
James O. Malley
Degenkolb Engineers
And
Jon A. Heintz
Applied Technology Council

SEAOC Convention, September 2008
PBE as Applied to Tall Building Design

- Some present provisions in ASCE 7 are challenging to tall building design
  - Limits system choices (Dual Systems, e.g.)
    - Significant impact to economics and architectural expression in many cases
- Performance Based Engineering (PBE)
  - Used on many major projects to demonstrate performance equivalent to code intent
  - No standards on how to implement
    - LATBSDC and City of SF AB-083 provide guidance
  - Peer Review required, but can be inconsistent
Issues in Tall Building Design

• Building systems and materials
• Performance objectives and hazard considerations
• Ground motion time histories, including basement effects
• Modeling, simulation and acceptance criteria
• Instrumentation

SEAOC Convention, September 2008
PEER Tall Buildings Initiative

• Goal is to develop PBE based guidelines that:
  – Promote consistency in design approaches
  – Facilitate design and review
  – Help ensure safety and performance objectives of stakeholders are met

• Tasks are the following:
  – Task 1 - Establish advisory committee
  – Task 2 – Develop consensus on performance objectives

SEAOC Convention, September 2008
PEER Tall Buildings Initiative (Cont.)

- Tasks (cont.):
  - Tasks 3 through 6 – Development of guidelines on ground motions for design
  - **Task 7 – Guidelines on modeling and acceptance**
  - Task 8 – Input ground motions for buildings with subterranean levels
  - Task 9 – Presentation at conferences, etc.
  - Task 10 – Development of design framework and publication of design guidelines
Task 7 of PEER TBI

• Focus is on developing technical information on modeling, simulation and acceptance criteria (NOT specifically design)
  – Primary audience is Task 10 guidelines writers

• Two Subtasks
  – Workshop on design and analysis Issues
  – Development of technical information
  – ATC is subcontractor to PEER TBI for Task 7
Task 7 Team

- Greg Deierlein, Stanford
- Helmut Krawinkler, Stanford
- Joe Maffei, Rutherford and Chekene
- Mehran Pourzanjani, Saiful/Bouquet
- John Wallace, UCLA
- Jon Heintz, ATC
- Jim Malley, Degenkolb

SEAOC Convention, September 2008
Task 7.1 (ATC 72-1) - Workshop

- Thirty plus designers, regulators and researchers participated
- Many issues discussed, with focus on
  - Reinforced concrete wall systems
  - Inelastic element response modeling
  - Effects of podium on force transfers, etc.
  - Capacity Design
  - Damping, P-Delta, etc.

SEAOC Convention, September 2008
ATC 72-1 Organization

- Chapter 1 – Background and Context
- Chapter 2 – General Modeling Issues (GD/HK)
- Chapter 3 – Nonlinear Properties Characterization (HK/GD)
- Chapter 4 – Modeling Wall Systems and Components (JW)
- Chapter 5 – Floor Diaphragms, Collectors, Podium and Backstay Effects (J Maf.)
- Chapter 6 – Issues not addressed

SEAOC Convention, September 2008
Chapter 2 – General Modeling Issues

- Overview of Modeling Issues for NLRHA
  - Types of models, energy dissipation vs. damping, gravity load effects, acceptance criteria
- Deterioration
  - Modes, sources, consequences, modeling
- P-Delta Effects
- Damping
  - Sources, survey of assumptions, measurement, modeling, recommendations
- Expected Properties and Uncertainty

SEAOC Convention, September 2008
General Modeling Approaches

• Discusses various options for element models
• Hysteretic energy dissipation vs. viscous damping
• Gravity effects
Response Deterioration

• Monotonic vs. cyclic
• Element vs. global
• Accounting for deterioration?
  – If not, limit drifts
  – If so, how?
  – Capping point is key
  – Sensitivity analyses needed

SEAOC Convention, September 2008
Damping

- Maybe most interesting discussion of entire process
- Hysteretic vs. viscous
- Rayleigh vs. Mass proportional
- Must deal with period range of interest
- Survey of other work

\[ D = \frac{\alpha}{N} \]

*Where* \( N \) = no. of stories

Dual Systems (RC core wall plus RC or steel frame): \( \alpha = 130 \)
- RC MF Systems: \( \alpha = 100 \)
- RC core wall systems: \( \alpha = 80 \)
- Steel MF Systems: \( \alpha = 80 \)
- Steel BF Systems: \( \alpha = 70 \)
Chapter 3 – Characterizing Nonlinear Component Properties

