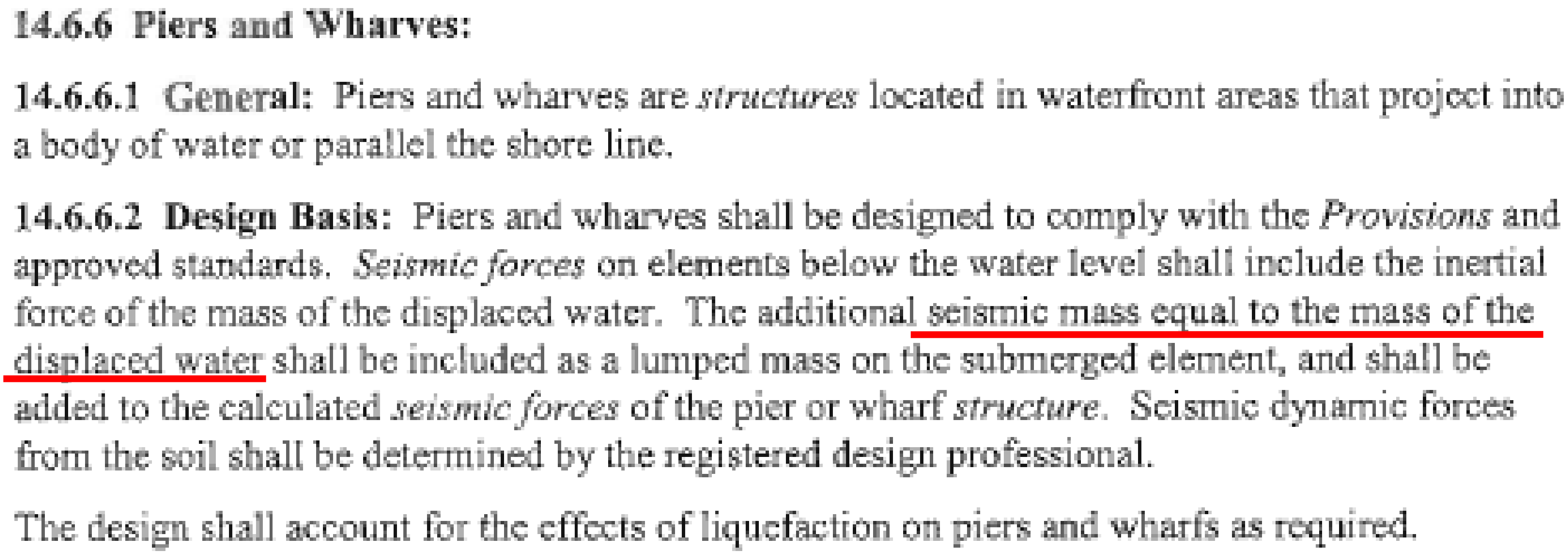
2000 NEHRP



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.

