# The Art of Designing Ductile Concrete in the Past 50 Years: The Impact of the PCA Book and Mete A. Sozen, Part 1

ACI Fall 2012 Convention
October 21 – 24, Toronto, ON

ACI WEB SESSIONS

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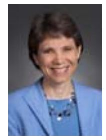

**Sharon L. Wood**, Robert L. Parker, Sr. Professor in Engineering and Chair, Department of Civil, Architectural, and Environmental Engineering, University of Texas at Austin. Professor Wood is a fellow of the American Concrete Institute (ACI) and chaired its Technical Activities Committee between 2003 and 2006. She is also a member of the Structural Concrete Building Code Committee. She served on the ACI Board of Direction from 1997 through 2000 and as chair of the ACI Publications Committee from 1995 through 2002. In 1993 she received the Alfred Noble Award from the American Society of Civil Engineers for her paper “Seismic Response of R/C Frames with Setbacks.” She received the Arthur J. Boase Award from the Reinforced Concrete Research Council in 1998 in recognition of her research and teaching in the field of structural concrete, the Joe W. Kelly Award from the American Concrete Institute in 2002 “in recognition of her dedication to improving the seismic behavior and design of reinforced concrete structures through the education of students and engineers,” and the Henry L. Kennedy Award from the American Concrete Institute in 2006 “for outstanding technical and administrative contributions to the Institute, particularly as a member of ACI Committee 318, Chair of the ACI Publications Committee, and Chair of the Technical Activities Committee.”

ACI WEB SESSIONS

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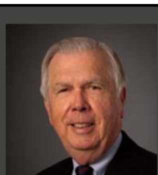

## DUCTILE DESIGN OF CONCRETE STRUCTURAL WALLS

Sharon L. Wood, University of Texas at Austin

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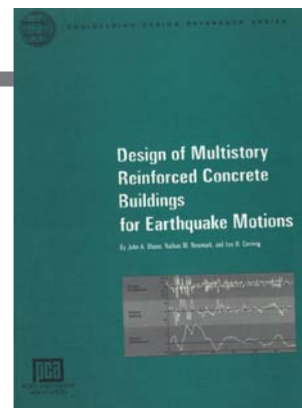
## PCA

- Bearing Walls
- Infill Walls

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## PCA

| Wall Thickness, in. | Horizontal Reinforcement Spacing, in. | | Vertical Reinforcement Spacing, in. | |
|---|---|---|---|---|
| | #3 | #4 | #3 | #4 |
| 6 | 7 | 13 | 12 | 16 |
| 8 | 5 | 10 | 9 | 16 |
| 10* | 9 | 16 | 12 | 16 |
| 12* | 7 | 13 | 12 | 16 |

* Spacing in each of two curtains.

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## PCA

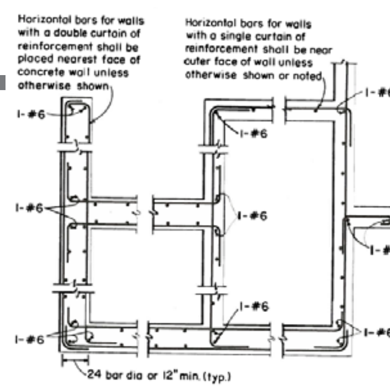
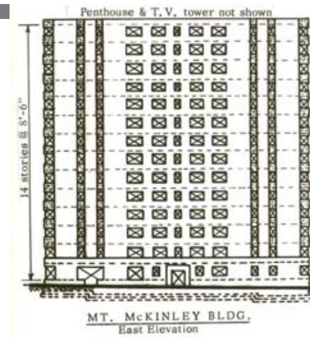



Fig. 6-9. Plan view showing typical wall reinforcement details.

