SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

ASCE 61-14: A NEW SEISMIC DESIGN STANDARD FOR PIERS AND WHARVES

Presented by:

Gayle S. Johnson

Simpson Gumpertz & Heger (SGH)

Prevention First

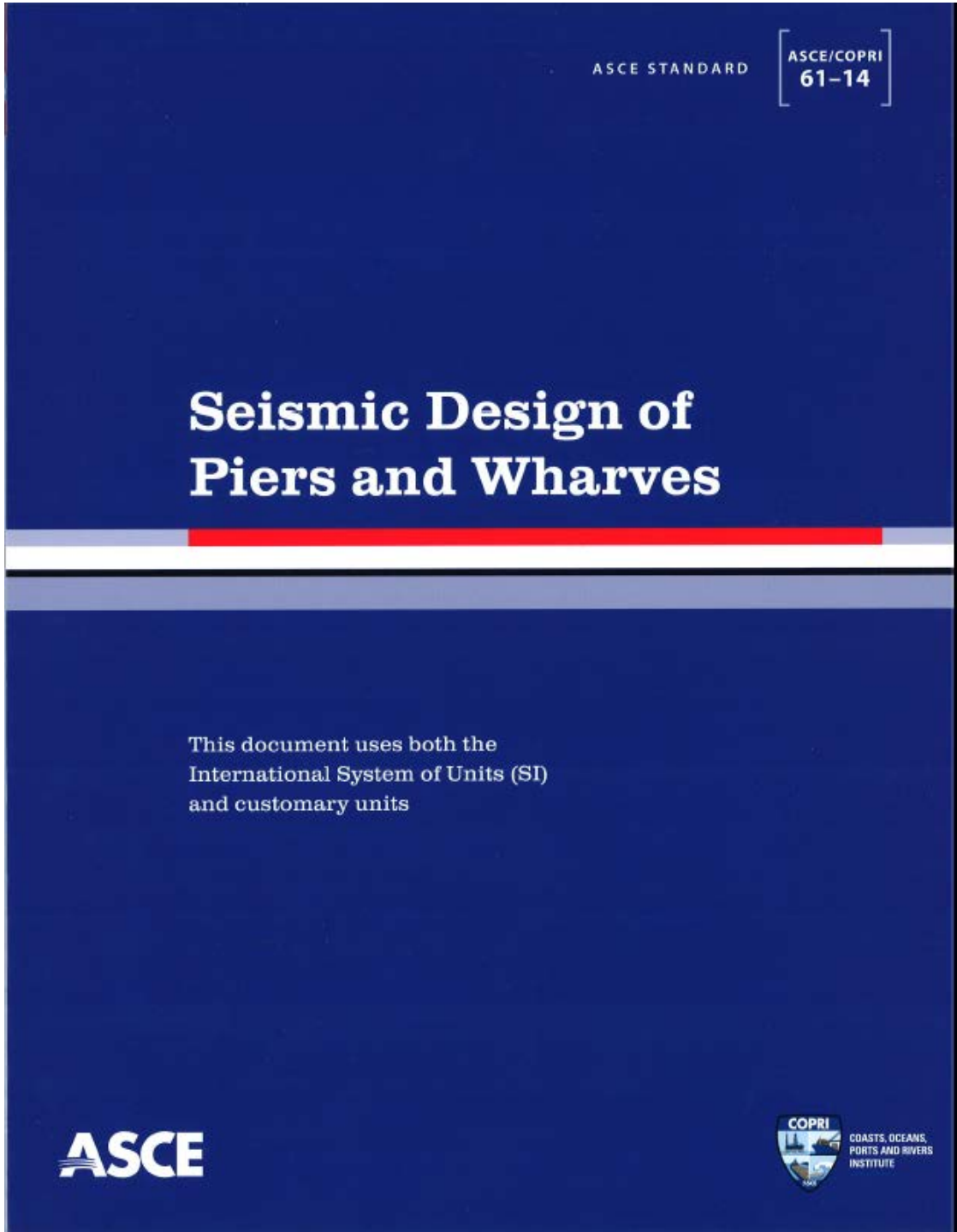
October 8, 2014

AGENDA

- Introduction
- A Brief History
- Some Details About the Standards
- What’s Next

At Long Last:

- First Meeting: June 23, 2005
- Published **July 25, 2014**



WHY CREATE THIS STANDARD ?

- Not just for fun
- Conventional building codes are inadequate
  - Codes developed by building designers with no understanding of marine industry
  - Expanding scope to specifically cover piers and wharves
  - Refused to acknowledge existing industry practice

ANCIENT HISTORY – PORT SEISMIC DESIGN

- Through 1980's equivalent lateral force methods – mostly AASHTO based (treated like bridges)
- Lateral force often specified, not calculated for each project using R values, site factors, etc.
- Each major California port (POLA, POLB, POAK) set their own criteria
  - Port of Los Angeles – 1981 used V = 0.12 W

Economics

BERTHS 216-218 POLA	JOB No. 7053-5-2	SHEET No. 1
	DESIGNED BY	DATE MAY 81
DESIGN CRITERIA	APPROVED	

PSEUDO STATIC FORCE OF 0.12 g BOTH TRANSVERSE AND LONGITUDINAL DIRECTION.

g = TOTAL DEAD LOAD OF WHARF + CRANE DEAD LOAD.

~~ASSUMED~~ CRANE DEAD LOAD = 1000 ^{k}

EARLY PORT PERFORMANCE-BASED DESIGN

- Probabilistic Seismic Hazard Analyses common by mid-1980s
- Two level force-based design

1994 Example from Port of Oakland

(Governs)

SEISMIC CRITERIA:

EARTHQUAKE LEVEL	1	2
TYPE OF SEISMIC EVENT	EXTREME	MODERATE
PROBABILITY OF EXCEEDANCE IN 50 YEARS (240 year RP)	20%	50%
PEAK GROUND ACCELERATION	0.35g	0.25g
% DAMPING	5	5
DUCTILITY/RISK FACTOR, Z	5	2
PEAK OF DAMPED SPECTRAL ACCELERATION (PDSA)	0.95 W	0.65 W

$$V_u = \frac{PDSA}{Z} W$$

LATE 1990's DESIGN

SEISMIC CRITERIA:

EARTHQUAKE LEVEL	1	2	3
PROBABILITY OF EXCEEDANCE IN 50 YEARS	50%	20%	10%
% DAMPING	5%	5%	5%
TOP OF PILE FORCE REDUCTION FACTOR, R	2	4	5
IN-GROUND PILE FORCE REDUCTION FACTOR, R	1	2	2
PEAK GROUND ACCELERATION (PGA)	0.25g	0.37g	0.44g
PEAK OF DAMPED SPECTRAL ACCELERATION (PDSA)	0.82g	1.16g	1.38g

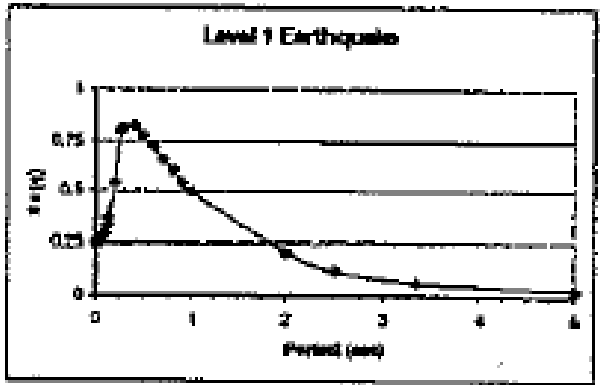
NOTE: PGA AND PDSA REPRESENT GROUND MOTION 10 FEET BELOW SURFACE FOR THE CDSM CONFIGURATION.