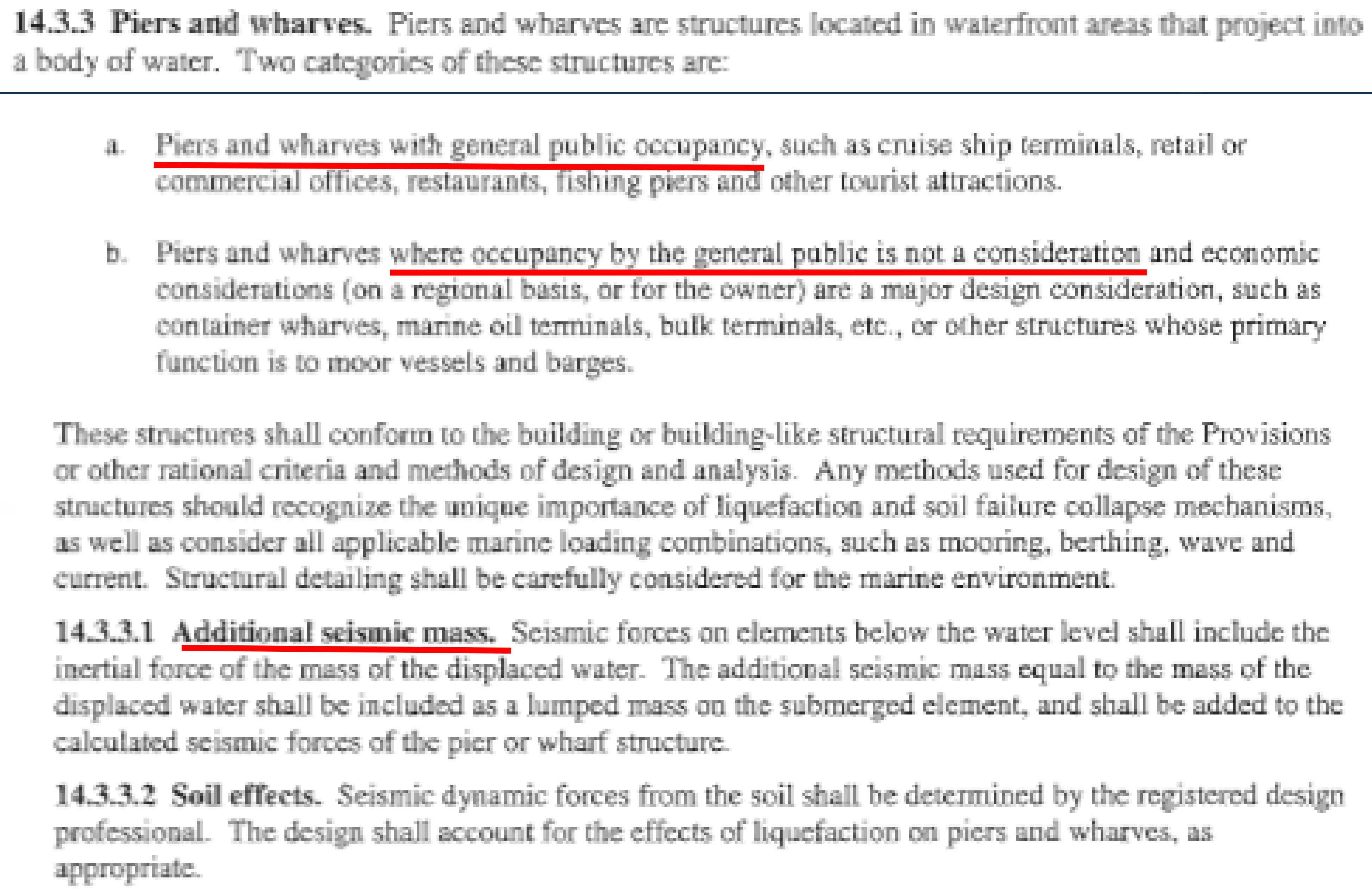
14.6.6.2 Design Basis: Piers and wharves shall be designed to comply with the *Provisions* and approved standards. *Seismic forces* on elements below the water level shall include the inertial force of the mass of the displaced water. The additional seismic mass equal to the mass of the displaced water 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

2003 NEHRP



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.

