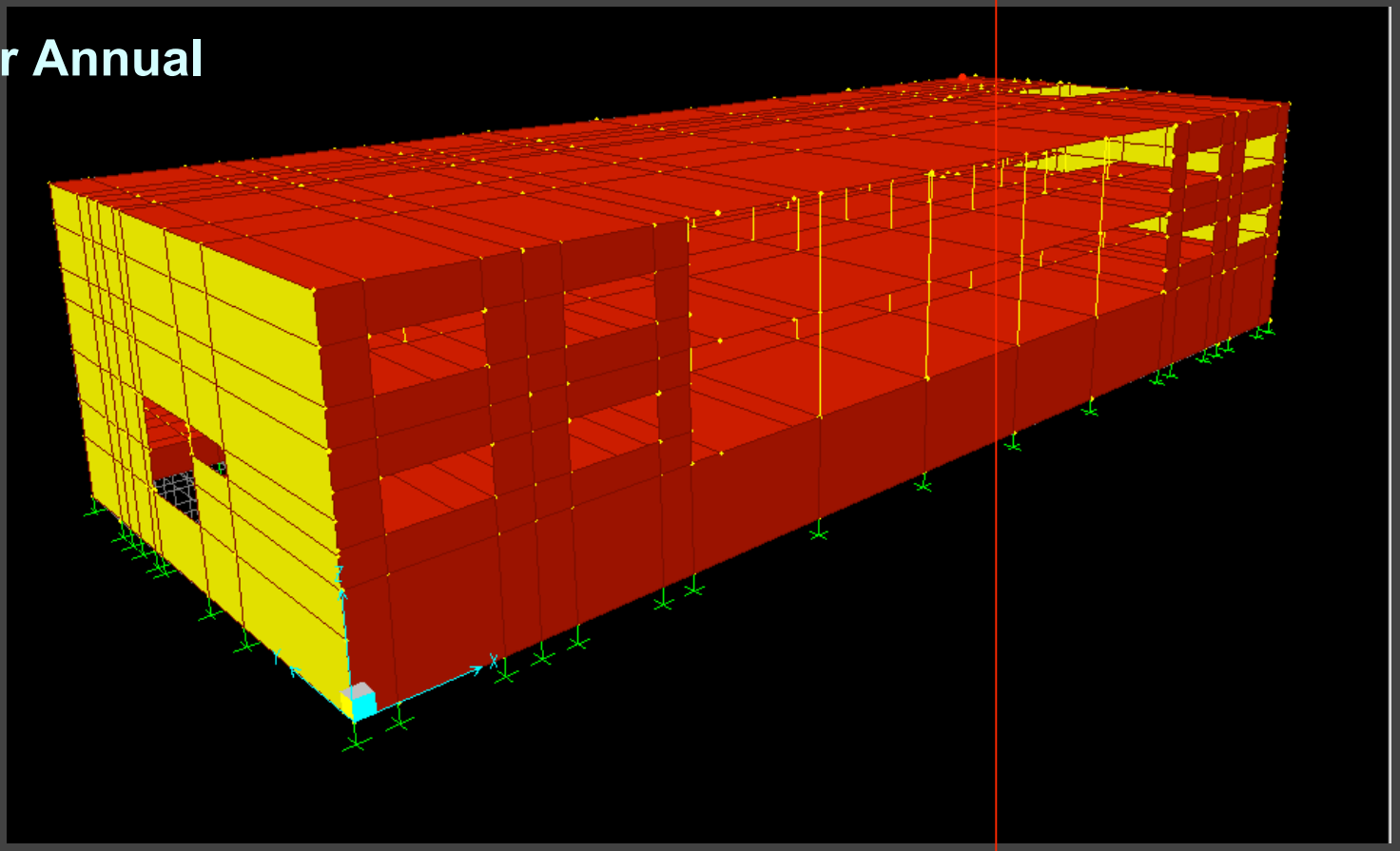
Example projects, design solutions, and use of research

