August 2024

WG225 -Seismic Design Guidelines for Port Structures

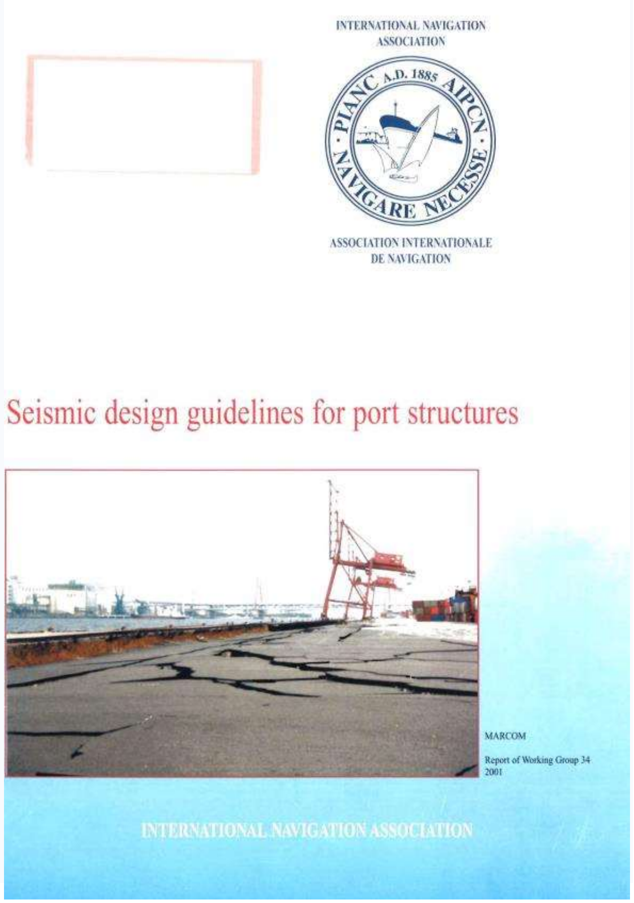
Work in Progress Update

Delivering Solutions, Changing the World.℠

KBR CONFIDENTIAL

Agenda

- Introduction
- Purpose
- Guidelines update summary



INTERNATIONAL NAVIGATION
ASSOCIATION

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Seismic design guidelines for port structures

MARCOM

Report of Working Group 34
2001

INTERNATIONAL NAVIGATION ASSOCIATION

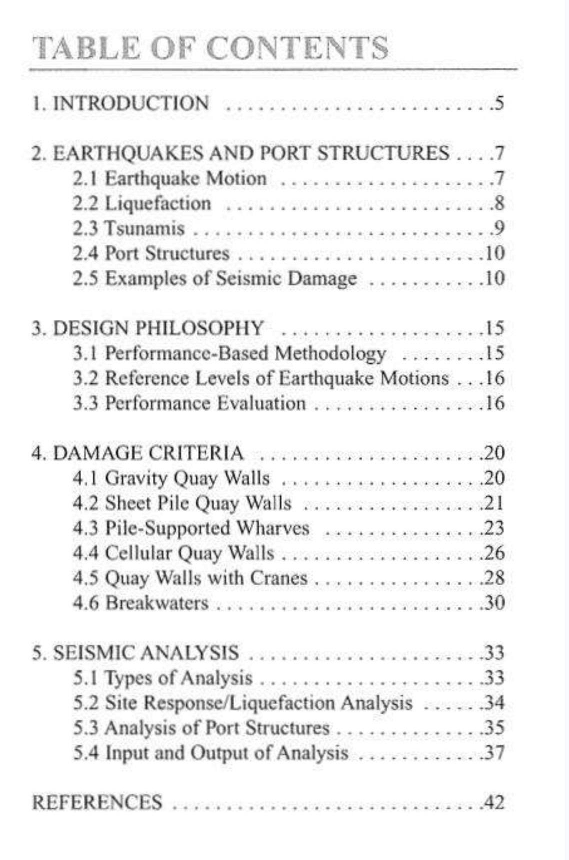
Introduction

- The current PIANC 2001 Report (WG34) reflect lessons learned from the 1995 Kobe earthquake disaster (6,400fatalities and over $100b).
- New codes and standards, reports
  - OCDI: 2020 – Technical standards and commentaries for port and harbour facilities in Japan
  - ASCE 61-2014 Seismic Design of Piers and Wharves
  - KYDY: 2020 – Coastal Structures Earthquake Regulation(Turkey)
  - MOTEMS: 2022 – Marine Oil Terminal Engineering and Maintenance Standards
  - AS1170.4-2007 Amd 2:2018 Structural design actions

Introduction

- How does this guideline contribute to the advancement of the industry and profession?
  - a practical guidance on best practice approaches
- Does the guideline implement new and innovative techniques, materials, technologies, and delivery methods?
  - combine and reflect the current best practices used worldwide
- What was the most challenging aspect of the guideline and how it is being handled to ensure success?
  - melding the various approaches used worldwide to reflect a consistent concept
- Who is the target audience for this guideline?
  - Marine infrastructure facility owners / operators, designers / practitioners, regulators, scientists / academia