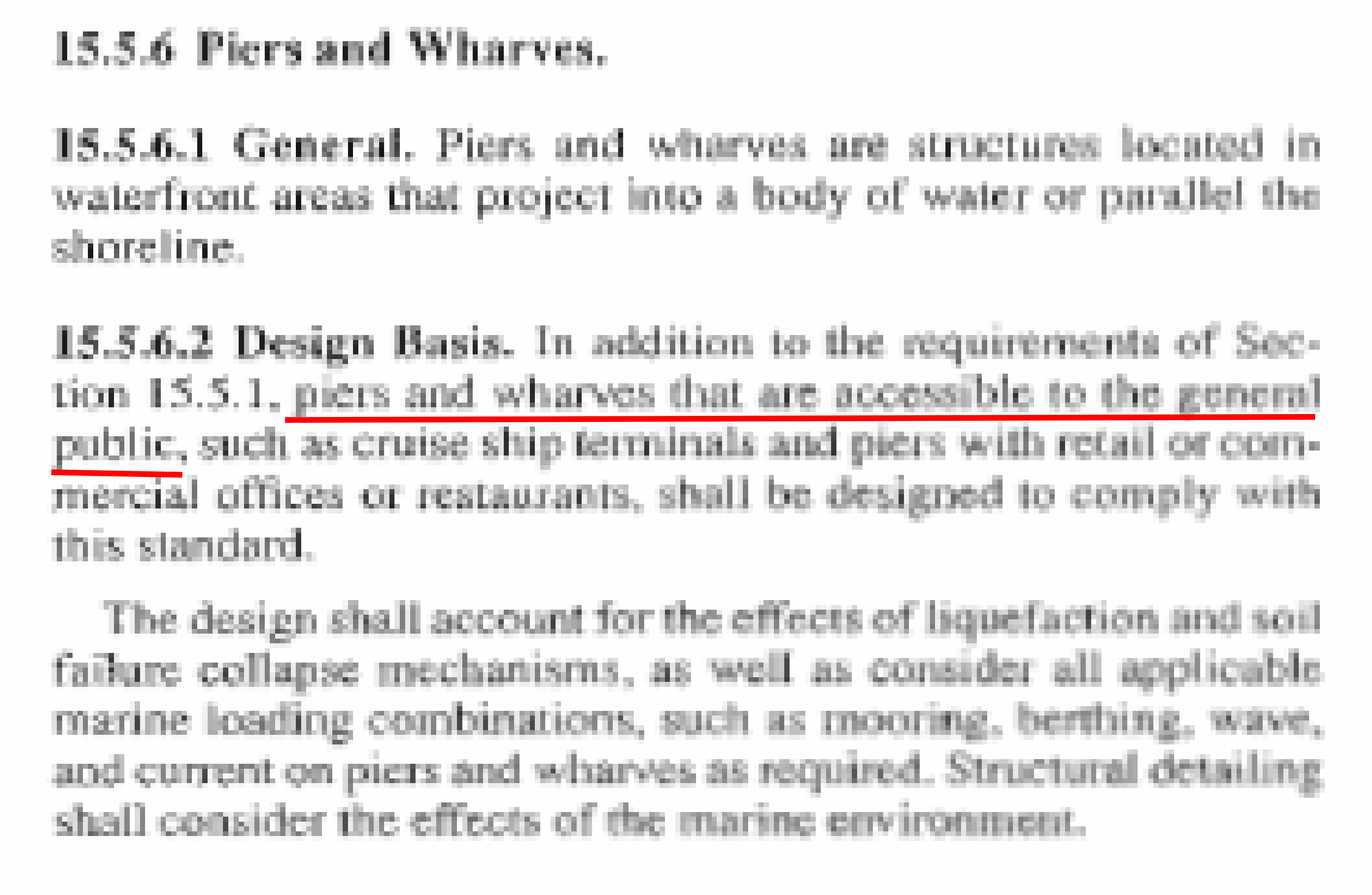
b. Piers and wharves where occupancy by the general public is not a consideration and economic considerations (on a regional basis, or for the owner) are a major design consideration, such as container wharves, marine oil terminals, bulk terminals, etc., or other structures whose primary function is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

ASCE 7-05



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

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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**