• Important parameters
  – Discussion of general issues, modeling and acceptance criteria for each of elements below
• Steel beams and columns
• Steel joint panel zones
• RC beams, columns and joints
• Axially loaded steel braces
Steel Elements – Beams and Columns

- Compilation of previous results
  - Moment frame beams
- Recent tests from UCSD on column ductility
- Strong column-weak beam comparison
- Recommendations on deterioration modeling

SEAOC Convention, September 2008
Steel Joint Panel Zones

- Modeling recommendations for stiffness and capacity
- Comparison to present provisions
- Limitations on rotations for MCE analyses to avoid fracture induced by “kinking”

SEAOC Convention, September 2008
RC Beams and Columns

- Beam stiffness, capacity and deterioration all addressed
  - Bond-slip, yield penetration, etc.
- Columns as well, including influence of axial force
- ASCE 41-07 referenced
Chapter 4 – Wall Systems and Components

• Modeling approaches for planar and core walls
  – Beam-column, fiber and FEM models, shear deformations, axial-flexure-shear coupling

• Assessment of modeling for planar and flanged walls
  – Effective stiffness, sensitivity

• Coupling beams
  – Design requirements, behavior, modeling

• Behavior of core wall systems
  – Configuration, geometry, behavior

• Slab-column frame modeling
  – ASCE 41-06, modeling

SEAOC Convention, September 2008
Slab-Column Frames – Gravity System

- Deformation compatibility required
- Use of effective slab width model
  - To model coupling of core walls with frame
  - Check failure modes and shear at interface

SEAOC Convention, September 2008
Typically use a more refined mesh where yielding is anticipated; however, nonlinear strains tend to concentrate in a single element, thus, typically use an element length that is approximately equal to the plastic hinge length (e.g., 0.5\(l_w\)). Might need to calibrate them first (this is essential).

Calibration of fiber model with test results, or at least a plastic hinge model, is needed to impose a “reality” check on the element size and integration points used.

SEAOC Convention, September 2008
Planar, Flanged and Core Walls

- Extrapolation?
- Varying response
- Stiffness/capacity
- Deterioration
- Shear behavior models are tricky, and response coupling even trickier

SEAOC Convention, September 2008
Coupling Beams

• Diagonal vs. rectangular reinforcing
• Modeling approaches
• Comparison to ASCE 41
• Recent tests results
• Influence of axial loads

SEAOC Convention, September 2008
Chapter 5 – Diaphragms, Collectors
Podium, Backstay Effects

• Common conditions
• Backstay effects
  – Variation in response depending on system
• Additional effects of configuration
  – Non-podium buildings, setbacks
• Multiple towers on common base
• Buildings on sloping sites
• Capacity design
  – Bracketing assumptions
• Role of diaphragms and collectors
• Recommended properties

SEAOC Convention, September 2008
Podium and Backstay Effects

- Reverse shear and diaphragm demands
  - Wall and foundation stiffness and transfers
- Setback diaphragms
- Outriggers (not shown)
Capacity Design Concepts

• Ensure anticipated inelastic response (location and type)
• Bracketing assumptions for sensitivity analyses
  – Capacity
  – Stiffness
• Two stage design process
• Use of NLRH

SEAOC Convention, September 2008
Transfer Diaphragm Modeling

- Strut and Tie Models
- Consideration of openings – local shears
- Collector/chords, including eccentricities

SEAOC Convention, September 2008
Chapter 6 – Recommendations for Additional Study

• Bi-axial effects in columns, shear walls
• Soil foundation interface, uplift
• Variation in axial force
• Non-conforming components
• Local failure modes and detailing effects
• Dispersion of geotechnical properties
• Other issues identified by Workshop
PEER TBI Guidelines Development

• Underway. Initial draft in October, 2008
• Ron Hamburger leading writing team
• Primary audience of designers and regulators
• Completion in mid-2009

• TOC
  – Introduction
  – Design Objectives
  – Design Process Overview
  – Design Criteria
  – Seismic Input
  – Preliminary Design
  – Service Level Evaluation
  – Collapse Level Evaluation
  – Presentation of Results
  – Project Review

SEAOC Convention, September 2008
Conclusions

• ATC 72 –1 will provide detailed information on modeling and acceptance criteria. Completion later this year.
• Topics of primary interest in most recent tall building design being addressed
• Many topics still need further development and others not addressed
• PEER TBI guidelines document coming in mid-2009