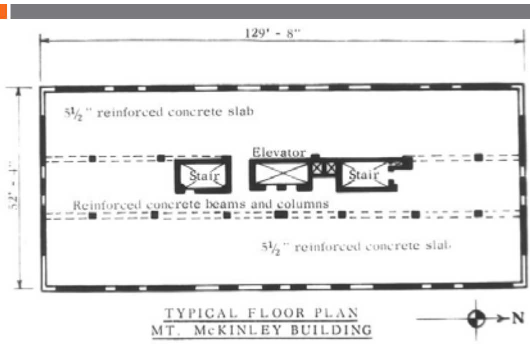
## 1964 Earthquake, Anchorage

## Mt. McKinley Building

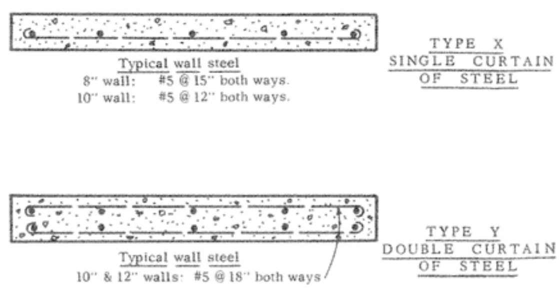
- Constructed in 1952
- 14 Stories
- Exterior Bearing Walls
- Interior Core Walls




## Mt. McKinley Building




## Mt. McKinley Building



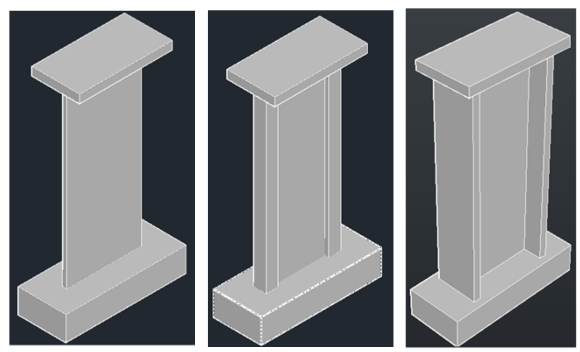

## PCA

- Phase I – 1976
  Oesterle, Fiorato, Johal, Carpenter, Russell, Corley
- Phase II – 1979
  Oesterle, Aristizabal-Ochoa, Fiorato, Russell, Corley

Earthquake Resistant Structural Walls – Tests of Isolated Walls

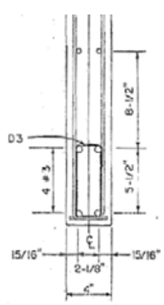
## Experimental Parameters

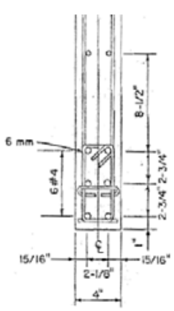
| Parameter | Range |
|---|---|
| Longitudinal Reinforcement Ratio | 1.1 to 6.0% |
| Vertical Web Reinforcement Ratio | 0.25 to 0.31% |
| Horizontal Web Reinforcement Ratio | 0.31 to 1.38% |
| Axial Stress $(P/Af_c')$ | 0.3 to 14.1% |
| Aspect Ratio $(H_w/L_w)$ | 2.4 |
| Loading History | |



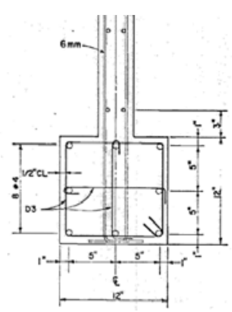
**Rectangular** **Barbell** **Flanged**

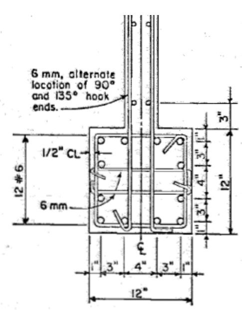
## Boundary Elements – Rectangular Walls