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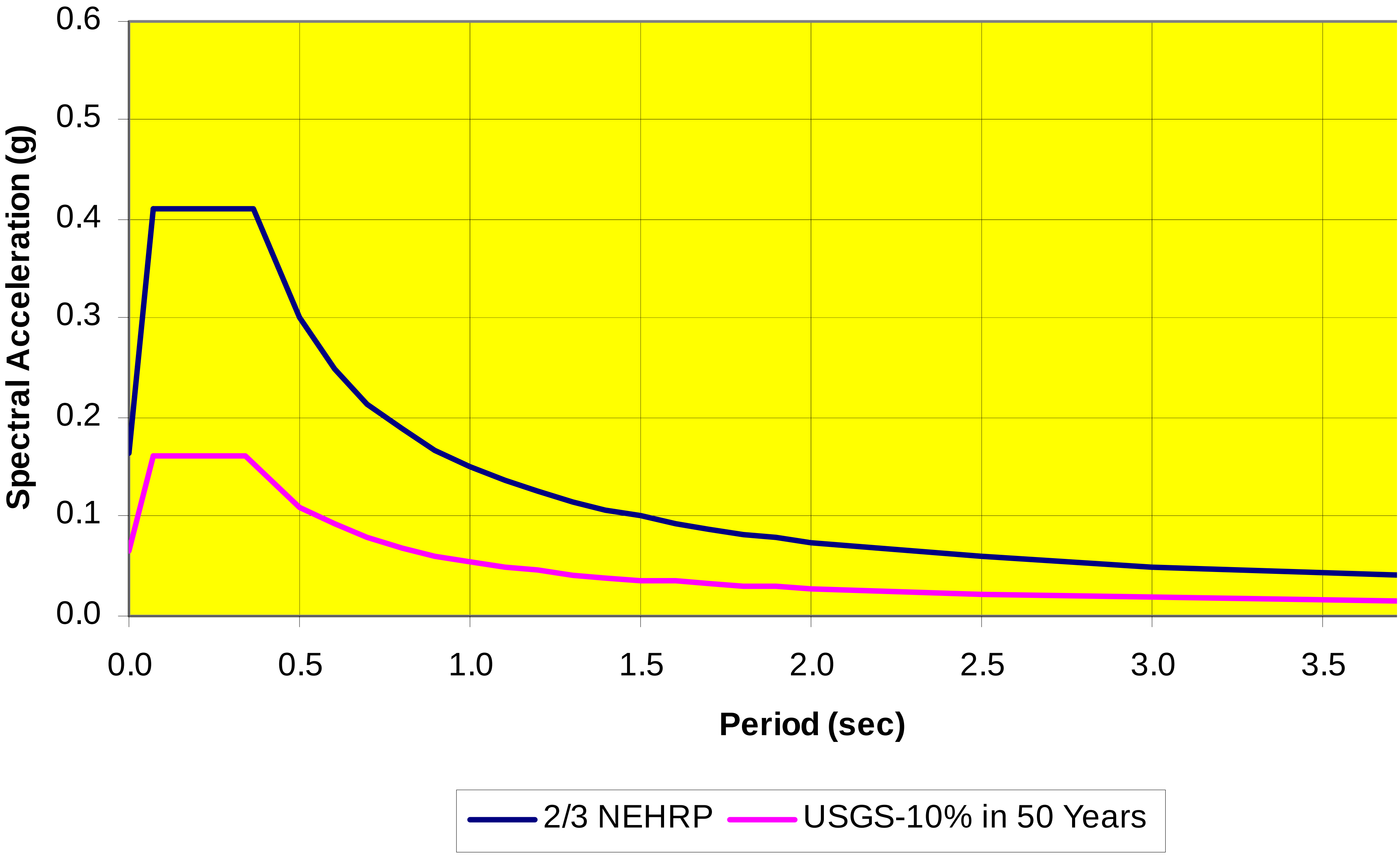