WG34-2001



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WG225 Chapters

- Chapter 1: Introduction
  - Discussion of intent and scope
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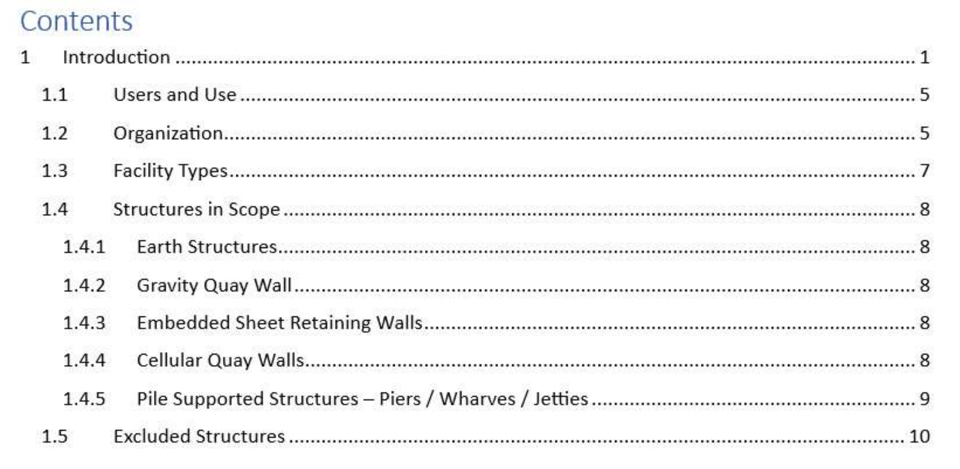
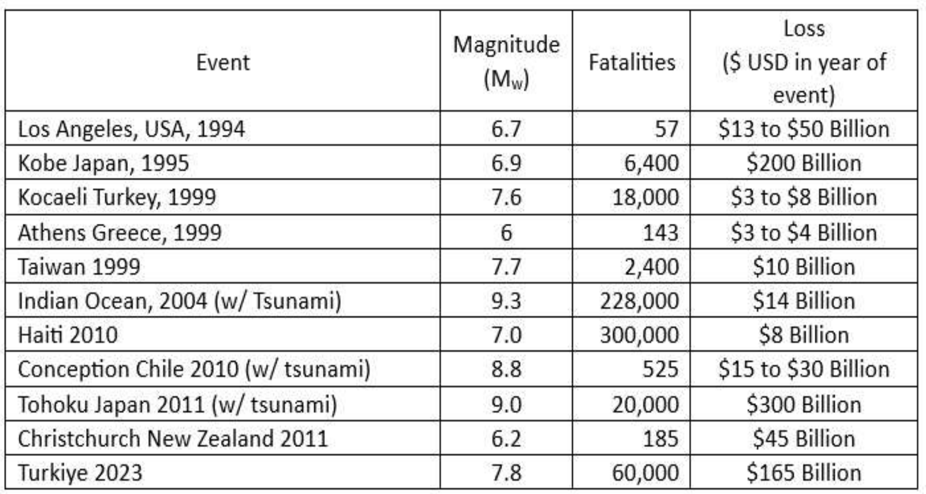
  - Discussion of earthquake hazards and how those hazards influence port structure response
- Chapter 3: Design Philosophy
  - Discussion of design criteria utilized to determine performance objectives and demand design events
- Chapter 4: Damage Criteria
  - Discussion of acceptable design criteria for different functions and type of structures
- Chapter 5: Seismic Action
  - Discussion on geotechnical inputs and seismic soil characterisation
- Chapter 6: Seismic Analysis
  - Discussion of methodologies for analysis of each structural type
- Chapter 7: Best practices in Design
  - Discussion of ductile detailing and lessons learned

WG225 – Chapter 1: INTRODUCTION



Contents

Example of Significant Historic Events



Event	Magnitude (M_w)	Fatalities	Loss ($ USD in year of event)
Los Angeles, USA, 1994	6.7	57	$13 to $50 Billion
Kobe Japan, 1995	6.9	6,400	$200 Billion
Kocaeli Turkey, 1999	7.6	18,000	$3 to $8 Billion
Athens Greece, 1999	6	143	$3 to $4 Billion
Taiwan 1999	7.7	2,400	$10 Billion
Indian Ocean, 2004 (w/ Tsunami)	9.3	228,000	$14 Billion
Haiti 2010	7.0	300,000	$8 Billion
Conception Chile 2010 (w/ tsunami)	8.8	525	$15 to $30 Billion
Tohoku Japan 2011 (w/ tsunami)	9.0	20,000	$300 Billion
Christchurch New Zealand 2011	6.2	185	$45 Billion
Turkiye 2023	7.8	60,000	$165 Billion

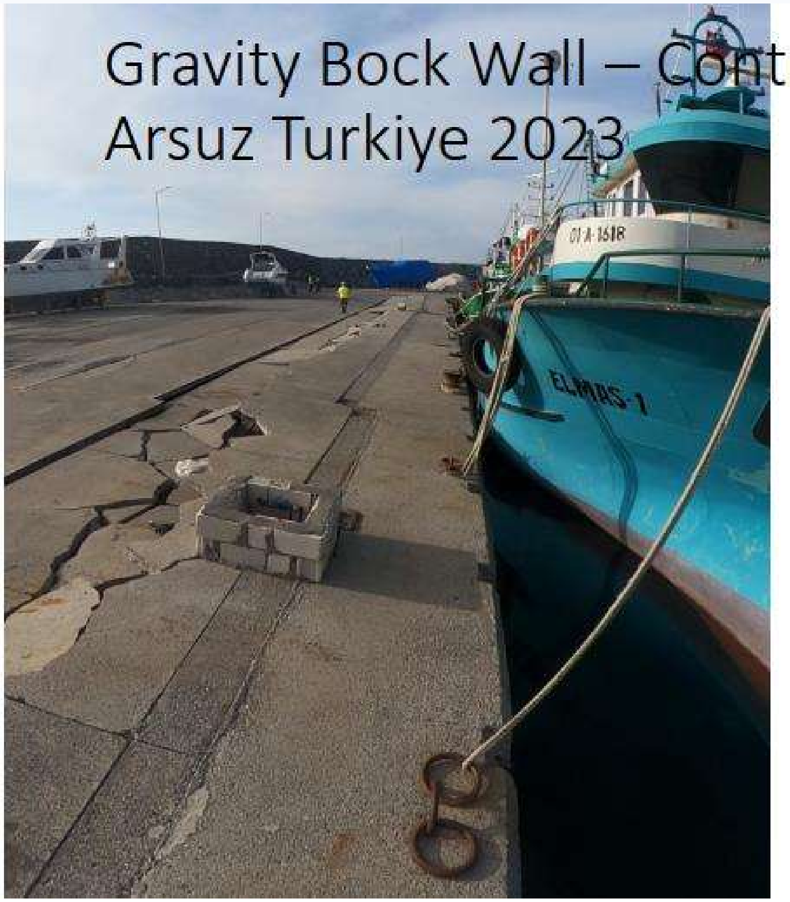
Significant earthquakes since PIANC 2001 report

Damage sustained by a building in Concepción, located around 100 kilometres south of the epicenter.