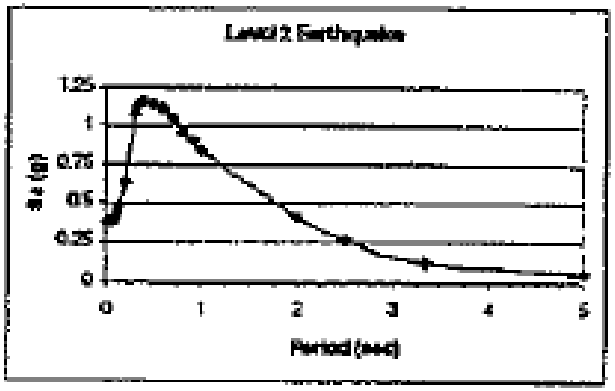
SEISMIC LOAD COMBINATIONS
(1) 1.4 DL + 1.0 EQ + 0.1 (VERTICAL LIVE LOAD FOR PILE DESIGN)
(2) 0.9 DL + 1.0 EQ

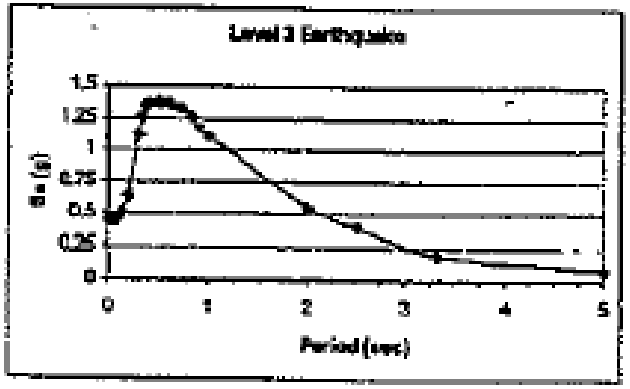
SITE-SPECIFIC RESPONSE SPECTRA HAVE BEEN DEVELOPED FOR THIS PROJECT BY SUBSURFACE CONSULTANTS, INC. MARCH 1998. FROM THESE SITE-SPECIFIC RESPONSE SPECTRA, THE FOLLOWING DESIGN RESPONSE SPECTRAS WERE DEVELOPED:

SLOPE DEFORMATION CRITERIA

SEISMIC EVENT	DEFORMATION LIMITS
POST-LEVEL 1	MINIMAL
POST-LEVEL 2	LESS THAN 6"
POST-LEVEL 3	LESS THAN 12"







RECENT PORT PERFORMANCE-BASED DESIGN

- California Ports and Oil Terminals
  - POLA and POLB created their own criteria
  - MOTEMS

- International Projects
  - PIANC Guidelines

- Share a Common Approach
  - Different performance at each earthquake level
    - Little or no damage in small event
    - No collapse and repairable in large event
  - Deformation-based performance criteria

FIRST ATTEMPTED TO PLAY NICE WITH CONVENTIONAL CODE COMMITTEES

- 2003 Subcommittee of marine engineers
- Too big of a change for the building industry
- Overwhelmingly rejected by code committee
- Led to ASCE venue for new standard
- Expected to be “easy” to start with POLA, POLB, and MOTEMS and create a new ASCE Standard

WHAT ARE WE DOING THAT'S DIFFERENT?

- Emphasize geotechnical
  - Kinematic and inertial
- Common pier/wharf structural configurations
  - "Irregularities"
  - Sloping foundations
  - Battered piles
  - Strong beam / weak column
- Code developers who work in the industry
  - Incorporate lessons learned in ports

LESSONS LEARNED FOR PORTS

- Deaths are not common, even where “collapse” occurs
- Collapse not attributed to inertial loading
  - Liquefaction induced ground deformation is key issue

1995 MANZANILLO, MEXICO EARTHQUAKE

LESSONS LEARNED FOR PORTS

- Deaths are not common
- Collapse not attributed to inertial loading
  - Liquefaction induced ground deformation is key issue
- “Failure” is usually related to economic loss and functionality
  - Usually not a structural “collapse”

1999 TURKEY EARTHQUAKE “FAILURE”

1999 TURKEY EARTHQUAKE
FAILURE ≠ COLLAPSE

LESSONS LEARNED FOR PORTS

- Deaths are not common
- Collapse not attributed to inertial loading
  - Liquefaction induced ground deformation is key issue
- “Failure” is usually related to economic loss and functionality
  - Usually not a structural “collapse”
  - Bigger concerns may not be structural

1999 TURKEY EARTHQUAKE

2004 INDONESIA EARTHQUAKE / TSUNAMI

SCOPE OF DOCUMENT

- Pile-supported piers and wharves
  - Steel and concrete
  - Timber not covered
- Document doesn't cover bulkheads
  - Practical limitation for this edition
  - Will be in the 2nd Edition
- Excludes those with public access, such as cruise terminals
  - Needed to not be in conflict with ASCE 7
- Excludes LNG terminals, offshore platforms, other special structures

No Conflict with ASCE 7

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 that 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. Piers and wharves that are not accessible to the general public are beyond the scope of this section.

OVERARCHING PHILOSOPHY

- Specifically include performance-based design
  - Multi-level earthquakes
- Encourage displacement-based design
- Still allow force-based design
  - Low seismicity
  - Governed by other lateral loads
  - Conservatively designed

OVERARCHING PHILOSOPHY

- Fill gaps of conventional building codes
  - Geotech not decoupled from structural
  - Design for large ground deformations
    - Not require them to be eliminated
- Specify detailing for marine construction
  - Strong beam / weak column
- Consistent with latest industry practice
- Use work done by Ports of LA and LB, MOTEMS, and others

DESIGN APPROACH IN DOCUMENT

Structural

1. Define Design Classification
2. Based on Design Classification, determine performance levels and hazard levels
3. Determine design method (displacement-based and/or force-based)
4. Define ground motions
5. Determine soil/structure modeling parameters (p-y and t-z springs)
6. Determine other geotechnical loads

Geotech

DESIGN APPROACH IN DOCUMENT (CONT.)

7. Develop structural model with general modeling considerations
8. Calculate structural demands
9. Calculate structural capacity
10. Design connection details
11. Design ancillary components

Structural

Structural / Mechanical

PERFORMANCE CRITERIA

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 return period)	Minimal Damage	10% in 50 years (475-year return period)	Controlled and Repairable Damage	Design Earthquake per ASCE 7-05	Life-Safety Protection
Moderate	n/a	n/a	20% in 50 years (224-year return period)	Controlled and Repairable Damage	Design Earthquake per ASCE 7-05	Life-Safety Protection
Low	n/a	n/a	n/a	n/a	Design Earthquake per ASCE 7-05	Life-Safety Protection

WHY ASCE 7-05 ?

- ASCE 7-10 was not adopted yet at the time the bulk of our document was complete
- “Risk-based” ground motions were not understood, and were developed based on universal building fragilities
- ASCE 7-10 made a major change to the liquefaction assessment requirements

ASCE 7-05 vs. 7-10

11.8.3 Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F. The geotechnical investigation report for a structure assigned to Seismic Design Category D, E, or F shall include:

1. The determination of lateral pressures on basement and retaining walls due to earthquake motions.
2. The potential for liquefaction and soil strength loss evaluated for site peak ground accelerations, magnitudes, and source characteristics consistent with the design earthquake ground motions. Peak ground acceleration is permitted to be determined based on a site-specific study taking into account soil amplification effects or, in the absence of such a study, peak ground accelerations shall be assumed equal to $S_S/2.5$.

