PERFORMANCE-BASED SEISMIC DESIGN

JOE FERZLI, PE, SE
Performance-Based Seismic Design
**CODE VS PBSD**

**CODE**

**LAYOUT**

**PBSD**

**LAYOUT**
Governing Standards

ASCE Standard
ASCE/SEI 7-16

Minimum Design Loads and Associated Criteria for Buildings and Other Structures

TBI
Tall Buildings Initiative
Guidelines for Performance-Based Seismic Design of Tall Buildings

Version 2.01
May 2017

Developed by
Pacific Earthquake Engineering Center
Report No. 2017-20

Sponsored by
Charles Pankow Foundation
ACI Foundation (Concrete Research Council)
American Institute of Steel Construction
Federal Emergency Management Agency
Structural Engineering Institute of ASCE (SEI)
Structural Engineers Association of California

AN ALTERNATIVE PROCEDURE FOR SEISMIC ANALYSIS AND DESIGN OF TALL BUILDINGS LOCATED IN THE LOS ANGELES REGION

A CONSENSUS DOCUMENT

2017 Edition

June 8, 2017
**Shear Wall Behavior**

Concrete core wall without openings (Cantilever wall)

Concrete shear wall with openings (Coupled Wall)

Flexural plastic hinge location, detailed for ductility

Plastic hinge locations at coupling beams and base of wall
Coupled Walls
CORE WALL CONFIGURATIONS
Building Seismic Performance

Building Performance Levels

<table>
<thead>
<tr>
<th>Ground Motion Levels</th>
<th>Building Performance Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Level Earthquake</td>
<td>Immediate Occupancy</td>
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<tr>
<td>(43 years)</td>
<td>Life Safety</td>
</tr>
<tr>
<td>Design Earthquake (2/3 MCE_R)</td>
<td>Collapse Prevention</td>
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<tr>
<td>(~700 years)</td>
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<tr>
<td>Risk Adjusted Maximum</td>
<td></td>
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<tr>
<td>Considered Earthquake, MCE_R</td>
<td></td>
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<tr>
<td>(~2,000 years)</td>
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</tbody>
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Core Shear Comparison

- Shear, X-Dir (M+S)
- Shear, Y-Dir (M+S)

The diagram shows the comparison of core shear in X and Y directions (M+S) across different levels.
CORE GEOMETRY STUDY
CORE SHEAR COMPARISON

- Three Coupling Beams
- One Coupling Beam
**Dynamic Amplifications**

\[ V_b = \frac{M_{pr,CS}}{h_{eff}} \]
Dynamic Amplifications
Diagonally Reinforced Coupling Beams
**Diagonally Reinforced vs. SFRC Coupling Beams**

Diagonally Reinforced Concrete Coupling Beam

Steel Fiber Reinforced Concrete (SFRC) Coupling Beam
Bekaert Dramix® Steel Fibers

Diameter: 0.015"
Length: 1.18"
Strength: 445 ksi
Material: ASTM A820
Dosage: 1.5% by volume
= 200 #/YD³
**Coupled Wall Test**

- Conventional RC Coupling Beam
- SFRC Coupling Beam
SFRC Coupling Beam Testing

Tested with Aspect Ratios
[1.75  2.75  3.3]

3% Drift

5% Drift
**SFRC Coupling Beams**

**Figure 13.45** Coupling beam design space.

- (a) Special moment frame beam
- (b) Diagonally reinforced
- (c) At designers discretion
- (d) Strut and tie
- (e) Not permitted
- (f) Designs w/in shaded region may have constructability problems
3D Perform Model
**Analytical Model Calibration**

Moment vs Rotation
SFRC Test Specimen, L/h = 2.75

- Test Specimen
- Nonlinear Model
**Design Procedure of SFRC Beam**

- Full coupling beam section is active for resisting shear (reinforcement steel and concrete).
- Shear steel reinforcement shall be greater than 40% of design $V_{PR}$.
- The remainder of shear attributed to SFRC $\leq 3 \sqrt{f'_c}$.
- $V_{FRC} - V_{PR} - V_S < 3 \sqrt{f'_c}$.
- $V_S > 40\% \ V_{PR}$.
- $V_{PR} = 2*M_{PR} + V_{GRAVITY}$.
- Full Confinement.
- Two Critical Sections for Moment.
SFRC Coupling Beams Application
Performance-Based Seismic Design

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