Recentering PT Walls for Enhanced Seismic Resilience

Leo Panian, SE

TIPPING
STRUCTURAL ENGINEERS

2016 Convention | PT Buildings II
63% probability of M6.7+ earthquakes in the SF Bay Area in the next 30 years

Resilient design is sustainable, seismically durable design
Buildings and communities “bouncing back” - not just survival
Seismic Performance of Concrete Structures

Design codes are no guarantee

Serious vulnerabilities in existing and new construction

Individual building response vs. community resilience

From Life-Safety to Life Resumption
Inspiration and Adaptation

Shinbashira - traditional timber mast

Tough and damage resistant

Self-centering behavior

Maintains structural integrity

Protects building systems:
- Cladding
- Elevators
- Interiors
Concrete Mast

Cast-in-place cantilever wall with unbonded post-tensioning (SRCSW)

PT provides elastic restoring force

Mild steel yields to absorb energy

PT Wall Advantages

Self-centering
Reduced rebar congestion
Stronger and more compact
Reduced damage
PT Wall Components

High strength, green concrete

Multi-strand post-tensioning tendons and anchors

Heads & couplers in critical zones
PT Wall Design

0.5\textquoteright\ or 0.6\textquoteright\ diameter strands ASTM A416, Gr 270

Unbonded tendons distribute strains over entire length

Stressed to 0.6 to 0.8f_{pu}
Recentering Response

PT only

Mild-steel only

Combined

Rocking + Yielding = Hybrid

Post-tensioning: Non-linear, Elastic
Mild Reinforcement: Non-linear, Inelastic
Combined PT-CIP: Inelastic Self-Centering

a) Flexural Response of Unbonded P.T. Wall
b) Flexural Response of Conventional R.C. Wall
c) Combined Response of Unbonded PT-CIP Wall
Recentering Parameter

Post tensioning ratio:

\[ \gamma_{PT} = \frac{A_{PT} f_{PTi}}{A_{PT} f_{PTi} + A_s f_y} \]
Inelastic Mechanism Study

Proportioned for flexural yielding

Well defined plastic hinge zone, confined boundaries

Capacity design, avoid shear failure, web crushing

Protect PT tendons - slenderness
Design Rules

M.J.N. Priestley
G.M. Calvi
M.J. Kowalsky

Displacement-Based
Seismic Design of Structures

Seismic Design of Reinforced
Concrete Buildings

...don’t just call is special, make it special
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## PT Wall Systems - Design Parameters

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PT Wall Systems - Design Parameters

David Brower Center

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SFPUC Headquarters

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Prescriptive Approach

Meets Special Concrete Shear Wall criteria in ACI 318 Chapter 21

PT in combination with mild steel for shear walls explicitly addressed in ACI 318 Section 18.11.2.3

“...the design and detailing for the post-tensioned concrete walls meet the requirements of the building code”

“...the structural concrete walls are detailed to meet the requirements for Special Concrete Walls contained in ACI 318-05 Chapter 21”
Resources
PT Wall Systems

- Planar walls
- Basement lock off
- Anchorage blockouts
PT Wall System

Core walls

Composite link beams

Micropiles for overturning
UCB Haas School - North Academic Building

Recentering PT Wall System
UCB Haas School - Typical Floor Plan

24" THICK WALLS, TYP
Self-centering PT concrete walls

Design CBC 2013 / ASCE-7 / ACI-318

Special RC shear walls:
\[ R = 6 \quad \Omega = 2\% \]
\[ C_d = 5 \]
\[ \rho = 1.3 \quad I = 1.25 \]

Explicitly proportioned for flexure

Well-defined plastic hinges

Capacity designed
Haas NAB - PT Wall Analysis

Concrete Shear Walls

Non-Linear Model
Haas NAB - NLA Results

Peak H1 Interstory Drift, Mean Response

Peak H2 Interstory Drift, Mean Response
PT Wall Construction
Loop Anchors
Loop Anchors
Stressing Anchors
Fabrication & Assembly
Fabrication & Assembly
Anchorage & Stressing Blockout
Anchorage & Stressing Blockout
Tendon Assembly
Tendon Installation
Base Anchorage Blockout
Stressing Procedure
Tendon Installation & Stressing
Retrofit Application

Individually sheathed and greased strand bundles
Retrofit Application

Placed with rebar
Stressing Anchors for Retrofit
Green at Its Core
An innovative and robust seismic frame is a key part of a San Francisco office building’s sustainable strategy and its bid for LEED Platinum, by Joanne Gerosch, AIA

POSTPONED AND HEAVILY-REVISIONED. The project that caused controversy and led to the cancellation of the 2018 edition of the 2019 edition of Architectural Record, will now be published in 2020. The project, a building in the heart of the city, was designed by the firm of SOM and will be completed in 2020.

Learning objectives:
1. Describe the firm’s design and construction strategies.
2. Explain the building’s sustainability features.
3. Discuss the implications of the project for the urban environment.

Additional Resources
Recentering PT Walls for Enhanced Seismic Resilience

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Thank You