ASCE 7-05

ASCE 7-10

11.8.3 Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

The geotechnical investigation report for a structure assigned to Seismic Design Category D, E, or F shall include all of the following, as applicable:

1. The determination of dynamic seismic lateral earth pressures on basement and retaining walls due to design earthquake ground motions.
2. The potential for liquefaction and soil strength loss evaluated for site peak ground acceleration, earthquake magnitude, and source characteristics consistent with the MCE_G peak ground acceleration. Peak ground acceleration shall be determined based on either (1) a site-specific study taking into account soil amplification effects as specified in

STRAIN LIMITS – EACH PERFORMANCE LEVEL

Table 3.1 Strain limits for "Minimal damage"

Pile Type	Component	Hinge Location		
		Top of pile	In-ground	Deep in-ground (>10D_p)
Solid Concrete Pile	Concrete	$e_c \leq 0.005$	$e_c \leq 0.005$	$e_c \leq 0.008$
	Reinforcing Steel	$e_s \leq 0.015$		
	Prestressing Steel		$e_p \leq 0.015$	$e_p \leq 0.015$
Hollow Concrete Pile [a]	Concrete	$e_c \leq 0.004$	$e_c \leq 0.004$	$e_c \leq 0.004$
	Reinforcing Steel	$e_s \leq 0.015$		
	Prestressing Steel		$e_p \leq 0.015$	$e_p \leq 0.015$
Steel Pipe Pile	Steel Pipe		$e_s \leq 0.010$	$e_s \leq 0.010$
	Concrete	$e_c \leq 0.010$		
	Reinforcing Steel	$e_s \leq 0.015$		

POLA Experimental Program at UCSD

Current Experimental Work – Phase I

Final Semi-cycle from 7 to 8 in. Displacement

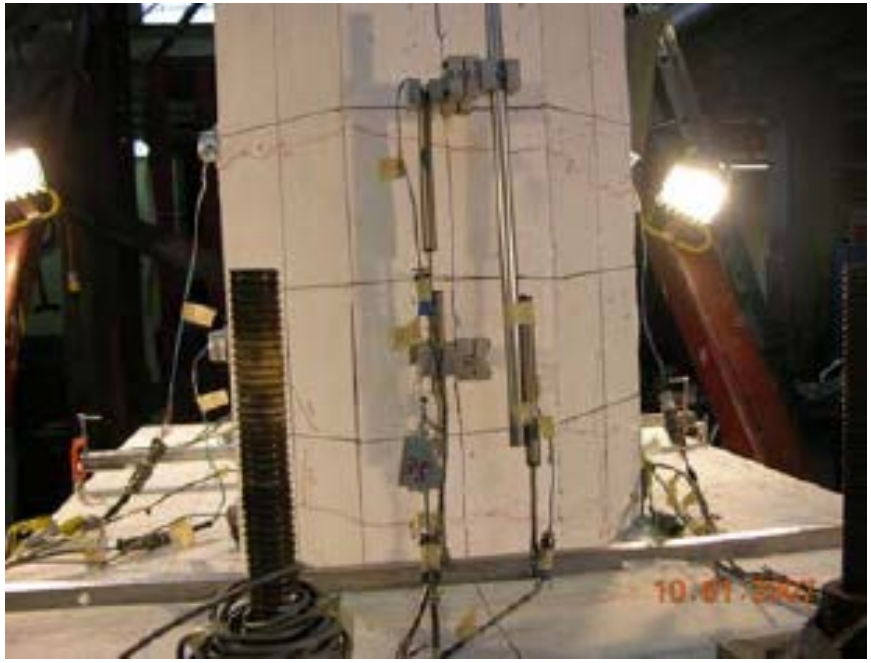
non-seismic Pile Test Unit

TESTS AT U.C. SAN DIEGO

TESTS AT UNIVERSITY OF WASHINGTON

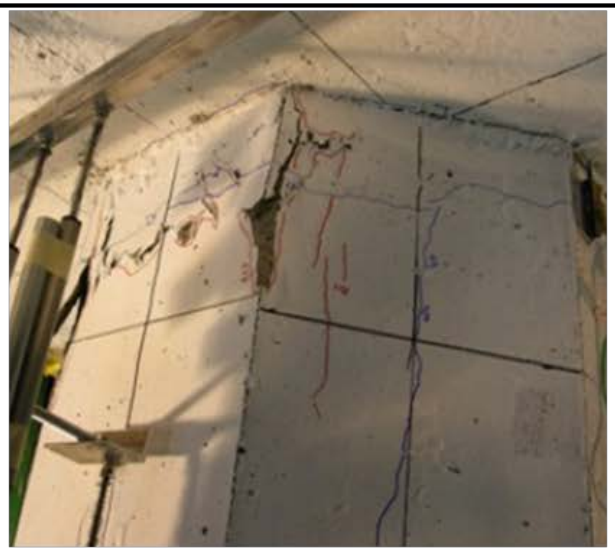
TESTS AT UNIVERSITY OF WASHINGTON

1.75 % Drift



9% Drift

DAMAGE LEVELS

Minimal Damage OLE	Controlled and Repairable Damage CLE	Life Safety Protection DE
		
Initial cracking and spalling of the pile and/or deck	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	Broken connection from either spalling into the core, fractured dowel bars or buckled strand.

GEOTECHNICAL DESIGN

- Long term static F.S. > 1.5
- Post earthquake F.S. > 1.1
- Pseudo-static slope stability
  - If F.S. > 1.1, no further evaluation
  - If F.S. < 1.1, evaluate deformations and structure
- **Evaluate inertial and kinematic loads**
  - **Not a consensus on how and when to combine them**
- Develop upper- and lower-bound soil springs
- Bulkheads to be added next edition

