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Advancing concrete knowledge

Joint KCI-ACI Session: International-Level Research, Practice, and Partnerships

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

ACI
WEB SESSIONS

Thomas Kang. Prof. Kang is a faculty member of architectural engineering at Seoul National University (SNU), and a licensed Professional Engineer (P.E.) in California, U.S.A. Prior to joining SNU in 2011, he had been an Assistant Professor of civil engineering at the University of Oklahoma, Norman for 4 years and had worked as a consulting engineer in California for 3 years. He earned his Ph.D. from the University of California, Los Angeles (UCLA), his M.S. from Michigan State University, and his B.S. from SNU. Prof. Kang's research and teaching interests encompass a number of subjects relating to the design, repair and materials of structural concrete. He received a prestigious ACI award, the Wason Medal for Most Meritorious Paper, as Lead Author in 2009.

ACI
WEB SESSIONS

Practical Research in Tall High-Rise Buildings in the U.S.

Thomas Kang, Ph.D., P.E.
Assistant Professor
Seoul National University

ENGINEERING

Research collaboration between structural design firms and the Univ. of Oklahoma

- **High-rise Tube Building (Rosenwasser/Grossman)**
- **High-rise Dual Systems (Rosenwasser/Grossman)**
- **High-rise SPSW Systems (Nabih Youssef Assoc.)**
- **High-rise Core Wall-PT Flat Plate Bldg. (Ove Arup)**

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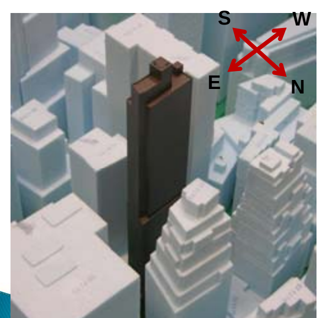
- **High-rise Tube Building (Rosenwasser/Grossman)**

THE STRUCTURAL DESIGN OF TALL AND SPECIAL BUILDINGS

* Shin, Kang and Pimentel (June 2012)
* Shin, Kang, LaFave and Grossman (Oct. 2010, On-line)

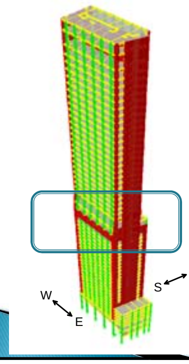
High-rise concrete tube building in NYC designed by Rosenwasser/Grossman



- Tube systems
  - N-S direction
  - Flange moment frames
  - Web shear walls
- Moment frames & core walls
  - E-W direction
- Use of belt walls

Designed by Rosenwasser/Grossman

High-rise concrete tube building in NYC designed by Rosenwasser/Grossman



- Tube systems
  - N-S direction
  - Flange moment frames
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- Moment frames & core walls
  - E-W direction
- Belt wall systems

Shin, Kang and Pimentel (2010)

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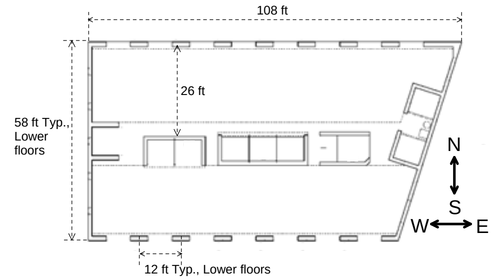
High-rise concrete tube building



Shin, Kang and Pimentel (2010)

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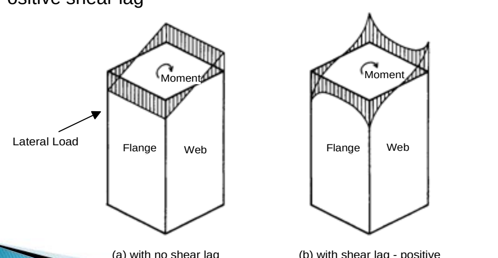
Tube action & shear lag behavior

- Shear lag behavior
  - Positive shear lag

Kwan (1996)



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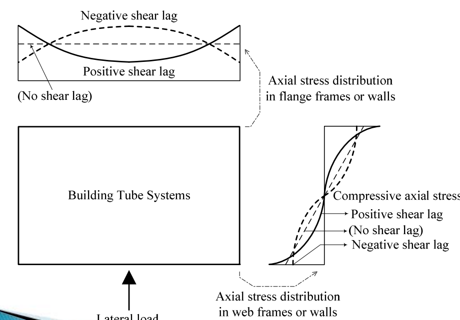
Shear lag behavior