2003 Peer Annual Meeting



Joe Maffei

Overview

- Three concrete buildings
  - wall shear, boundary ties, coupling, sliding shear, curtailment of reinforcement, gravity columns, collectors, foundation rocking
- Unreinforced masonry building
- Slab punching shear
- Conclusions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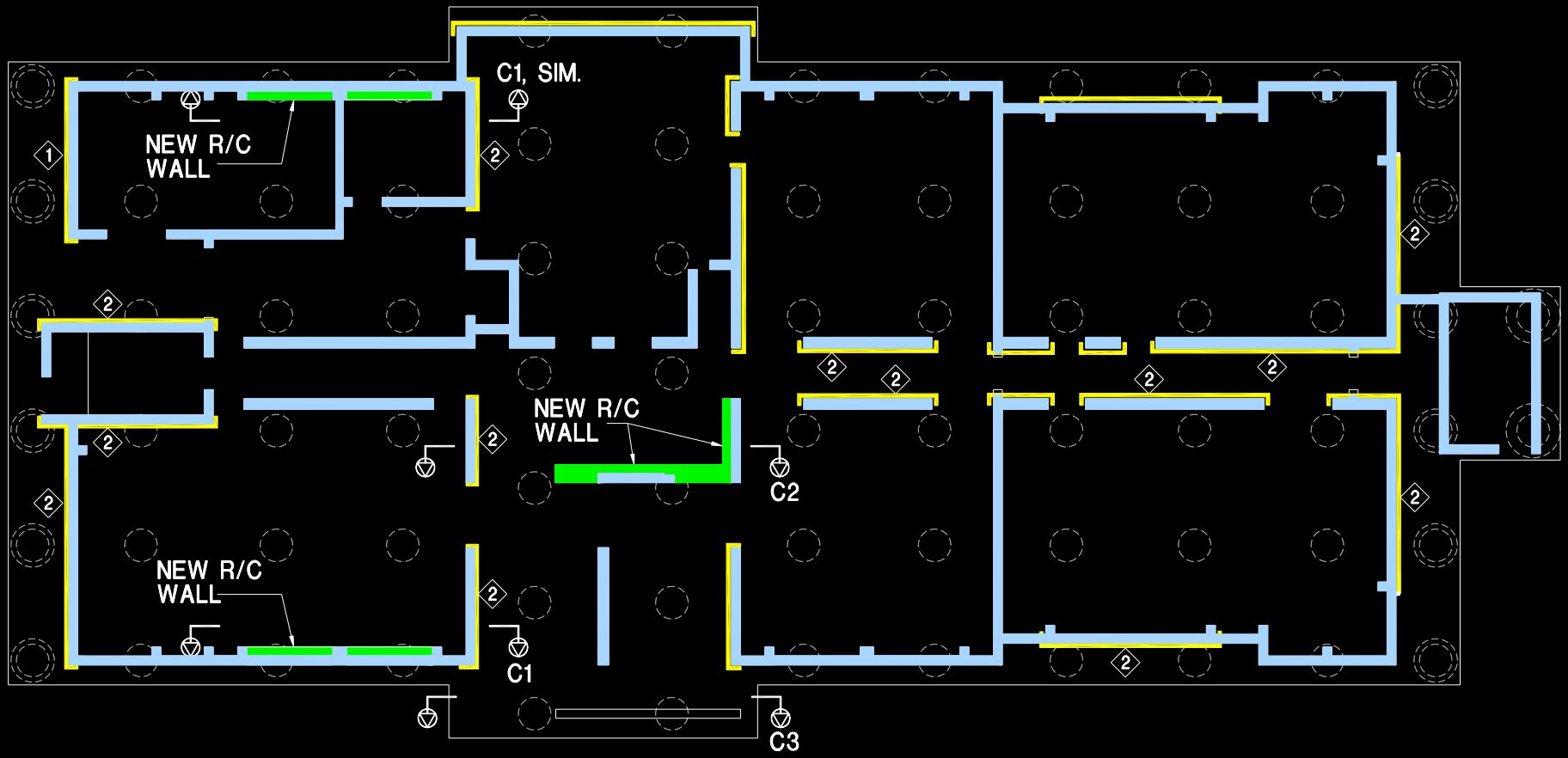
Proposed Retrofit Measures