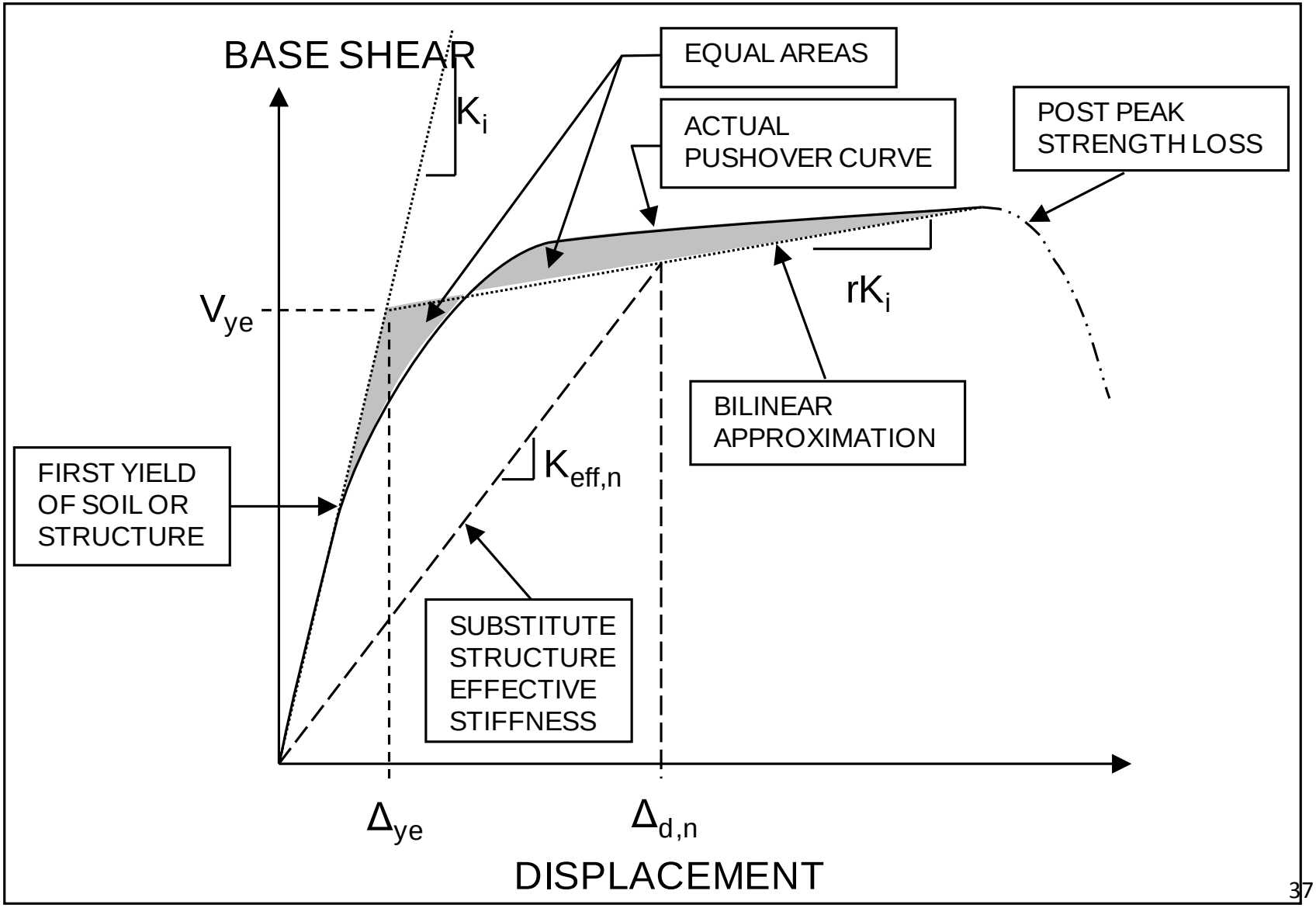
FORCE-BASED STRUCTURAL DESIGN

- Methods of ASCE 7-05
- R values limited
  - Wanted to make force-based design more conservative
- But,
- Removed some conservatisms from ASCE 7
  - Artificial period limitations

DISPLACEMENT-BASED STRUCTURAL DESIGN

- Not intended to be simple
  - Design for service loads already done
  - Preliminary design done for basic pile layout using simpler methods
- Modelling considerations
- Capacity analysis
  - Pushover or time history
- Demand analysis
  - Pushover, response spectrum, or time history