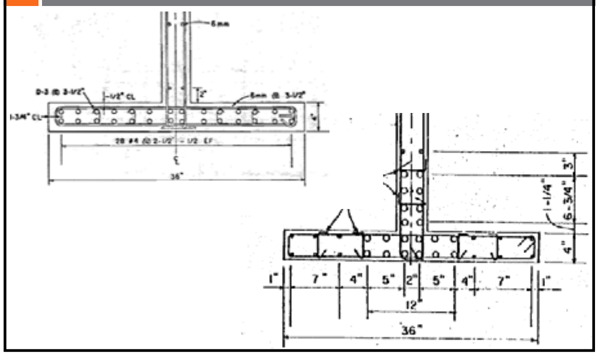




## Boundary Elements – Barbell Walls



## Boundary Elements – Flanged Walls

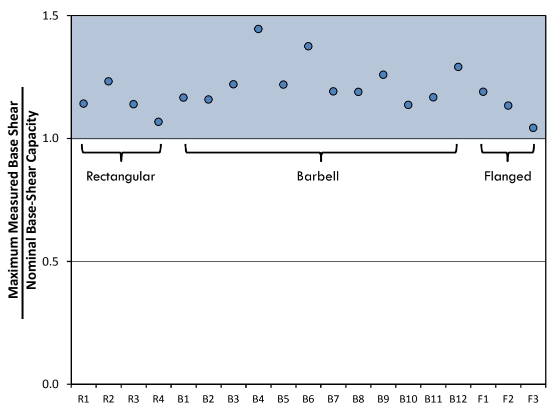



## Nominal Capacity

- Flexural Capacity, $V_{nf}$
- Shear Capacity, $V_{nv}$

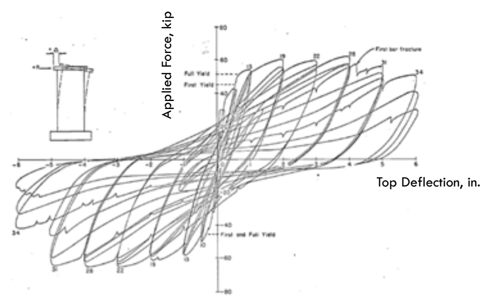
$$V_{nv} = \left(2\sqrt{f_c'} + \rho_n f_y\right) A_{cv}$$

- Nominal Capacity, $V_n$ = min ($V_{nf}$, $V_{nv}$)