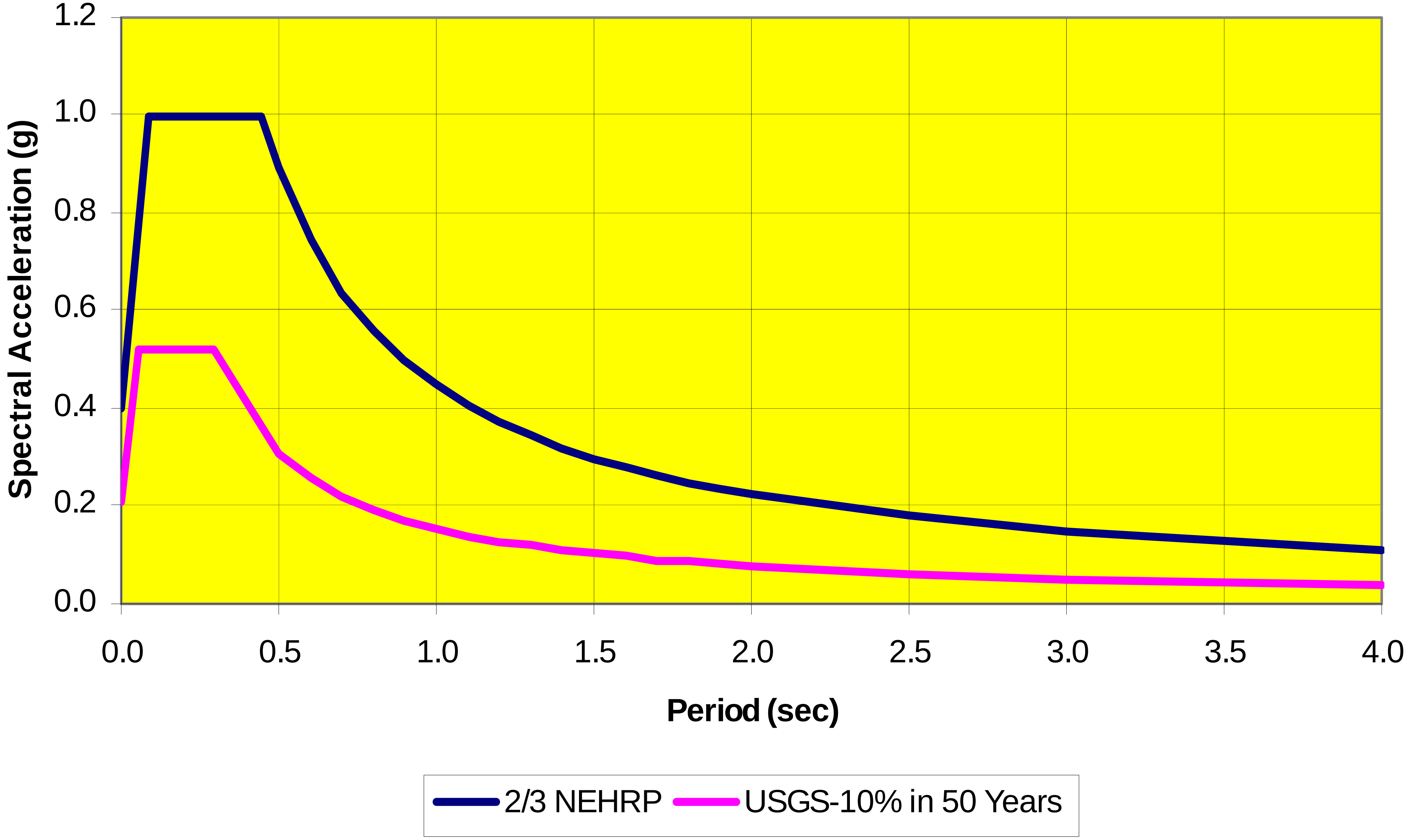
Why change the 475 year return period ?