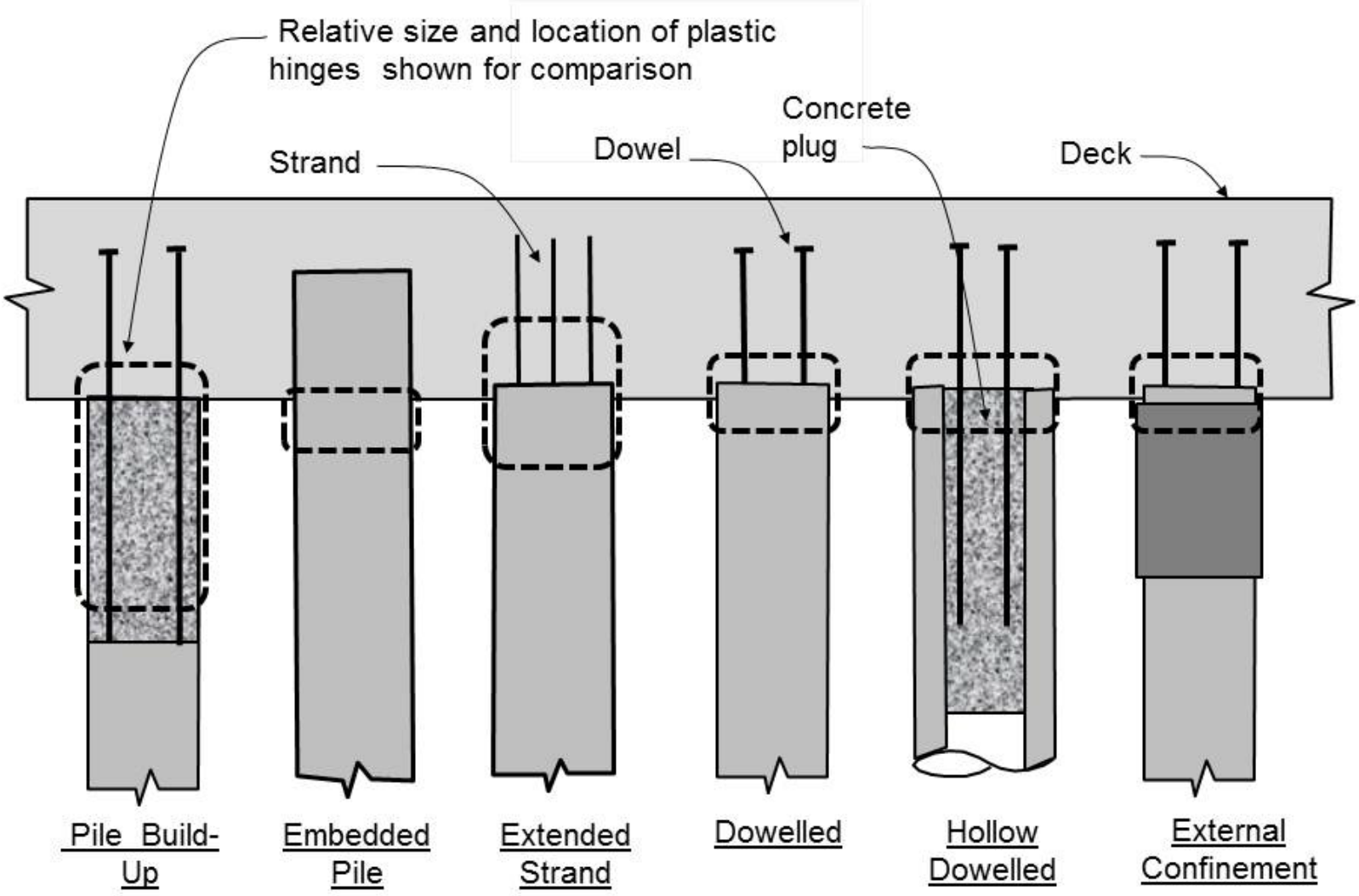
EFFECTIVE STIFFNESS - PUSHOVER MODEL



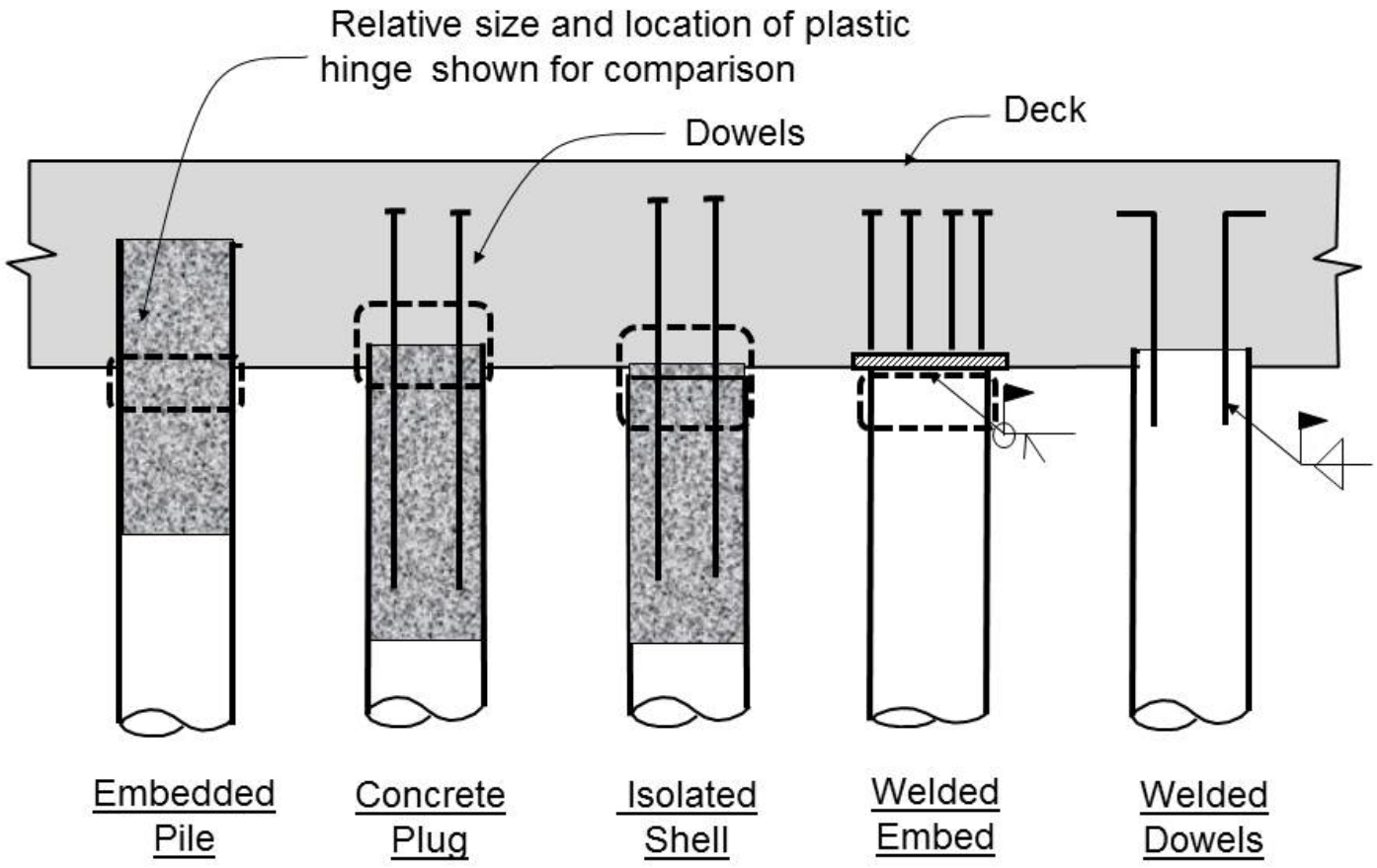
DETAILING

- Several types of connections specifically allowed
- Tried to capture common connection details used in practice throughout US
- Recognized that not everything can be covered
- Guidance in Commentary for predicting behavior when testing data not sufficient