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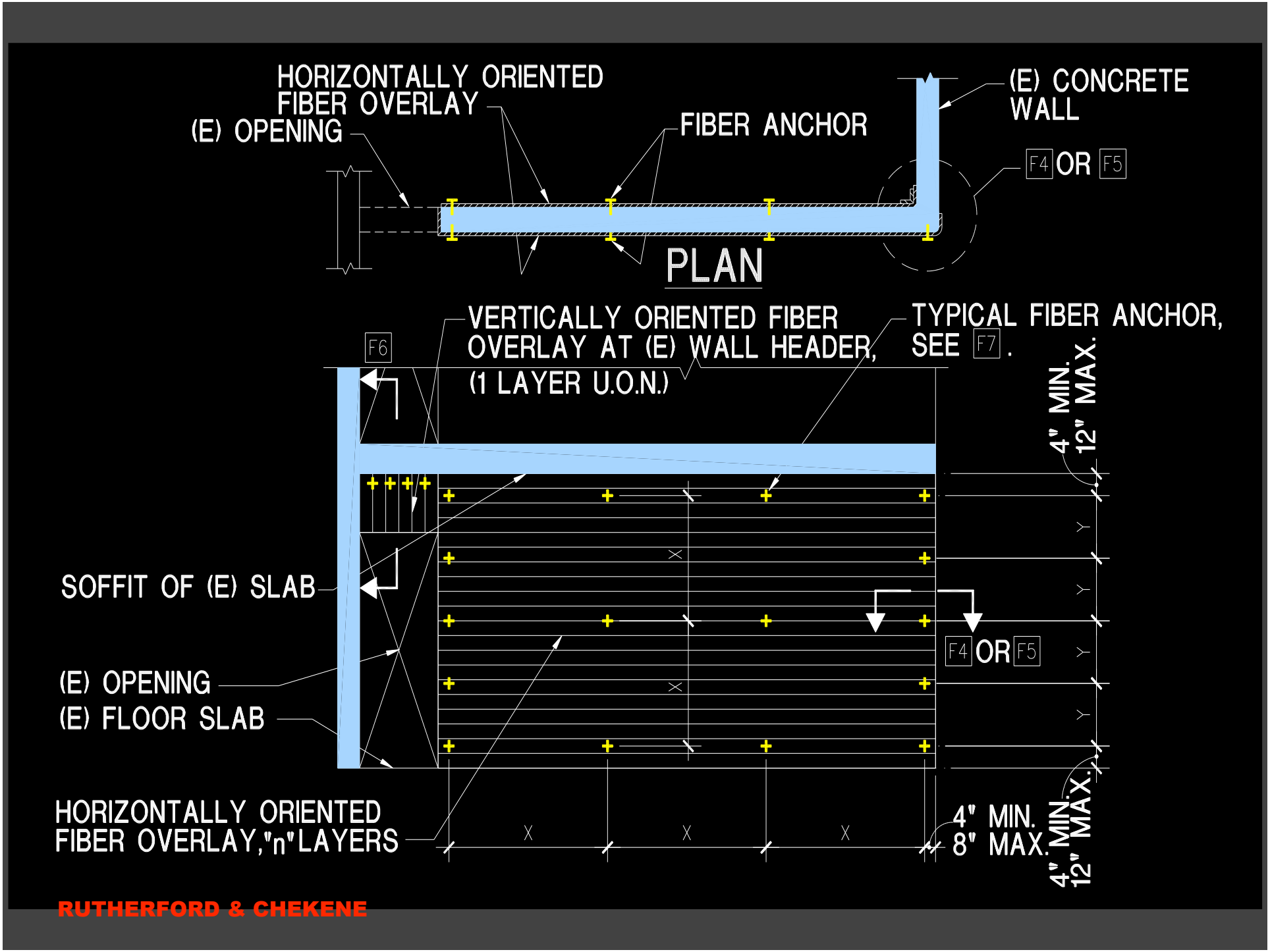