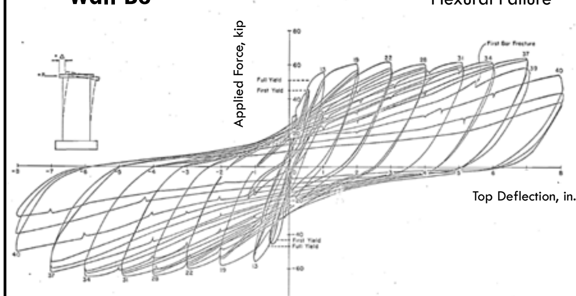

**Wall B1**

Flexural Failure

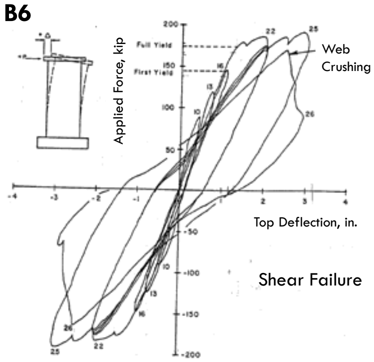



**Wall B3**

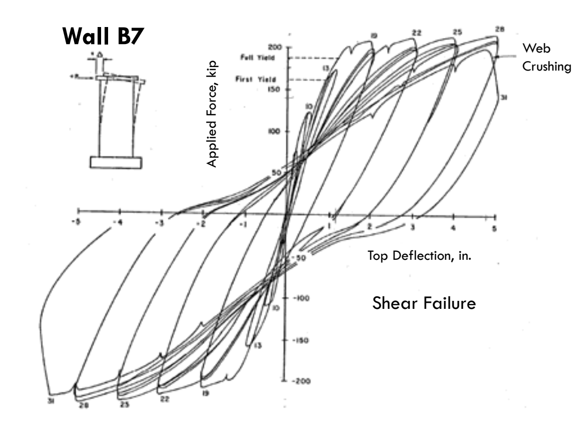
Flexural Failure




**Wall B6**



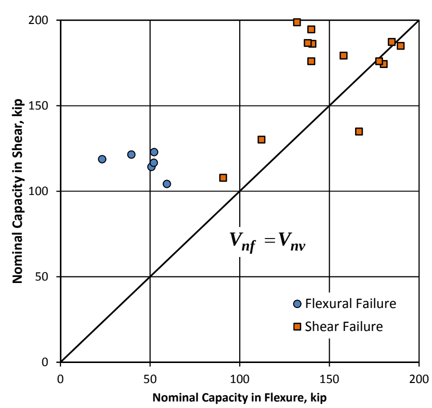

Shear Failure

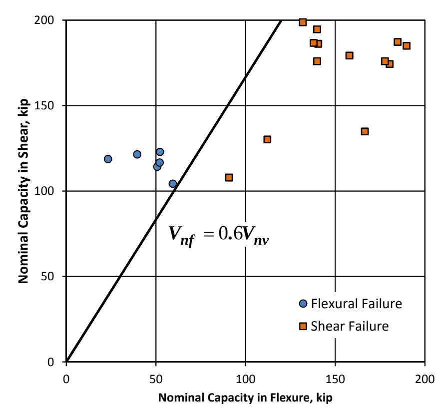


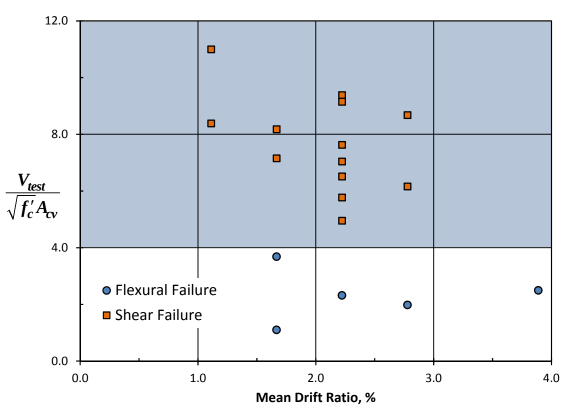

## Consequences of Shear Failures

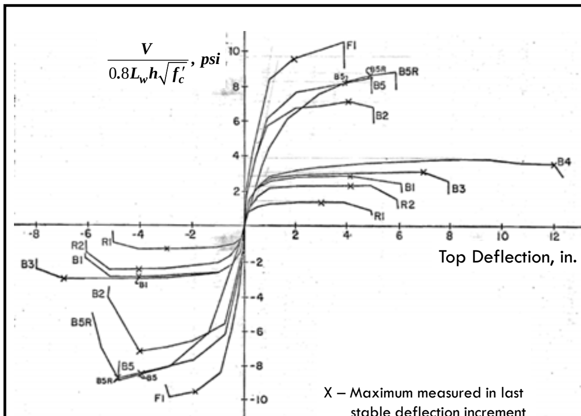
- Web Crushing
- Shear-Compression Failure of Boundary Elements
- Concentration of Distortion near Base of Wall

**Shear Failures Occurred after Longitudinal Reinforcement Yielded.**



## Slender Walls – Displacement Capacity

- All test specimens were able to sustain multiple cycles to drift ratios exceeding 1%.
- Walls with confined boundary elements were able to sustain larger inelastic deformations.
- Walls that experienced web crushing sustained slightly lower maximum inelastic deformations.
- Maximum inelastic displacement did depend on loading history.

## Slender Walls – Shear Capacity

- Average shear stress of $4\sqrt{f_c'}$ represented the boundary between flexural and shear failure mechanisms.
- If $V_{nf} > 0.6\ V_{nw}$, shear failure was observed under cyclic lateral loads.
- Walls with low web reinforcement ratios are susceptible to degradation of shear strength with cycling.

## Mt. McKinley Building

CFRP wrap was installed in 2006 and the building has been reoccupied.