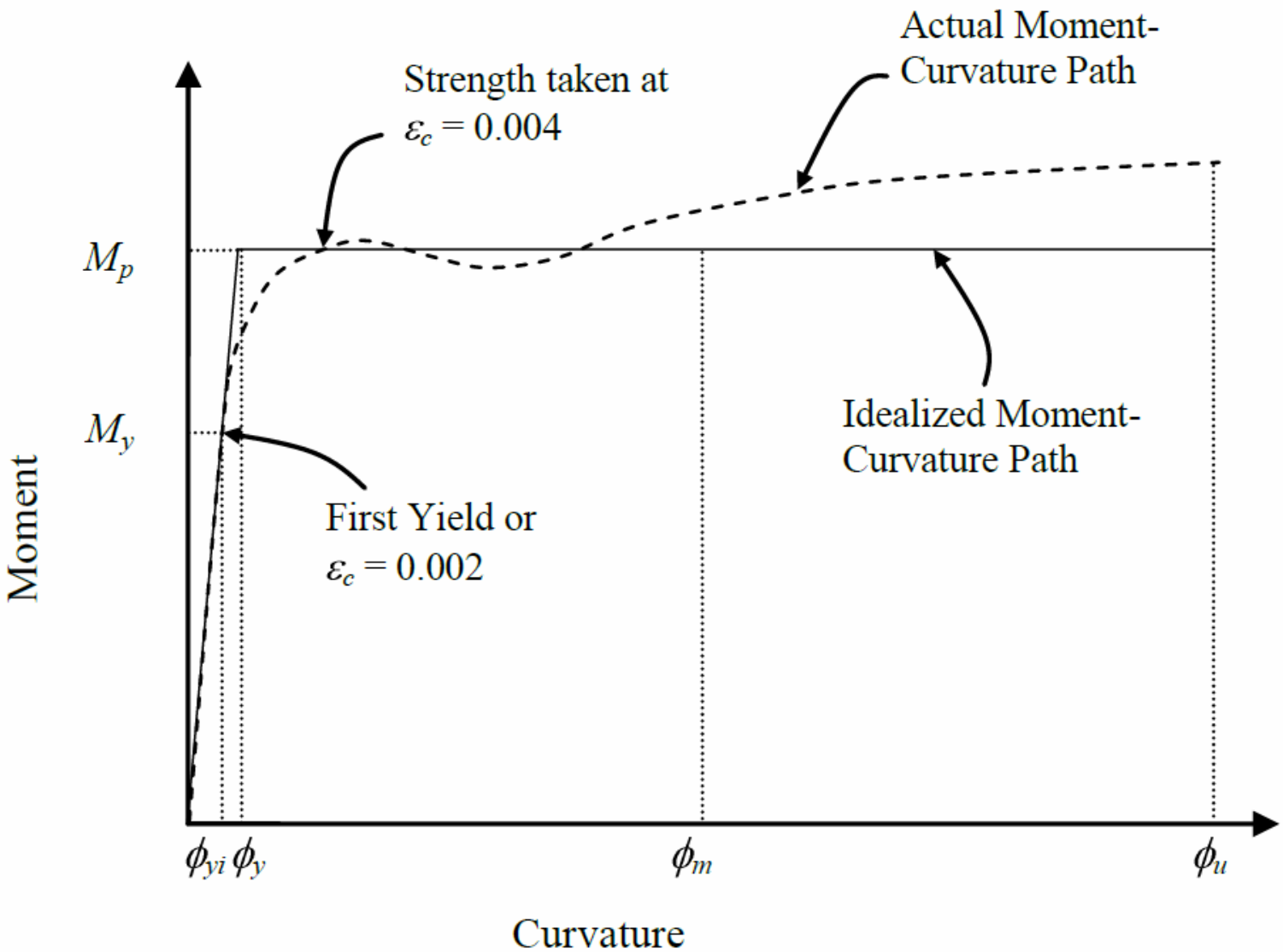
PRESTRESSED CONCRETE PILE CONNECTIONS



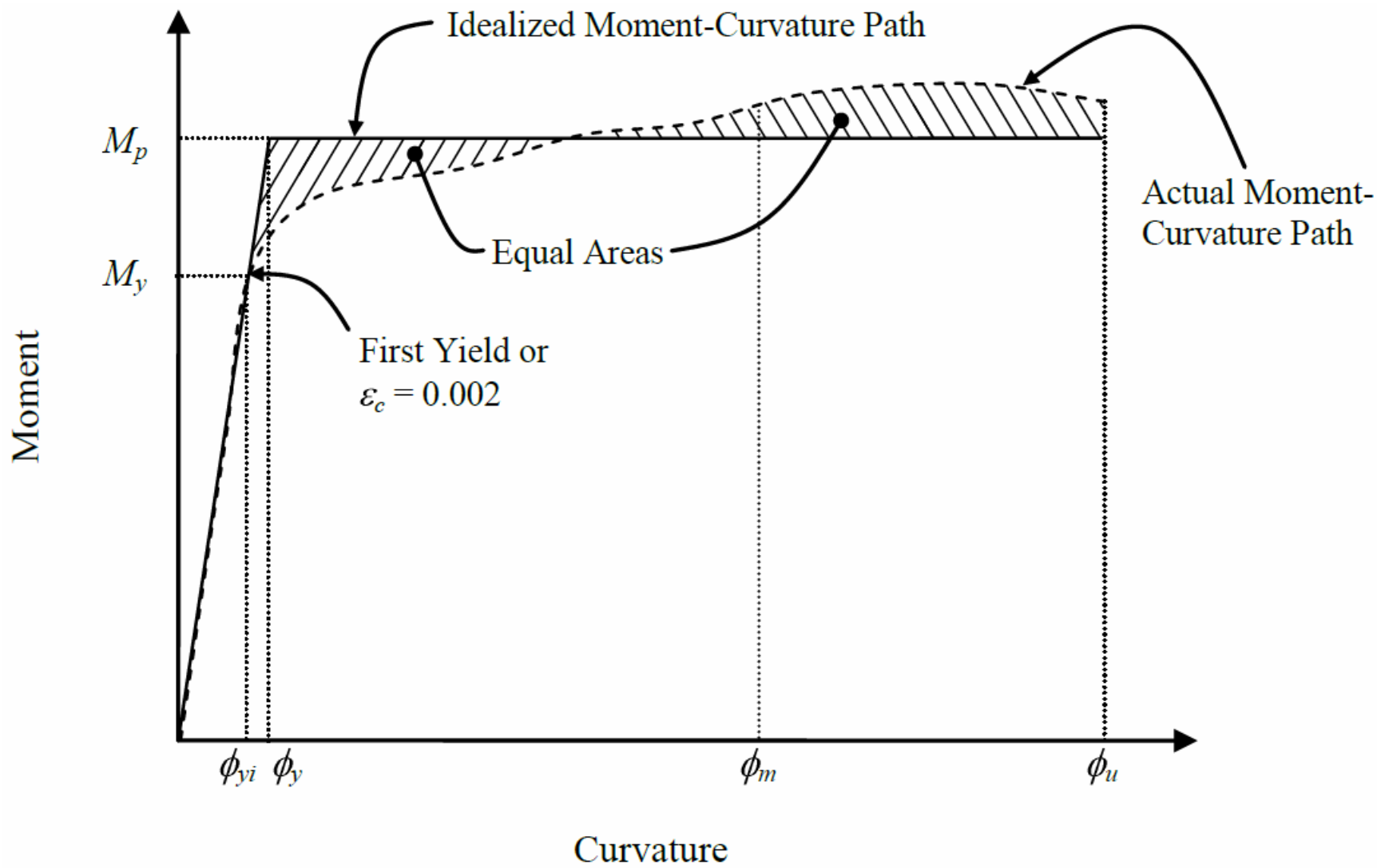
STEEL PIPE PILE CONNECTIONS



MOMENT CURVATURE – METHOD A (SPALLING)



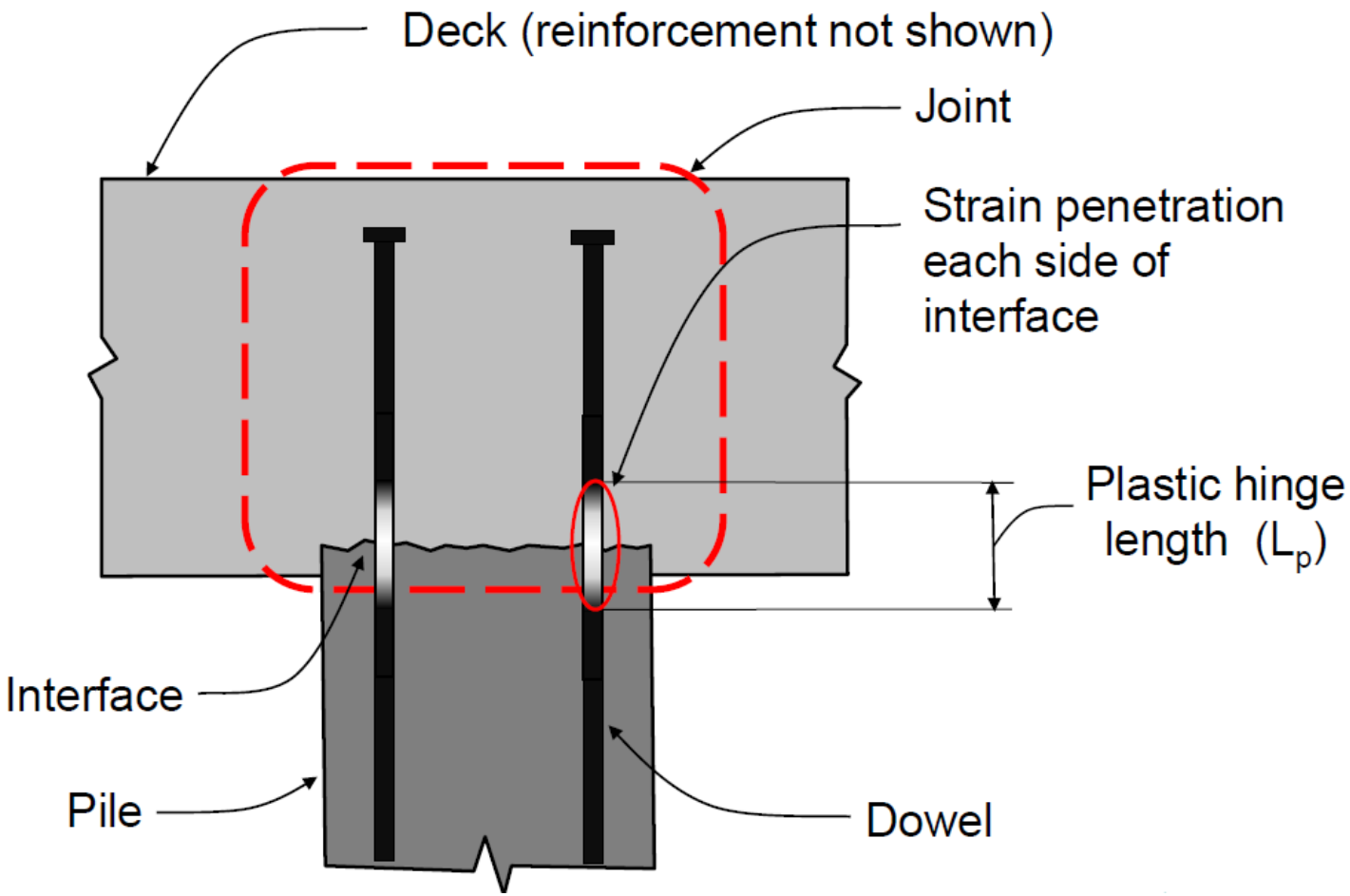
MOMENT CURVATURE – METHOD B (NO SPALLING)