Pile Supported Pier and Wharves –
Controlled and Repairable Structural Damage
San Vicente Chile 2010

Significant earthquakes since PIANC 2001 report

Gravity Bock Wall – Controlled and Repairable
Arsuz Turkiye 2023



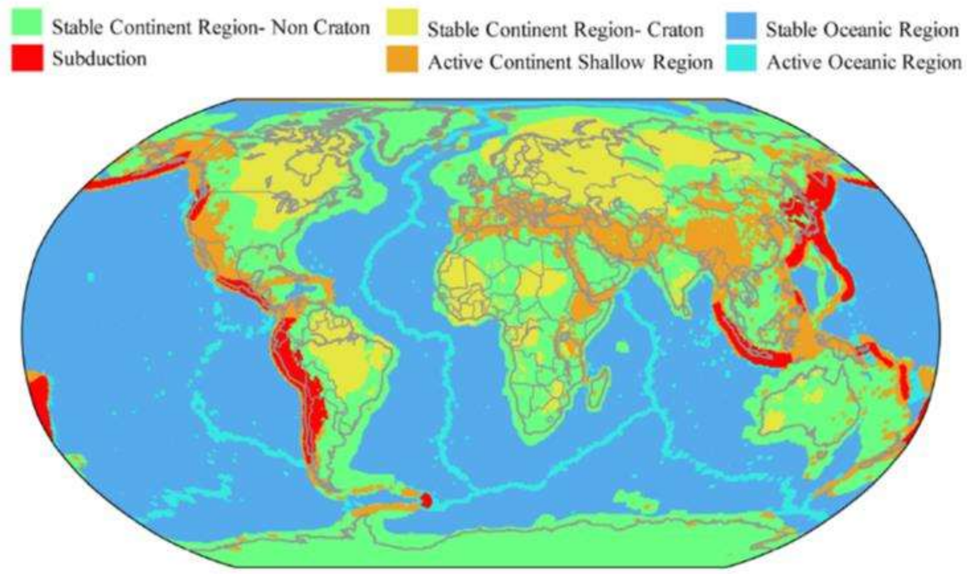
Significant earthquakes since PIANC 2001 report

Pile Supported Pier and Wharves –
Minimal Structural Damage
Severe Equipment Damage
Soma Japan 2011

Significant earthquakes since PIANC 2001 report

The coast in Wajima, Ishikawa Prefecture, was uplifted by up to 4 meters in the Jan. 1 Noto Peninsula earthquake. (Provided by Geological Survey of Japan, AIST)

WG225 – WORKING DRAFT – Chapter 1

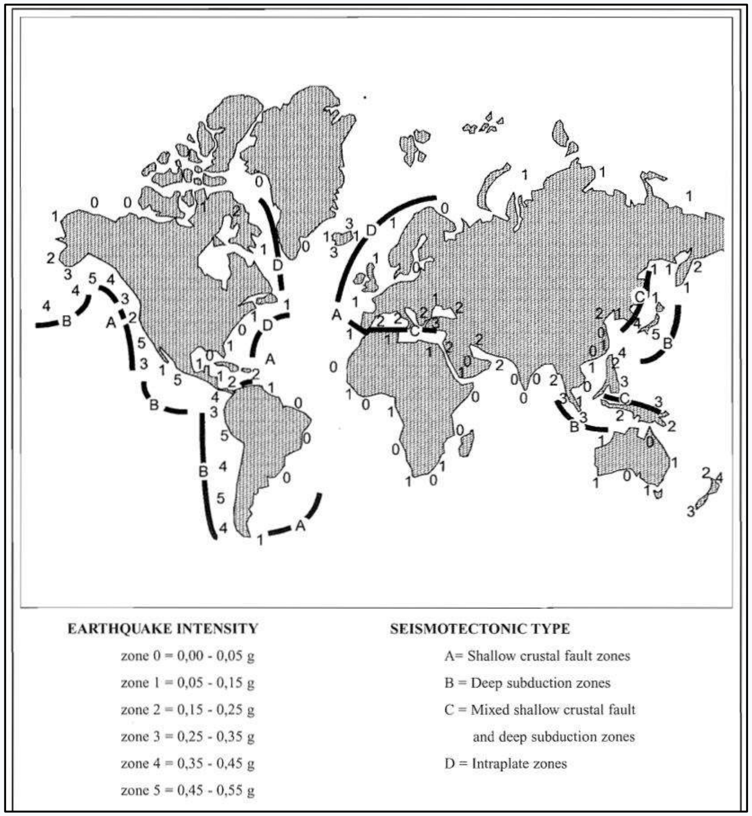


(b)

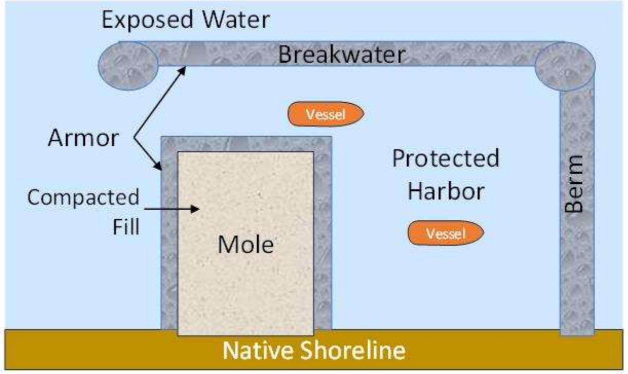
NOTE: Values of horizontal acceleration corresponding to a return period of 475 years.