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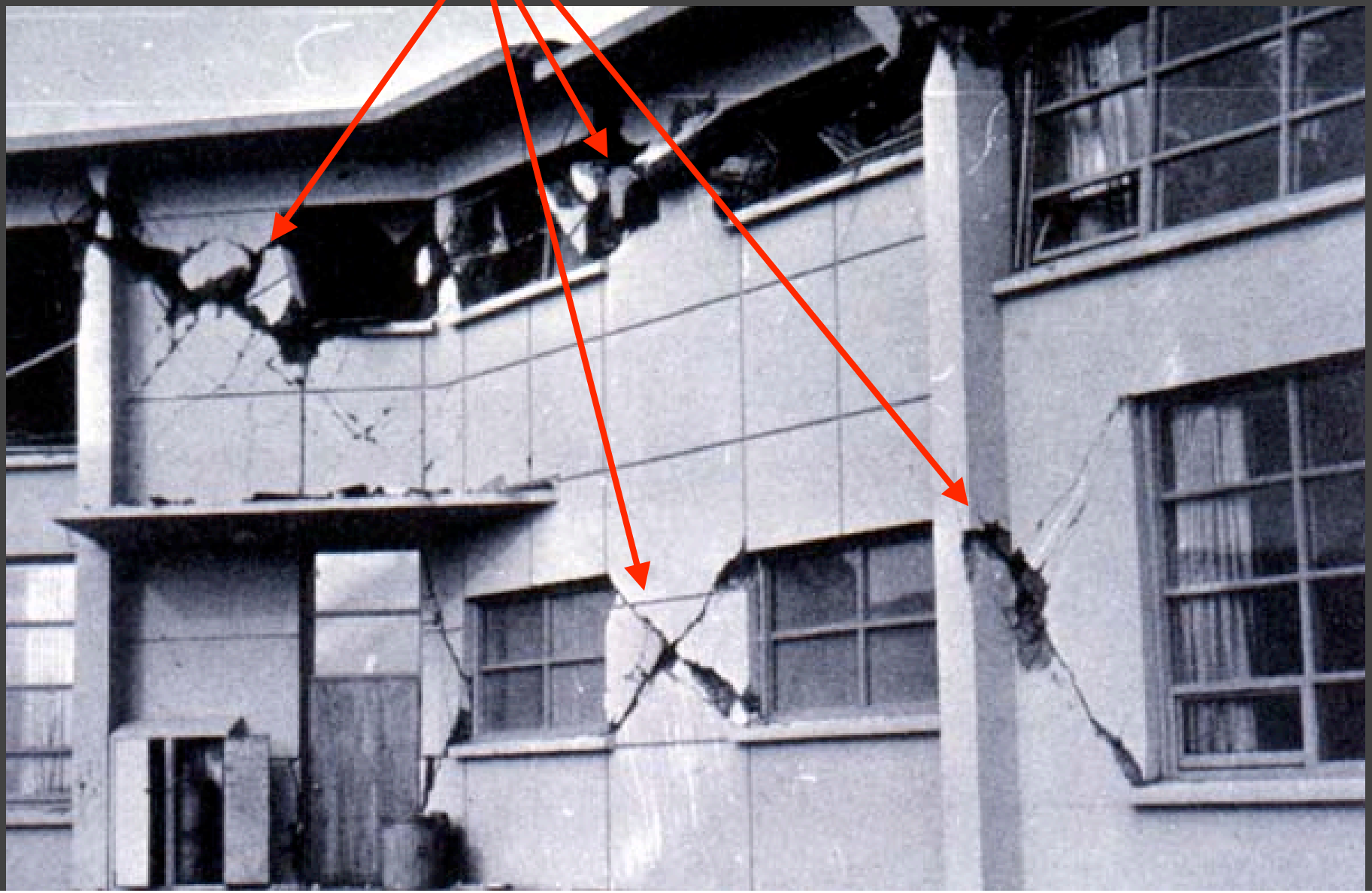