DOCUMENT STYLE

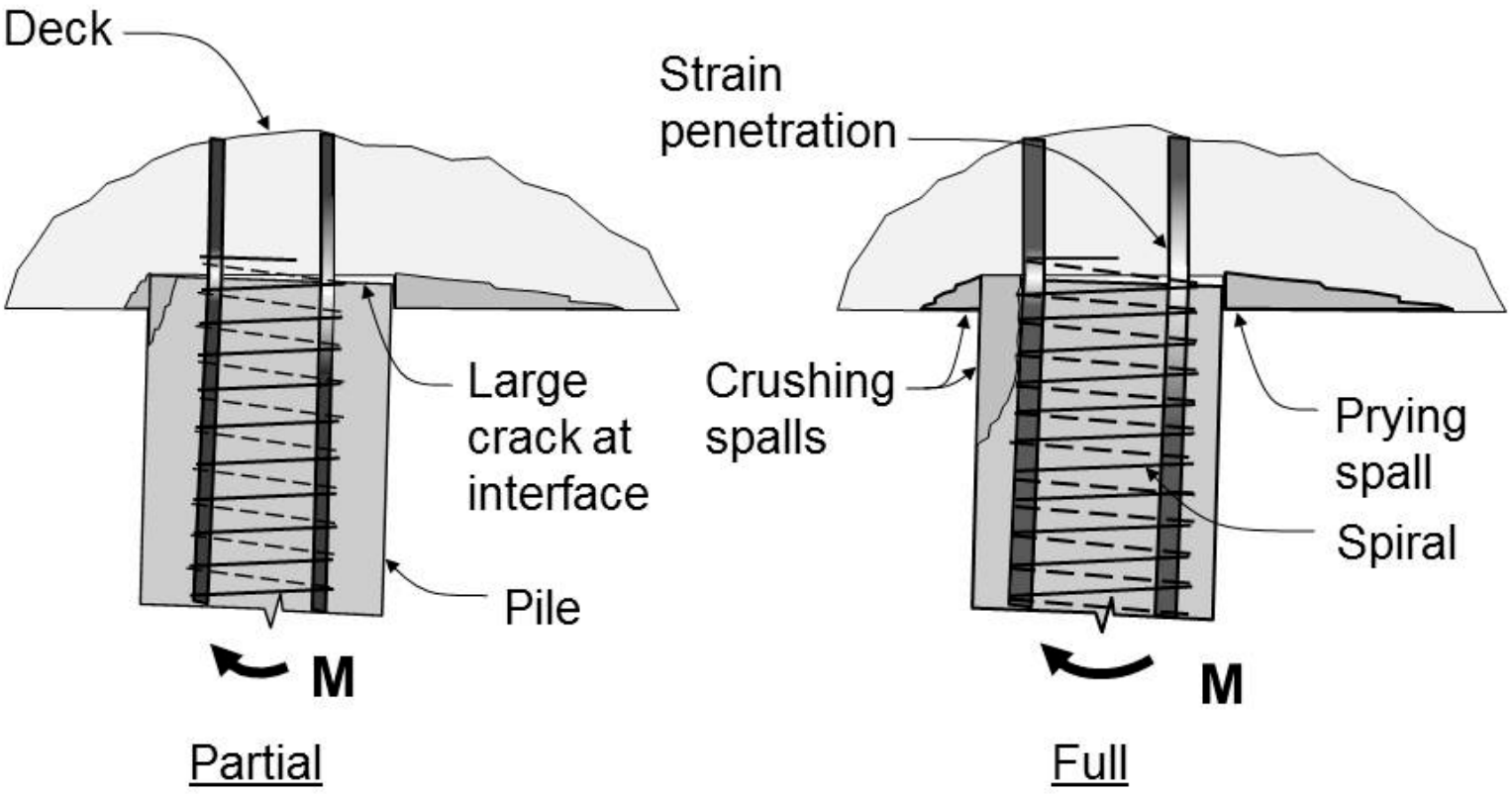
- Mandatory code language in the Provisions
- Written for experienced engineers, <u>not</u> as a cookbook
- Lots of figures where we felt it was necessary
- Substantial commentary