Figure 1-1: (a). Global seismic hazard map of the world (from K. Johnson, M. Villani, K. Bayliss, C. Brooks, S. Chandrasekhar, T. Chartier, Y. Chen, J. Garcia-Pelaez, R. Gee, R. Styron, A. Rood, M. Simionato, M. Pagani (2023). Global Earthquake Model (GEM) Seismic Hazard Map (version 2023.1 - June 2023), DOI: https://doi.org/10.5281/zenodo.8409647) (b). Global tectonic regionalization model (from Y.-S. Chen, G. Weatherill, M. Pagani, F.Cotton (2018). A transparent and data-driven global tectonic regionalization model for seismic hazard assessment, Geophysical Journal International, Volume 213, Issue 2, May 2018, Pages 1263–1280, https://doi.org/10.1093/gji/ggy005)

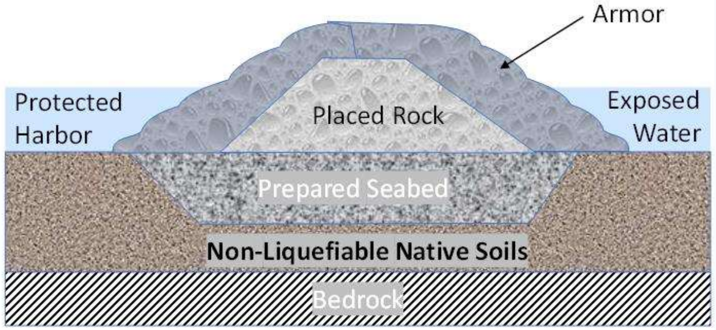
WG34



WG225 – WORKING DRAFT – Chapter 1



a) Plan view of Example Earth Structures



b) Section view of Example Earth Structure

Figure 1-3: Examples of Earth Structures

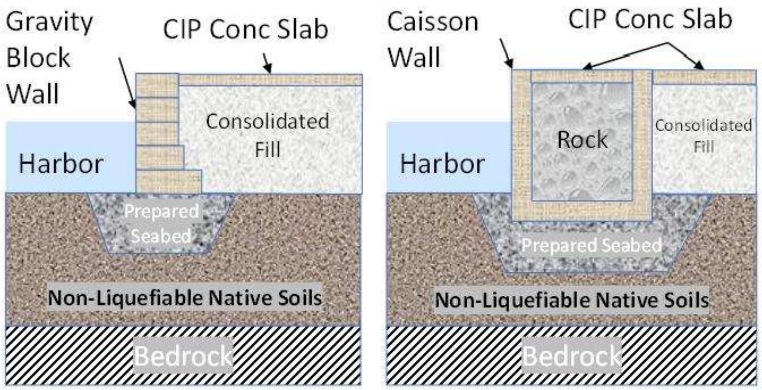


Figure 1-3: Examples of Gravity Quay Wall Systems

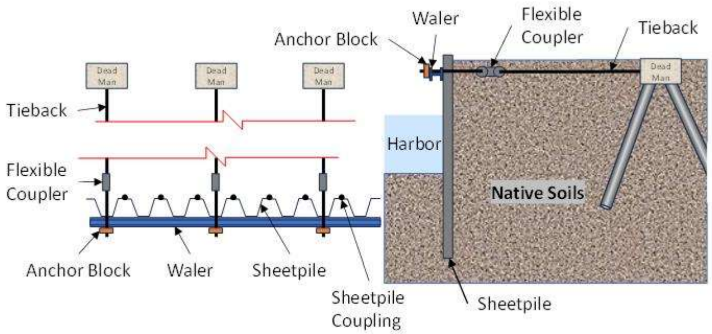
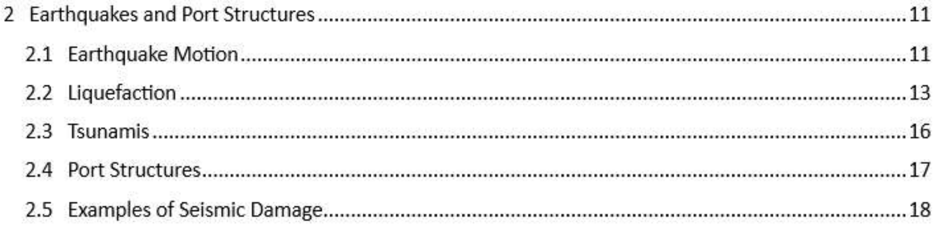


Figure 1-3: Examples of Embedded Sheet Retaining Wall Systems

WG225– Chapter 2:EARTHQUAKES AND PORT STRUCTURES



Mechanism of Liquefaction and Consequences

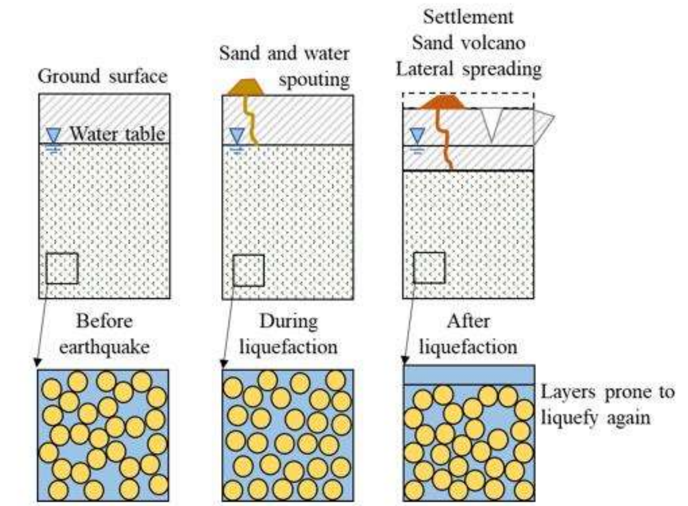


Fig. 2.3 - Mechanism of liquefaction and consequences

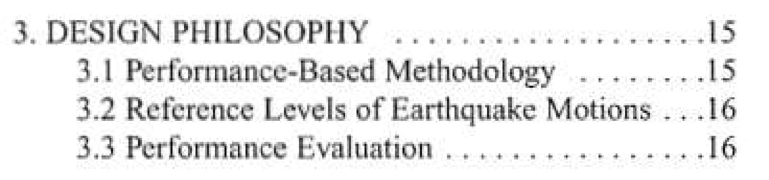
WG225– Chapter 2:EARTHQUAKES AND PORT STRUCTURES

2016 M7.8 Earthquake, Wellington Centreport

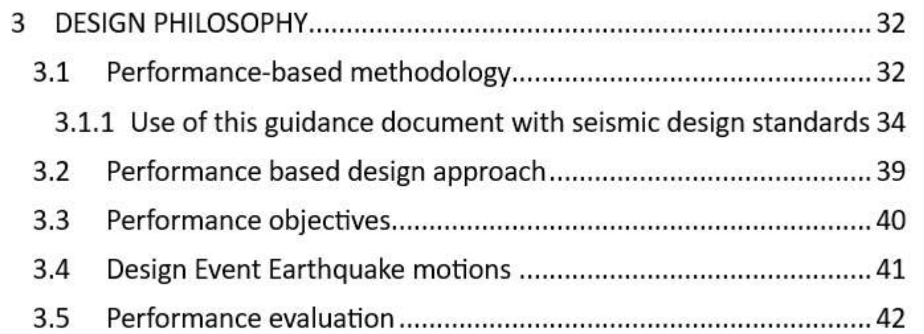
2010 M7.0 Earthquake Port-au-Prince, Haiti