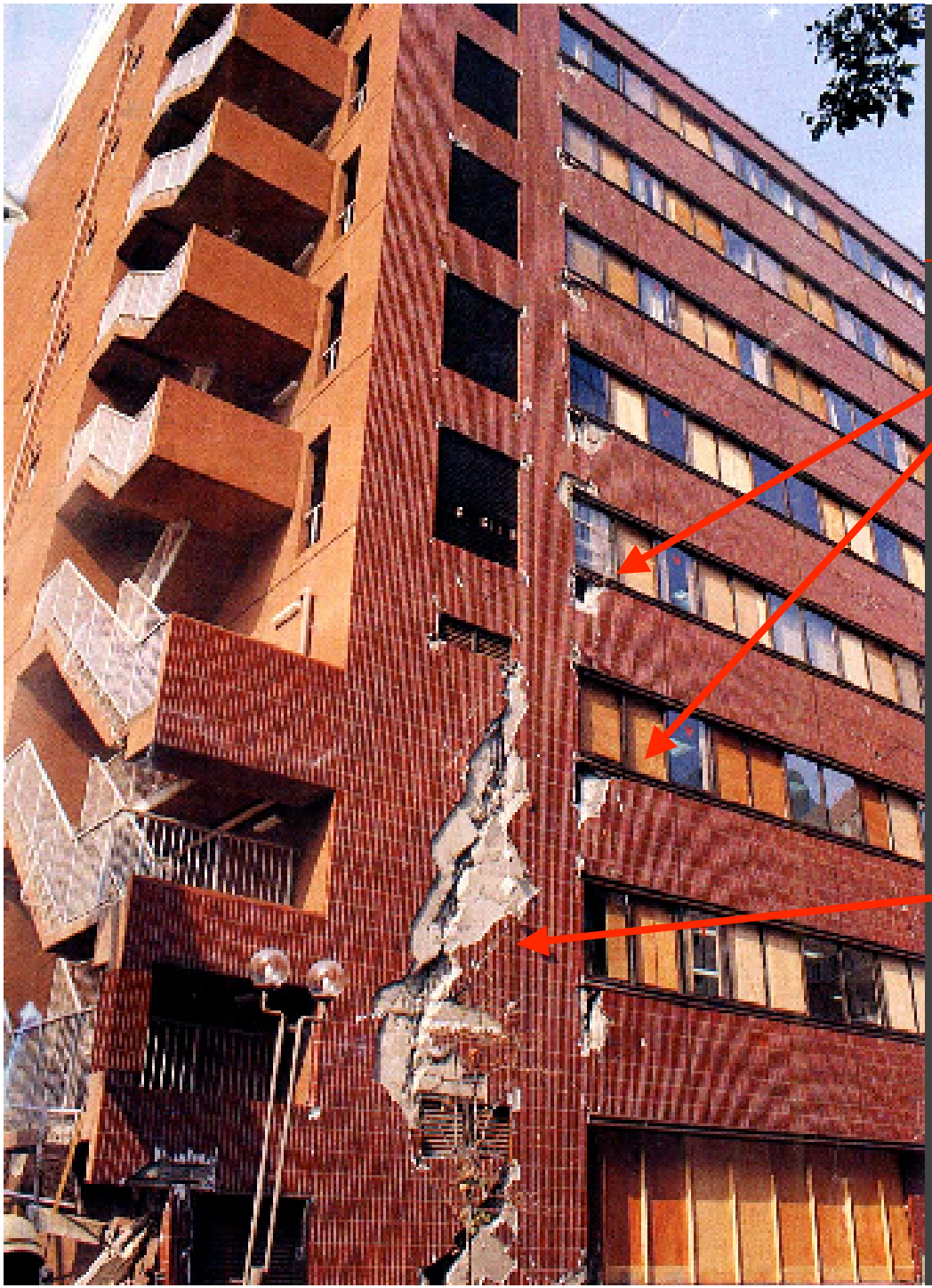
Behavior Mode:

Preemptive Shear Failure in Diagonal Tension

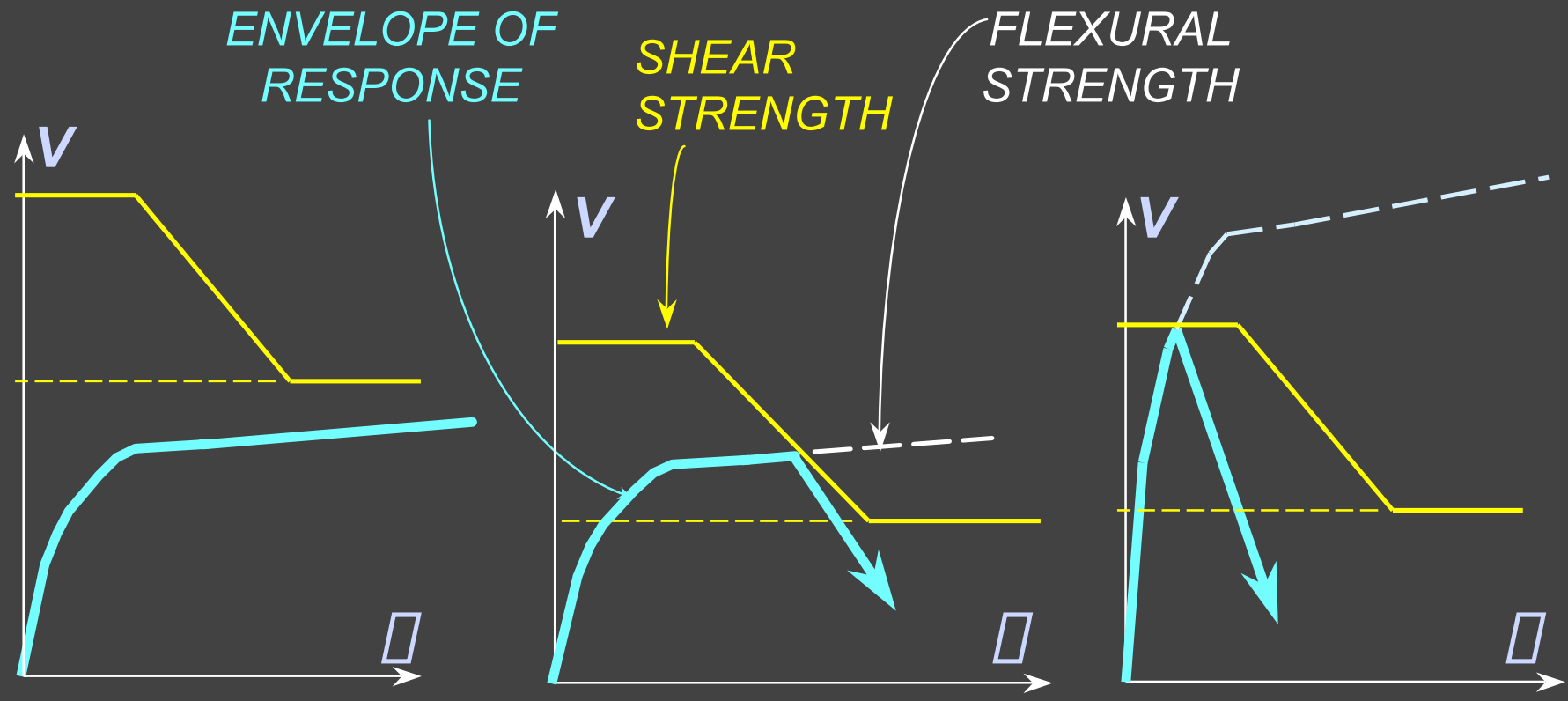
Northridge 1994

Preemptive diagonal tension




Weaker Spandrels
Shear Failure in Diagonal Tension