PILE TO DECK CONNECTION TERMINOLOGY

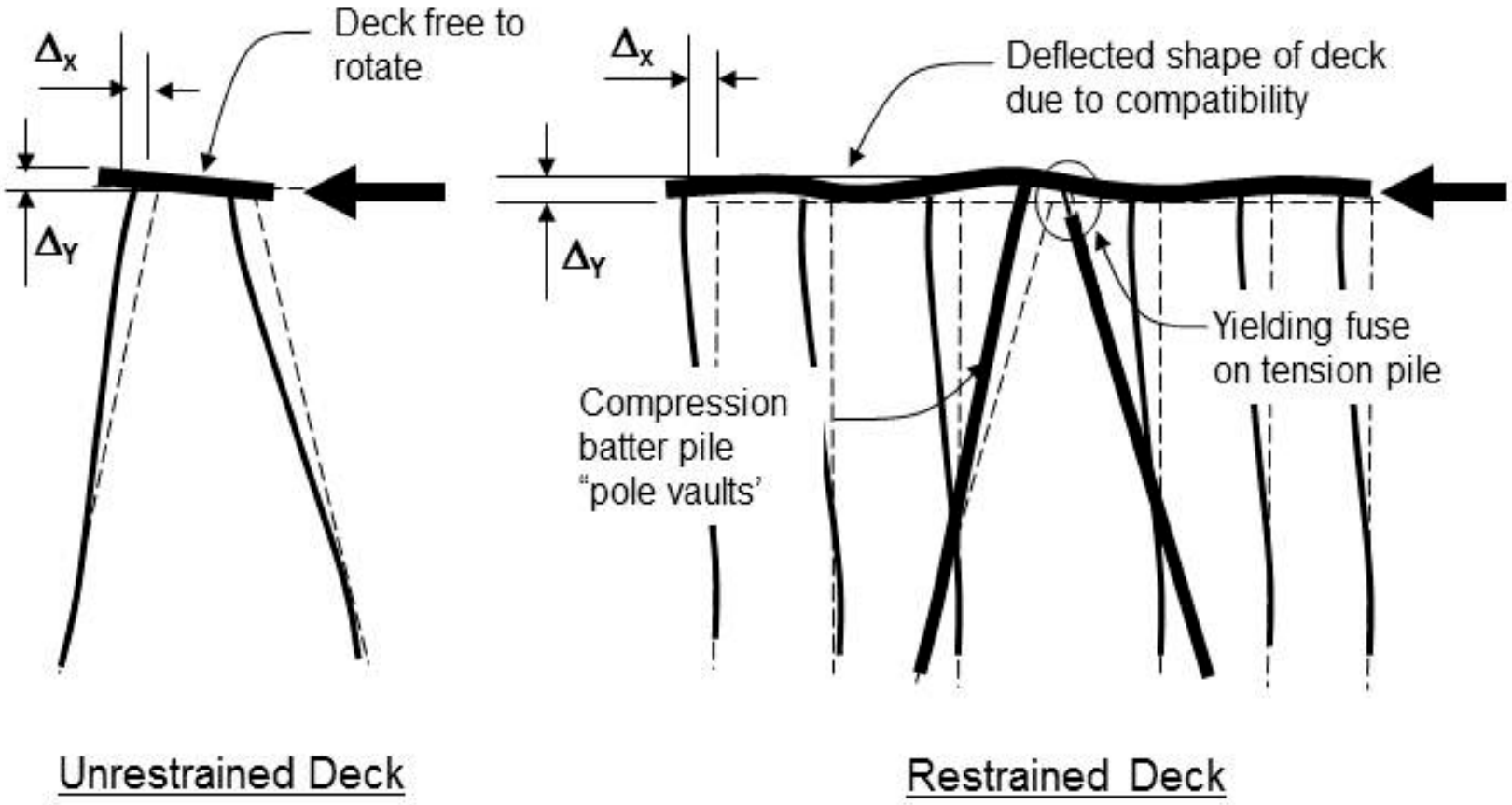


COMMENTARY: PARTIAL VS FULL MOMENT CONNECTIONS

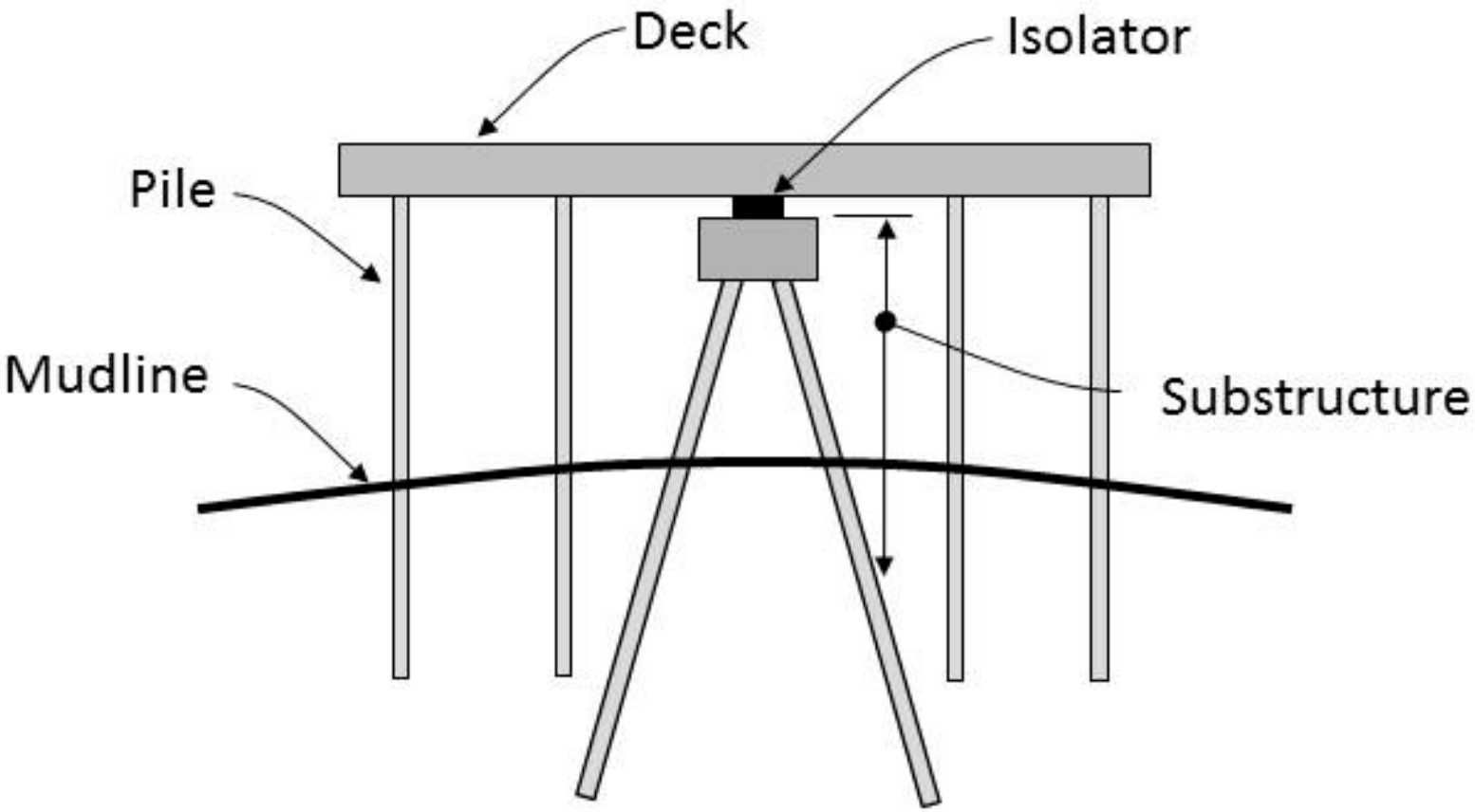
- Full – Interface has same strength as body of pile
- Partial – Underreinforced at interface



OTHER ISSUES: BATTER PILES



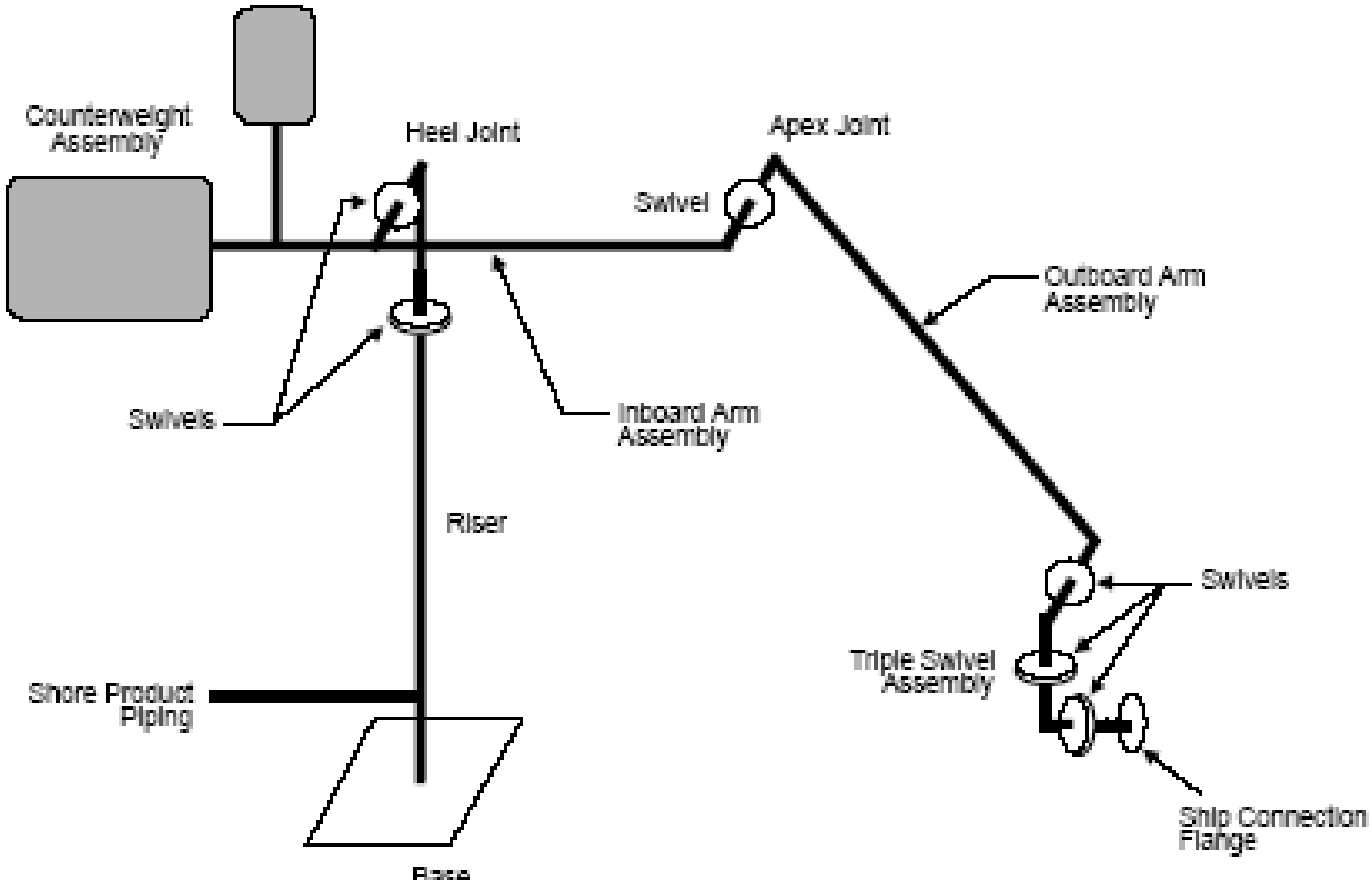
OTHER ISSUES: BASE ISOLATION



LAST BUT NOT LEAST: ANCILLARY STRUCTURES

- Specifically covered 3 main items:
  - Pipelines
  - Cranes
  - Marine Loading Arms

MARINE LOADING ARMS



WHAT'S NEXT ?

- ASCE 61-19
- Bulkheads
- Revisit ground motions
- Fun starts again November 6 !!!

SPECIAL THANKS

- Nate Lemme
- Bob Harn
- Cheng Lai / POLB

- Our friends from ASCE 7
  (for their hundreds of “helpful” Public Comments)