WG225– Chapter 3:DESIGN PHILOSOPHY

WG34-2001



WG225-Working Draft



- Design standards with performance-based seismic provisions have been published
- Performance-based design involves
  - assign a performance grade
  - obtain the associated performance objectives for various earthquake events
  - for each performance objective obtain the limiting damage criteria: typically maximum strain, stress or stability requirements for structural performance, and displacements / settlements for functional performance
  - carry out analysis / design to verify structural and functional limits are not exceeded for the corresponding earthquake events

WG225– Chapter 3:DESIGN PHILOSOPHY

Redefining the Levels of Earthquake motions:
~~Level 1 & Level 2~~

a) The level of earthquake motions that are likely to occur during the life-span of the structure, typically having 50% probability of exceedance during the lifetime of the structure;

b) The level of earthquake motions associated with infrequent rare events, that typically involve very strong ground shaking, typically having a probability of exceedance between 10% and 2% during the lifetime of the structure;

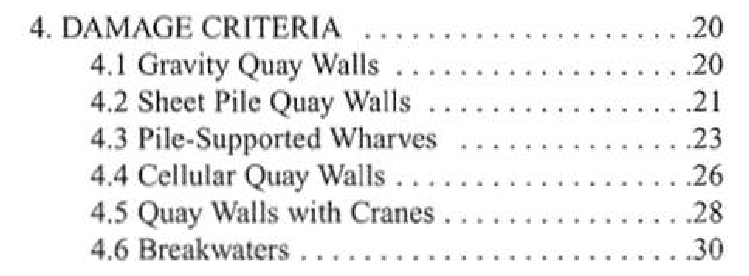
c) Possible intermediate level(s) of earthquake motions with probability of exceedance between a) and b)

Use of Guidelines:

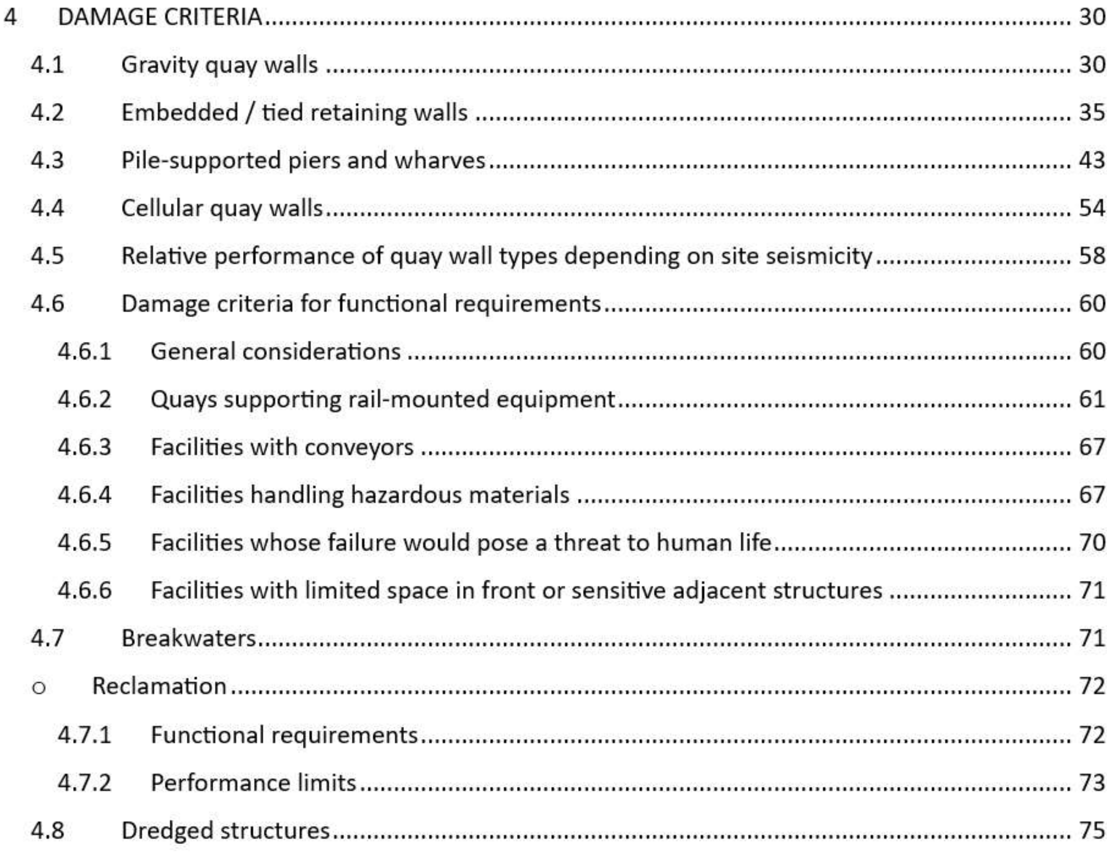
- Always the national general standard should be complied as minimum;
  - Check if there any seismic provisions
  - If not, use this guideline in addition to the national general standard, if deemed necessary by the engineer