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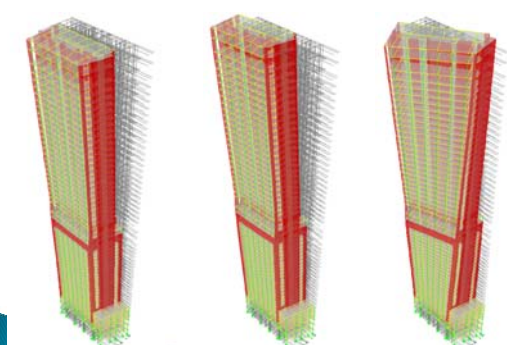
Dynamic modal analysis



Shin, Kang, LaFave and Grossman (2010)

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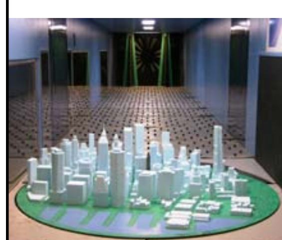
Wind tunnel tests (courtesy of RWDI)




Case study building located in the "building forest" in Manhattan, NY

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Wind tunnel tests (courtesy of RWDI)


Case study building located in the "building forest" in Manhattan, NY

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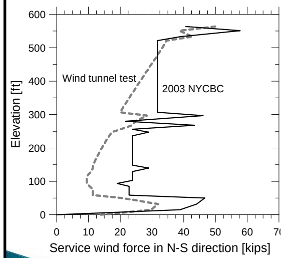
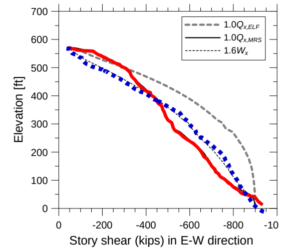
Comparisons of seismic and wind forces or between prescriptive and test values





Shin, Kang, LaFave and Grossman (2010)

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Analytical & Parametric studies

- 1. Analytical studies (five models)
  - Original design (T1 – with tube action)
  - No allowance of tube action (T1NT)
  - No belt walls – replaced by deep beams (T1NB)
  - Move mid-height belt walls to the topmost (T1TB)
  - Add top belt walls (T1DB)
- 2. Parametric studies (variation of member size)
  - With respect to the original design (T1)
  - Varying (i) spandrel beam depth, (ii) spandrel beam width, (iii) column depth, and (iv) column width [of flange moment frames]

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Analytical studies (conclusions)

- Tube action reduces about 30% of lateral drifts, particularly effective for upper stories.
- Tube action significantly increases overturning moment, but slightly increases lateral stiffness.
- Presence of belt-walls improves tube action & reduces positive shear lag below the belt-wall (but increases positive shear lag above the belt-wall – may be tolerable).
- Use of extra top belt-walls does not much advance lateral resistance.
- The optimal location of a single belt-wall system is about at mid-height of the bldg.

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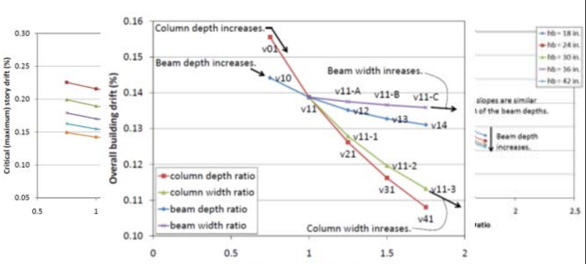
Parametric studies (drifts)



Shin, Kang and Pimentel (2010)

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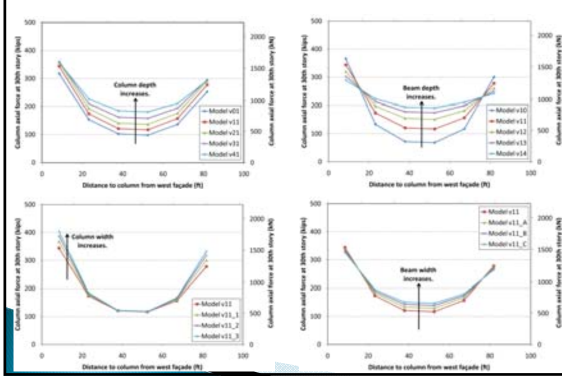
Shin, Kang and Pimentel (2010)

Parametric studies (col. axial force)