- 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

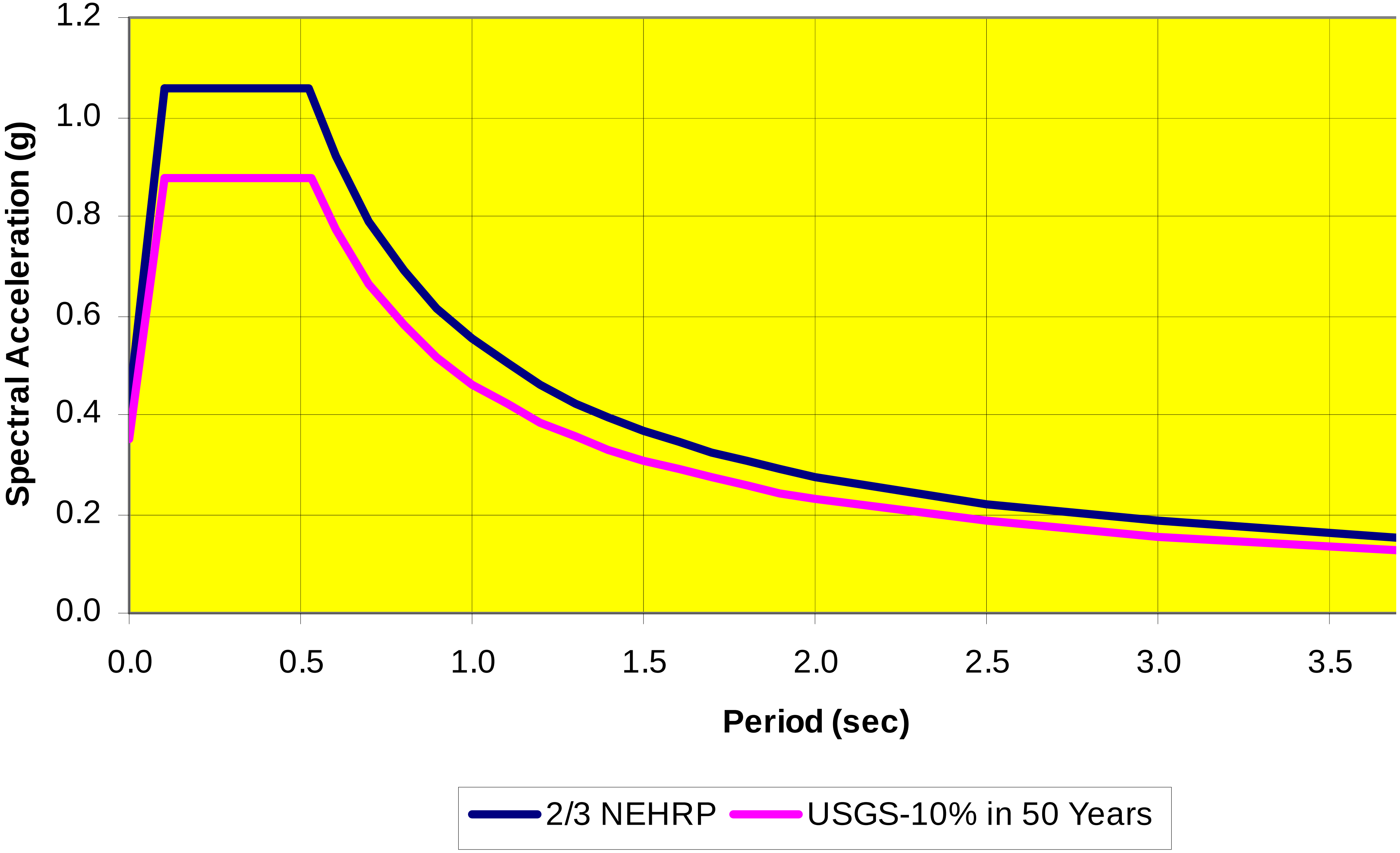
New York, NY
Site Class D



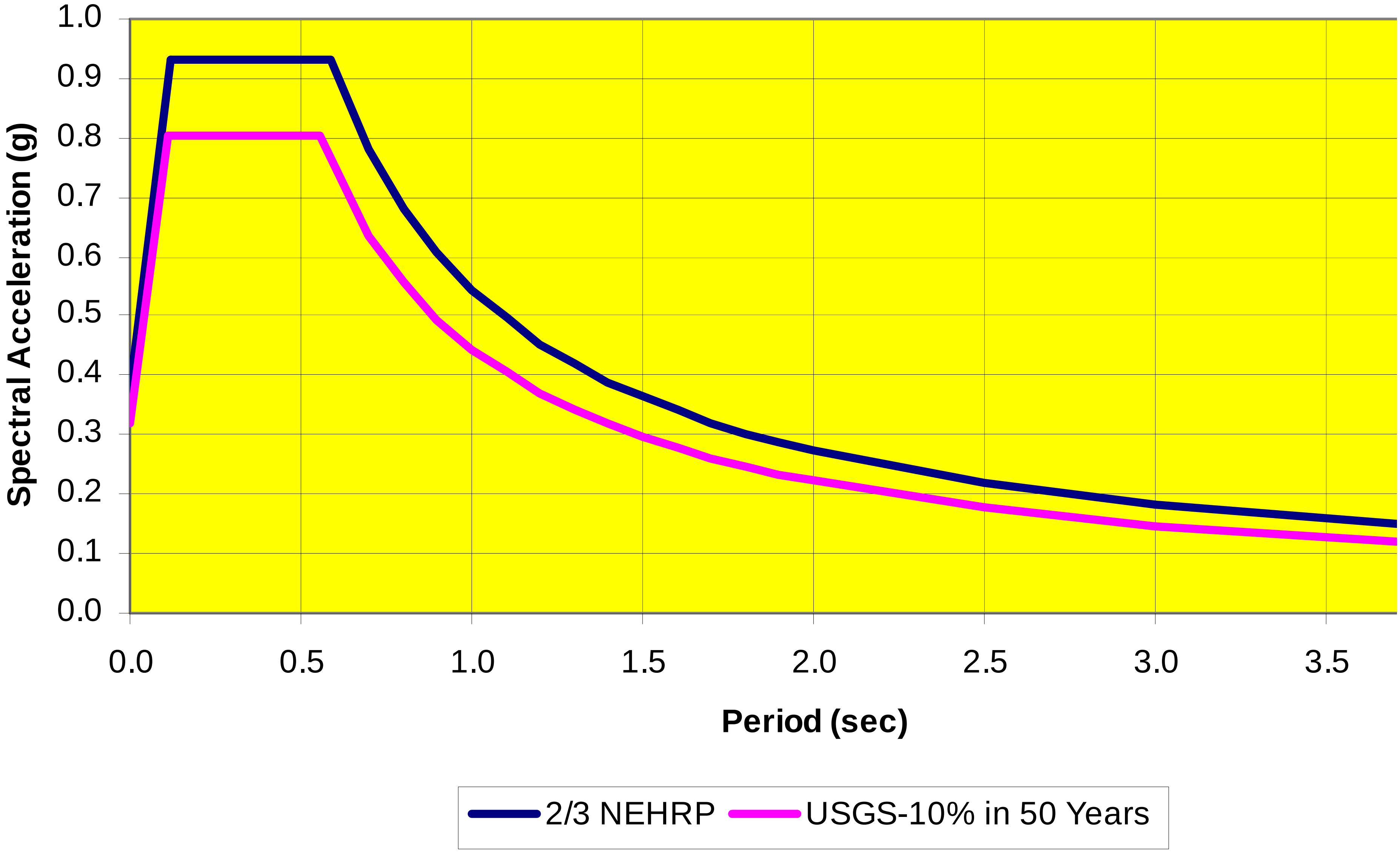
Charleston, SC
Site Class D



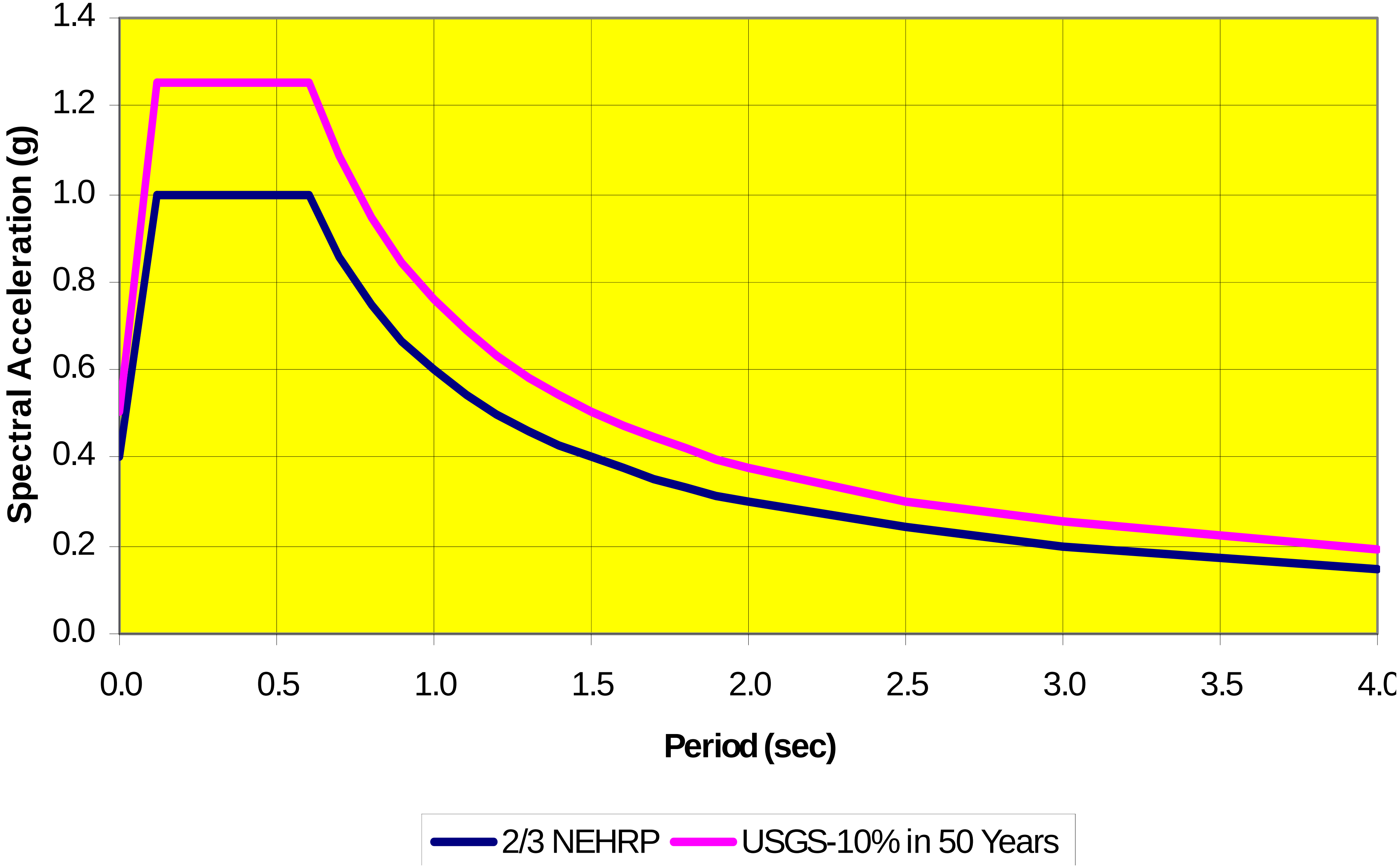
Seattle, WA
Site Class D



San Diego, CA
Site Class D



Oakland Outer Harbor Wharf, CA
Site Class D



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

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1989 Loma Prieta Earthquake

1989 Loma Prieta Earthquake

1995 Kobe Earthquake

1995 Kobe Earthquake

1995 Manzanillo, Mexico Earthquake

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1999 Turkey Earthquake

1999 Turkey Earthquake

'99 8 24

2004 Indonesia Earthquake / Tsunami


02/03/2005

New Standards

Design Classification	Seismic Hazard Level and Performance Level					
	Operating Level Earthquake (OLE)*		Contingency Level Earthquake (CLE)*		Design Earthquake (DE)	
	Ground Motion Probability of Exceedance	Performance Level	Ground Motion Probability of Exceedance	Performance Level	Seismic Hazard Level	Performance Level