WG225– Chapter 4:DAMAGE CRITERIA

WG34-2001

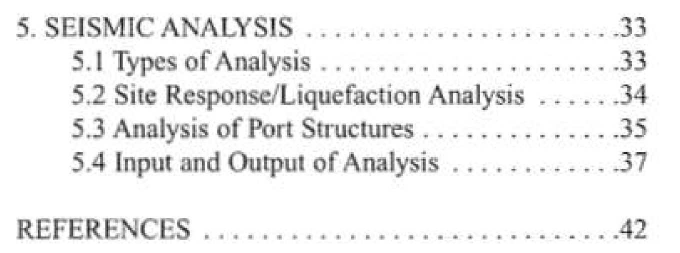


WG225-Working Draft

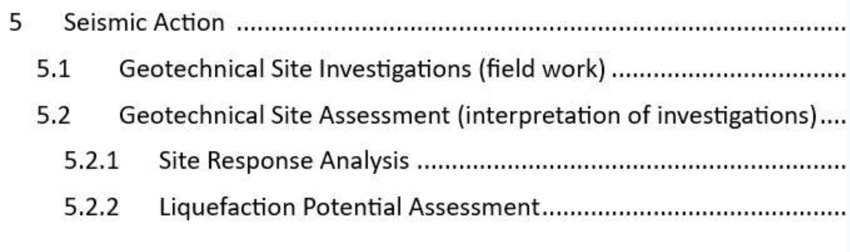


WG225– Chapter 5:Seismic Action, Chapter 6: Seismic Analysis

WG34-2001



WG225-Working Draft



WG225-Working Draft

WG225–Chapter 6: Seismic Analysis

Analysis Method Selection – Types of Analyses

				Increasing Risk -->			
			Risk:	Low	Moderate	High	Special
			Performance Grade:	C	B	A	S
			Earthquake Exposure:	Low Sa < 33%	Moderat to High		
				Method Use at Design Level			
Structure Type	**Analysis Method**	**Damage Allowance:**	**System Complexity**	-	-	-	-
Bulkhead	Leastic Pseudo Static	No Damage	Simple	FINAL	NA	NA	NA
	Nonlinear Pseudo Static	Minor to Extenive	Moderate	FINAL	FINAL	Preliminary	Preliminary
	Newmark	Minor to Extenive	Moderate	FINAL	FINAL	FINAL	FINAL
	Nonlinear Dynamic (Time History)	Minor to Collapse	High	FINAL	FINAL	FINAL	FINAL
Pile Supported	Equivalent Lateral Force (Elastic)	No Damage	Regular SDOF	FINAL	NA	NA	NA
	Response Spectrum Anlaysis (Elastic)	Minor to Extenive	Elastic MDOF	FINAL	FINAL	FINAL	Preliminary
	Nonlinear Static (Pushover)	Minor to Extenive	Plastic SDOF	FINAL	FINAL	FINAL	FINAL
	Linear Dynamic (Time History)	No Damage	Elastic MDOF	FINAL	FINAL	FINAL	FINAL
	Pushover and RSA Combination	Minor to Extenive	Plastic MDOF	FINAL	FINAL	FINAL	FINAL
	Nonlinear Dynamic (Time History)	Minor to Collapse	Plastic MDOF	FINAL	FINAL	FINAL	FINAL

Notes:

Preliminary = analysis method appropriate for initial concept to 30% design levels

FINAL = analysis method appropriate for final design construction documents

NA = analysis method not applicable for stated conditions

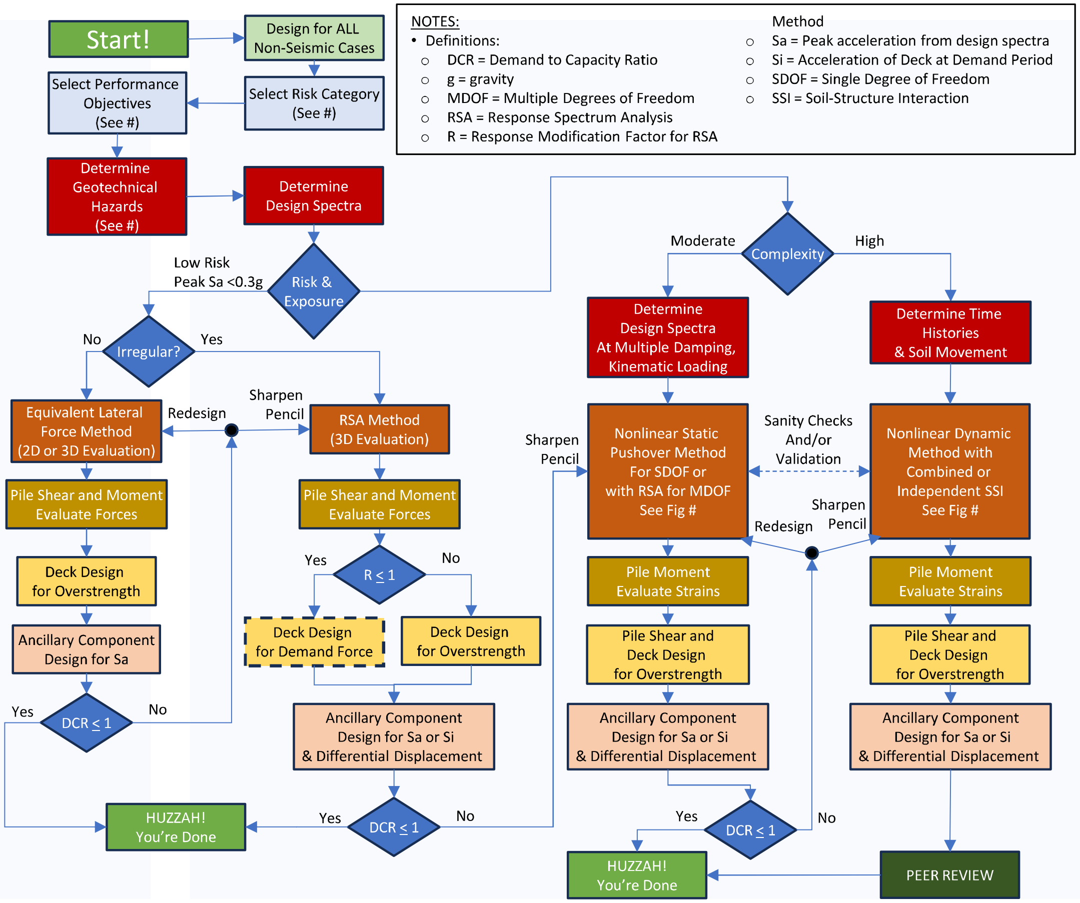
Sa = peak site response spectra acceleration (% gravity)

SDOF = Single Degree of Freedom System

MDOF = Multi Degree of Freedom System

WG225–Chapter 6: Seismic Analysis

Analysis Method Selection – Pile Supported wharves



NOTES:

- Definitions:
  - DCR = Demand to Capacity Ratio
  - g = gravity
  - MDOF = Multiple Degrees of Freedom
  - RSA = Response Spectrum Analysis
  - R = Response Modification Factor for RSA

Method
  - Sa = Peak acceleration from design spectra
  - Si = Acceleration of Deck at Demand Period
  - SDOF = Single Degree of Freedom
  - SSI = Soil-Structure Interaction

Start!