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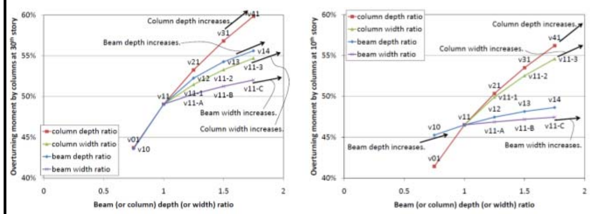
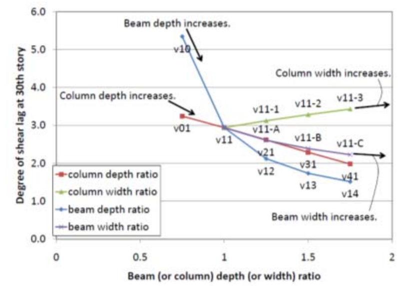
Parametric studies (overturning mom.)



Shin, Kang and Pimentel (2010)

Parametric studies (shear lag)



Shin, Kang and Pimentel (2010)

Parametric studies (conclusions)

- To reduce drifts, increase column depth & column width.
- The impact of beam depth or width on drifts is minimal.
- To increase overturning moment, increase column depth & beam depth (above the belt wall) or column width (below the belt wall).
- Upper stories (80% taken by flange); lower stories (40%)
- Tube action is modest for low-rise tubular structures.
- To reduce shear lag in the flange frame, increase beam depth & column depth (in contrast, column width adversely affects).

Research collaboration between structural design firms and the Univ. of Oklahoma

- **High-rise Tube Building (Rosenwasser/Grossman)**
- **High-rise Dual Systems (Rosenwasser/Grossman)**
- **High-rise SPSW Systems (Nabih Youssef Assoc.)**
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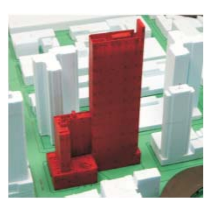
- **High-rise Dual Systems (Rosenwasser/Grossman)**

THE STRUCTURAL DESIGN OF TALL AND SPECIAL BUILDINGS

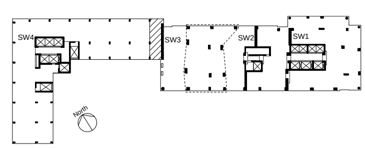
* Shin, Kang and Grossman (Nov. 2010)

High-rise concrete dual systems in NYC designed by Rosenwasser/Grossman

- Dual systems of RC walls and slab-column frames
- MWFRS (main wind-force-resisting systems)

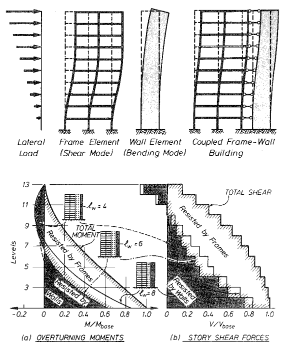


Designed by Rosenwasser/Grossman



- Use dual systems: if slab-column frames take more than 25% of design seismic forces (0.25*E*)
- If not likely, design walls to resist 1.0*E*!

Frame-wall Interaction



- Dual systems are superior to single systems
- Shear walls are much stiffer at lower stories
- Frames function well at upper stories
- Engineers are discouraged not to use dual systems by difficulties of design

Adapted from Paulay and Priestley (1991)

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Stiffness modeling of members and walls

- Ultimate state (strength design)

Members		Ultimate state
Beams		$0.35E_cI_g$
Columns		$0.70E_cI_g$
Walls	Uncracked	$0.70E_cI_g$ → **Upper 7/8 ~ 5/6 of total height**
	Cracked	$0.35E_cI_g$ → **Lower 1/8 ~ 1/6 of total height**

Based on past design experience
and verification by checking wall stresses (Shin et al, 2010)

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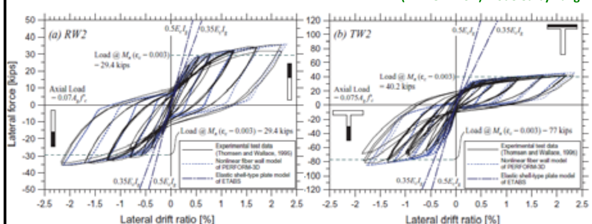
Wall stiffness modeling for lower stories