High	50% in 50 years (72 year RP)	Minimal Damage	10% in 50 years (475 year RP)	Controlled and Repairable Damage	as per ASCE-7	Life Safety Protection
Moderate	n/a	n/a	20% in 50 years (225 year RP)	Controlled and Repairable Damage	as per ASCE-7	Life Safety Protection
Low	n/a	n/a	n/a	n/a	as per ASCE-7	Life Safety Protection

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

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	CLE Strain Limits	
	Top of pile	**In-ground**
Solid Concrete Piles - Doweled	$0.005 \le \varepsilon_c \le 0.020^c$	$0.005 \le \varepsilon_c \le 0.008^{c,d}$
	$\varepsilon_{sd} = 0.050$? $0.6\varepsilon_{smd}$	$\varepsilon_p = 0.015^b$
Hollow Concrete Piles[a] - Doweled	$\varepsilon_c = 0.004$	$\varepsilon_c = 0.006$
	$\varepsilon_{sd} = 0.025$	$\varepsilon_p = 0.015$
Solid Concrete Piles - Fully Embedded	$0.005 \le \varepsilon_c \le 0.020^c$	$0.005 \le \varepsilon_c \le 0.008^{c,d}$
	$\varepsilon_p = 0.040$	$\varepsilon_p = 0.015^b$
Hollow Concrete Piles[a] - Fully Embedded	$\varepsilon_c = 0.004$	0.006
	$\varepsilon_p = 0.015$	$\varepsilon_p = 0.015$
Steel Pipe Piles (concrete plug doweled connection)	$\varepsilon_c = 0.025$	See Fully Embedded
	$\varepsilon_{sd} = 0.050 \le 0.6\varepsilon_{smd}$	?
Steel Pipe Piles (hollow steel section) - Fully Embedded	$\varepsilon_{s,c} = 0.025$	$\varepsilon_s = 0.025$
Steel Pipe Piles (concrete filled) - Fully Embedded	$\varepsilon_s = 0.035$	$\varepsilon_s = 0.035$

POLA Experimental Program at UCSD

Current Experimental Work – Phase I

● ● ✓ ● ●

Final Semi-cycle from 7 to 8 in. Displacement

non-seismic Pile Test Unit

Tests at Oregon State University

Tests at University of Washington

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

- Stu Werner – Seismic Systems and Risk Engineering
- Martin Eskijian – California State Lands Commission
- Peter Yin - Port of Los Angeles
- Scott Ashford – Oregon State University
- Amanda Jellin - University of Washington

Questions ?

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