Design for ALL Non-Seismic Cases

Select Risk Category (See #)

Select Performance Objectives (See #)

Determine Geotechnical Hazards (See #)

Determine Design Spectra

Risk & Exposure

Low Risk Peak Sa <0.3g

Irregular?

No

Yes

Equivalent Lateral Force Method (2D or 3D Evaluation)

Redesign

Sharpen Pencil

RSA Method (3D Evaluation)

Pile Shear and Moment Evaluate Forces

Deck Design for Overstrength

Ancillary Component Design for Sa

Yes

DCR ≤ 1

No

HUZZAH! You're Done

Pile Shear and Moment Evaluate Forces

Yes

R ≤ 1

No

Deck Design for Demand Force

Deck Design for Overstrength

Ancillary Component Design for Sa or Si & Differential Displacement

Yes

DCR ≤ 1

No

Complexity

Moderate

High

Determine Design Spectra At Multiple Damping, Kinematic Loading

Determine Time Histories & Soil Movement

Sharpen Pencil

Nonlinear Static Pushover Method For SDOF or with RSA for MDOF See Fig #

Sanity Checks And/or Validation

Nonlinear Dynamic Method with Combined or Independent SSI See Fig #

Redesign

Sharpen Pencil

Pile Moment Evaluate Strains

Pile Moment Evaluate Strains

Pile Shear and Deck Design for Overstrength

Pile Shear and Deck Design for Overstrength

Ancillary Component Design for Sa or Si & Differential Displacement

Ancillary Component Design for Sa or Si & Differential Displacement

Yes

DCR ≤ 1

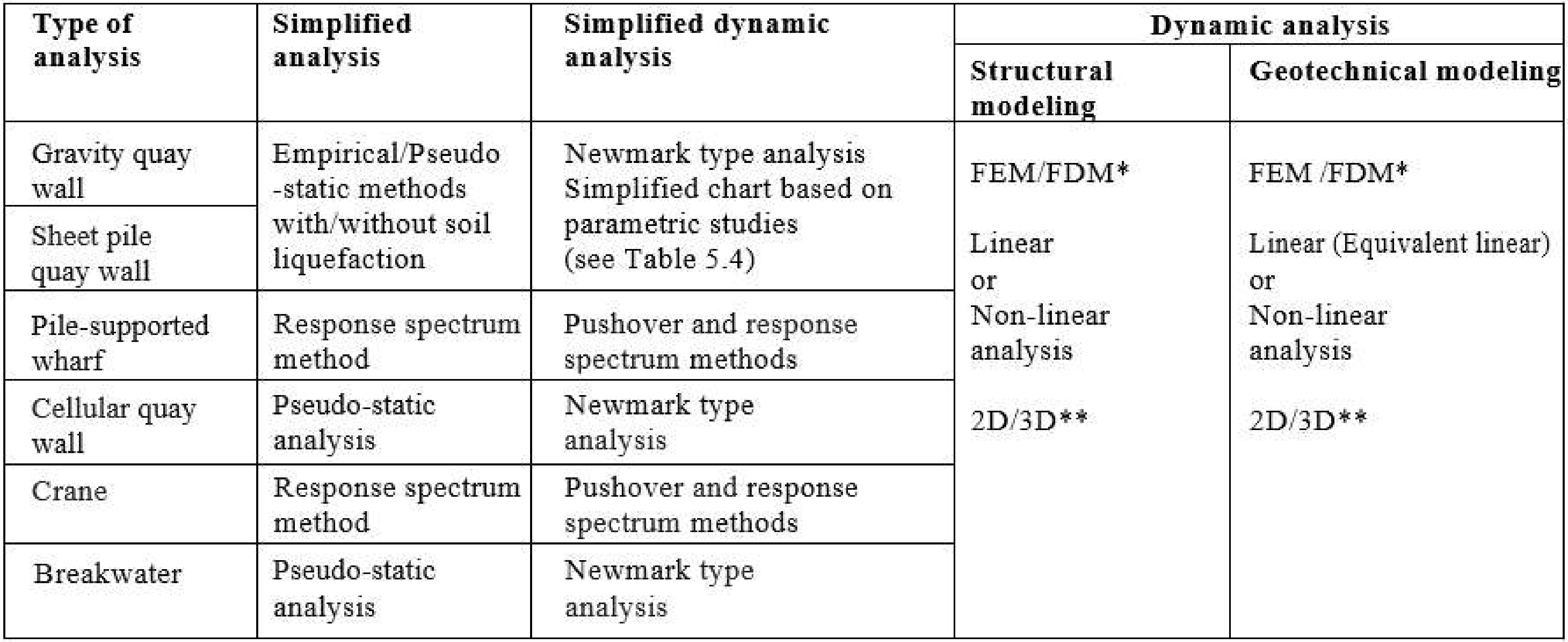
No

HUZZAH! You're Done

PEER REVIEW

WG225–Chapter 6: Seismic Analysis

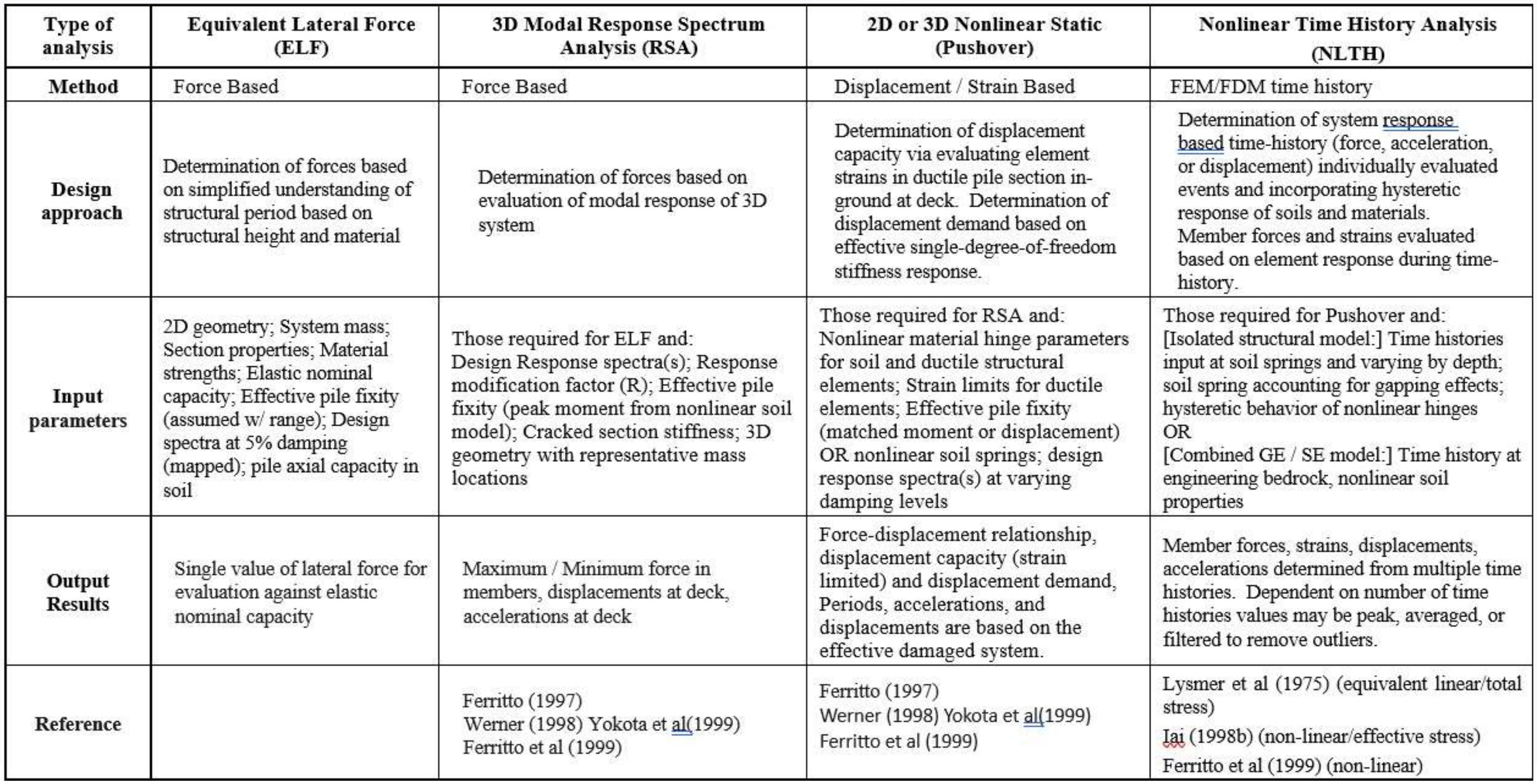
Analysis Methods for Port Structures



Type of analysis	**Simplified analysis**	**Simplified dynamic analysis**	**Dynamic analysis**	
			Structural modeling	**Geotechnical modeling**
Gravity quay wall	Empirical/Pseudo -static methods with/without soil liquefaction	Newmark type analysis Simplified chart based on parametric studies (see Table 5.4)	FEM/FDM* Linear or Non-linear analysis 2D/3D**	FEM /FDM* Linear (Equivalent linear) or Non-linear analysis 2D/3D**
Sheet pile quay wall				
Pile-supported wharf	Response spectrum method	Pushover and response spectrum methods		
Cellular quay wall	Pseudo-static analysis	Newmark type analysis		
Crane	Response spectrum method	Pushover and response spectrum methods		
Breakwater	Pseudo-static analysis	Newmark type analysis		

WG225–Chapter 6: Seismic Analysis

Summary of Approaches for Pile supported Structures



Type of analysis	**Equivalent Lateral Force (ELF)**	**3D Modal Response Spectrum Analysis (RSA)**	**2D or 3D Nonlinear Static (Pushover)**	**Nonlinear Time History Analysis (NLTH)**
Method	Force Based	Force Based	Displacement / Strain Based	FEM/FDM time history