RC walls tested by Thomsen and Wallace
(PERFORM-3D) modeled by Kang



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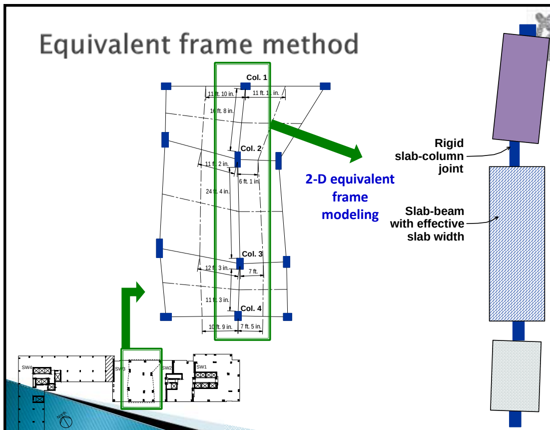
Equivalent frame method



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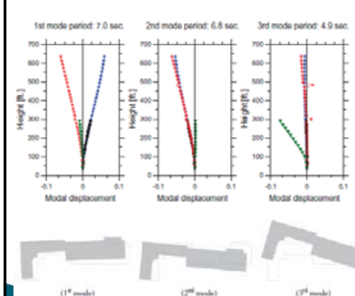
Linear lateral models for design forces and moments



Shin, Kang & Grossman (2010)

- Based on various calibrations,
  - Core wall dual systems: efficient in lateral resist.
  - esp. for irregular shapes
  - Adjust wall thickness (t) (as height up, t down)
  - Stiffness modeling was appropriate.

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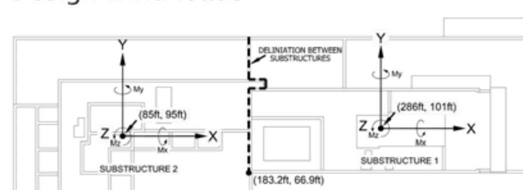
Design wind loads



Shin, Kang & Grossman (2010)

Structure	Fx (k)	Fy (k)	Mz (k-ft)
Tower	2190	4580	71500
Hotel	943	1280	21500

- 56 combinations of wind loads are investigated: 8 primarily for designing the connection between the two substructures.

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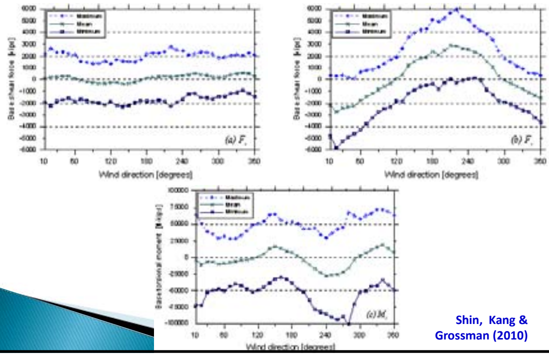
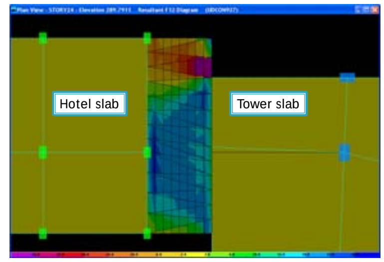
Resultants Induced from Design Wind Loads



Shin, Kang & Grossman (2010)

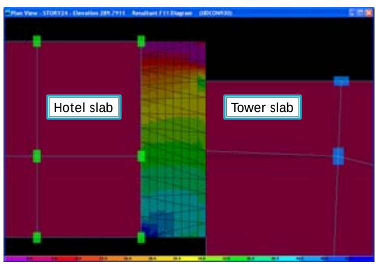
Shear between rigid diaphragms



Shin, Kang & Grossman (2010)

- WIND27: Fx1(-30%), Fy1(+100%), Mz1(-35%)
  Fx2(-30%), Fy2(+30%), Mz2(-40%)

Tension between rigid diaphragms

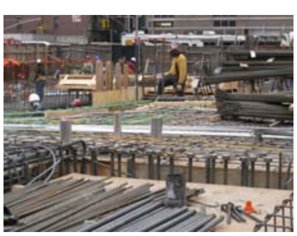


Shin, Kang & Grossman (2010)

- WIND30: Fx1(+75%), Fy1(+45%), Mz1(-30%)
  Fx2(-75%), Fy2(+60%), Mz2(+30%)

Under construction


Under construction




Under construction



Under construction

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- **High-rise SPSW Systems (Nabih Youssef Assoc.)**

THE STRUCTURAL DESIGN OF TALL AND SPECIAL BUILDINGS

* Kang, Martin, Park, Wilkerson and Youssef (Mar. 2011; On-line)