Design approach	Determination of forces based on simplified understanding of structural period based on structural height and material	Determination of forces based on evaluation of modal response of 3D system	Determination of displacement capacity via evaluating element strains in ductile pile section in-ground at deck. Determination of displacement demand based on effective single-degree-of-freedom stiffness response.	Determination of system response based time-history (force, acceleration, or displacement) individually evaluated events and incorporating hysteretic response of soils and materials. Member forces and strains evaluated based on element response during time-history.
Input parameters	2D geometry; System mass; Section properties; Material strengths; Elastic nominal capacity; Effective pile fixity (assumed w/ range); Design spectra at 5% damping (mapped); pile axial capacity in soil	Those required for ELF and: Design Response spectra(s); Response modification factor (R); Effective pile fixity (peak moment from nonlinear soil model); Cracked section stiffness; 3D geometry with representative mass locations	Those required for RSA and: Nonlinear material hinge parameters for soil and ductile structural elements; Strain limits for ductile elements; Effective pile fixity (matched moment or displacement) OR nonlinear soil springs; design response spectra(s) at varying damping levels	Those required for Pushover and: [Isolated structural model:] Time histories input at soil springs and varying by depth; soil spring accounting for gapping effects; hysteretic behavior of nonlinear hinges OR [Combined GE / SE model:] Time history at engineering bedrock, nonlinear soil properties
Output Results	Single value of lateral force for evaluation against elastic nominal capacity	Maximum / Minimum force in members, displacements at deck, accelerations at deck	Force-displacement relationship, displacement capacity (strain limited) and displacement demand, Periods, accelerations, and displacements are based on the effective damaged system.	Member forces, strains, displacements, accelerations determined from multiple time histories. Dependent on number of time histories values may be peak, averaged, or filtered to remove outliers.
Reference		Ferritto (1997) Werner (1998) Yokota et al(1999) Ferritto et al (1999)	Ferritto (1997) Werner (1998) Yokota et al(1999) Ferritto et al (1999)	Lysmer et al (1975) (equivalent linear/total stress) Iai (1998b) (non-linear/effective stress) Ferritto et al (1999) (non-linear)