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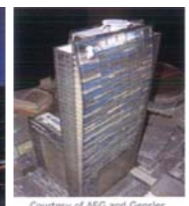
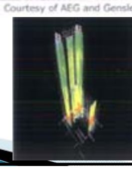
High-rise steel plate wall systems in L.A. designed by Nabih Youssef Associates





- L.A. Live
  - High Seismicity
  - Hotel + Residence
  - First SPSW high-rise building in LA
- SPSW
  - Reduce 35% mass
  - Reduce foundation
  - Reduce construction time

Designed by Nabih Youssef Associates

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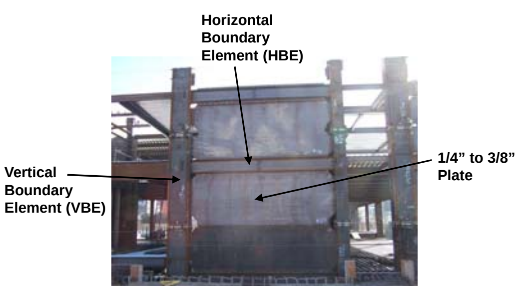
Steel Plate Shear Wall (SPSW)



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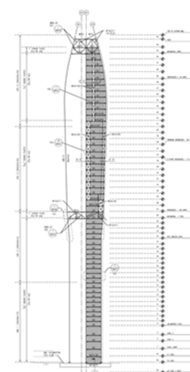
Completion stage of construction



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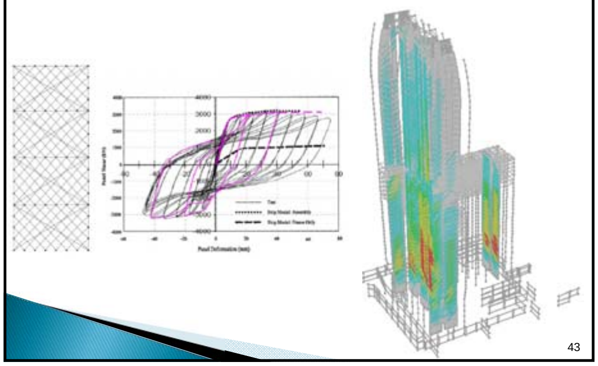

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Research collaboration between structural design firms and the Univ. of Oklahoma

- **High-rise Core Wall-PT Flat Plate Bldg. (Ove Arup)**

* Melek, Darama, Gogus and Kang (Sept. 2012)

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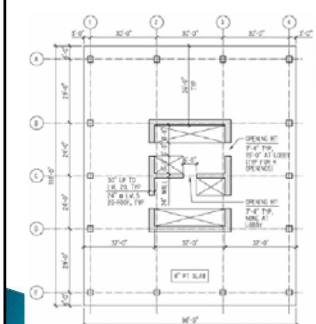
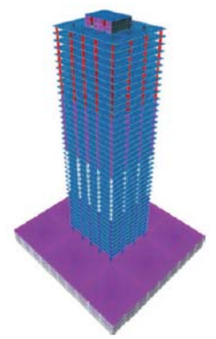
High-rise PT flat plate-wall systems in L.A. preliminarily designed by Ove Arup





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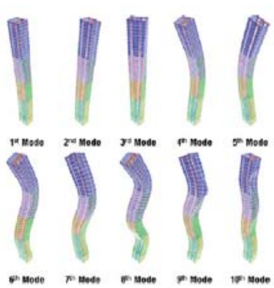

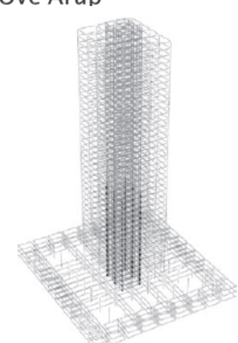

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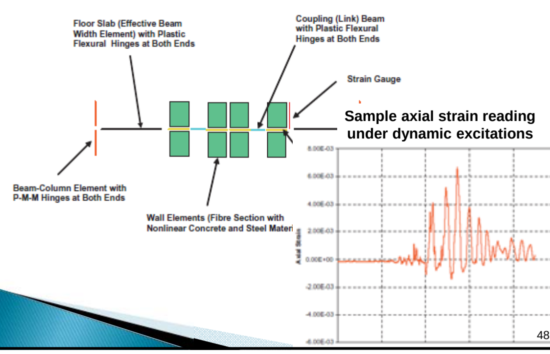

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Thank you!