Behavior Mode: Flexure/ Diagonal Tension



Ductile Mode

Combination Mode

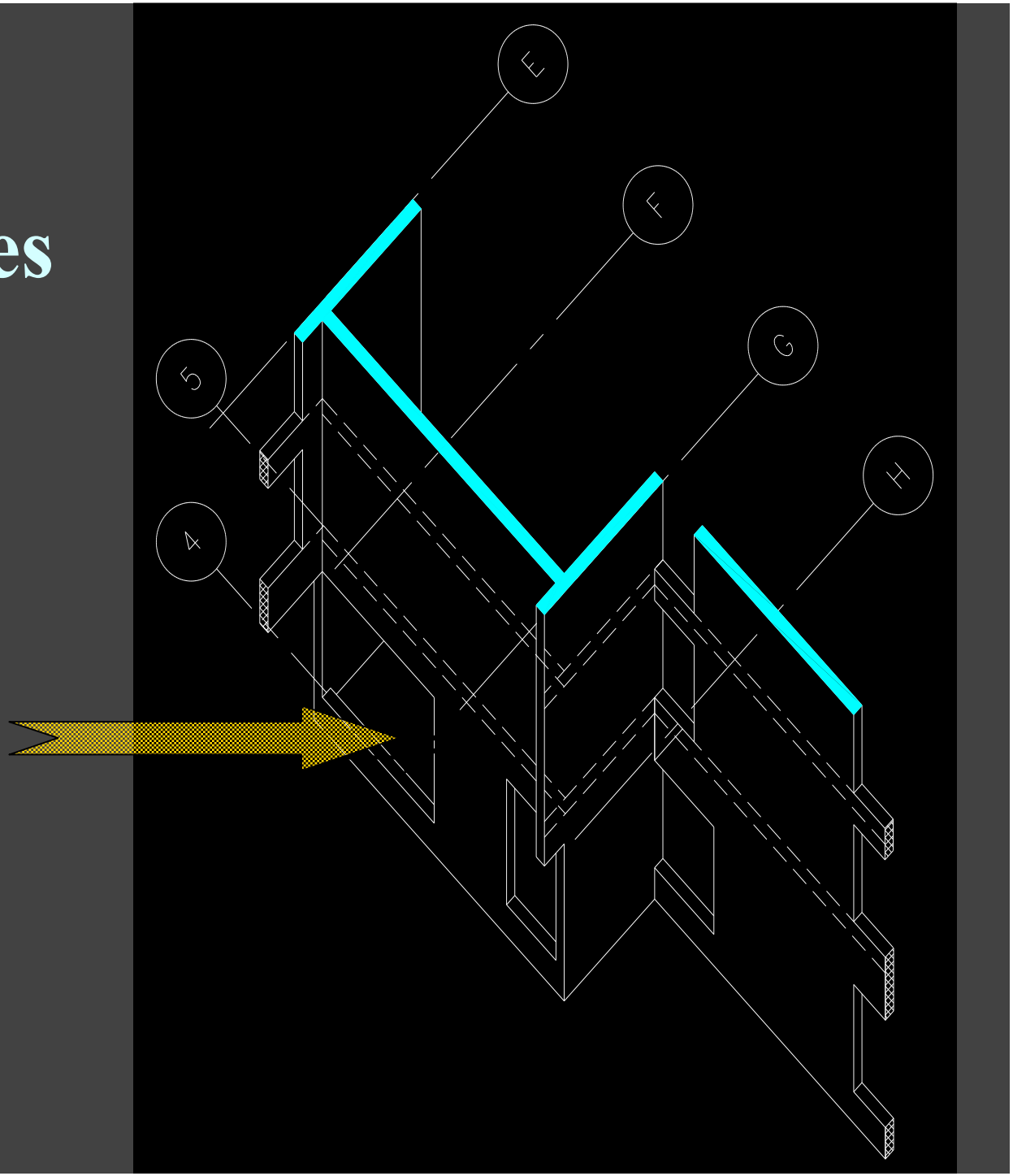
Preemptive Mode

Types of Behavior Modes

Fiber Overlay Installation

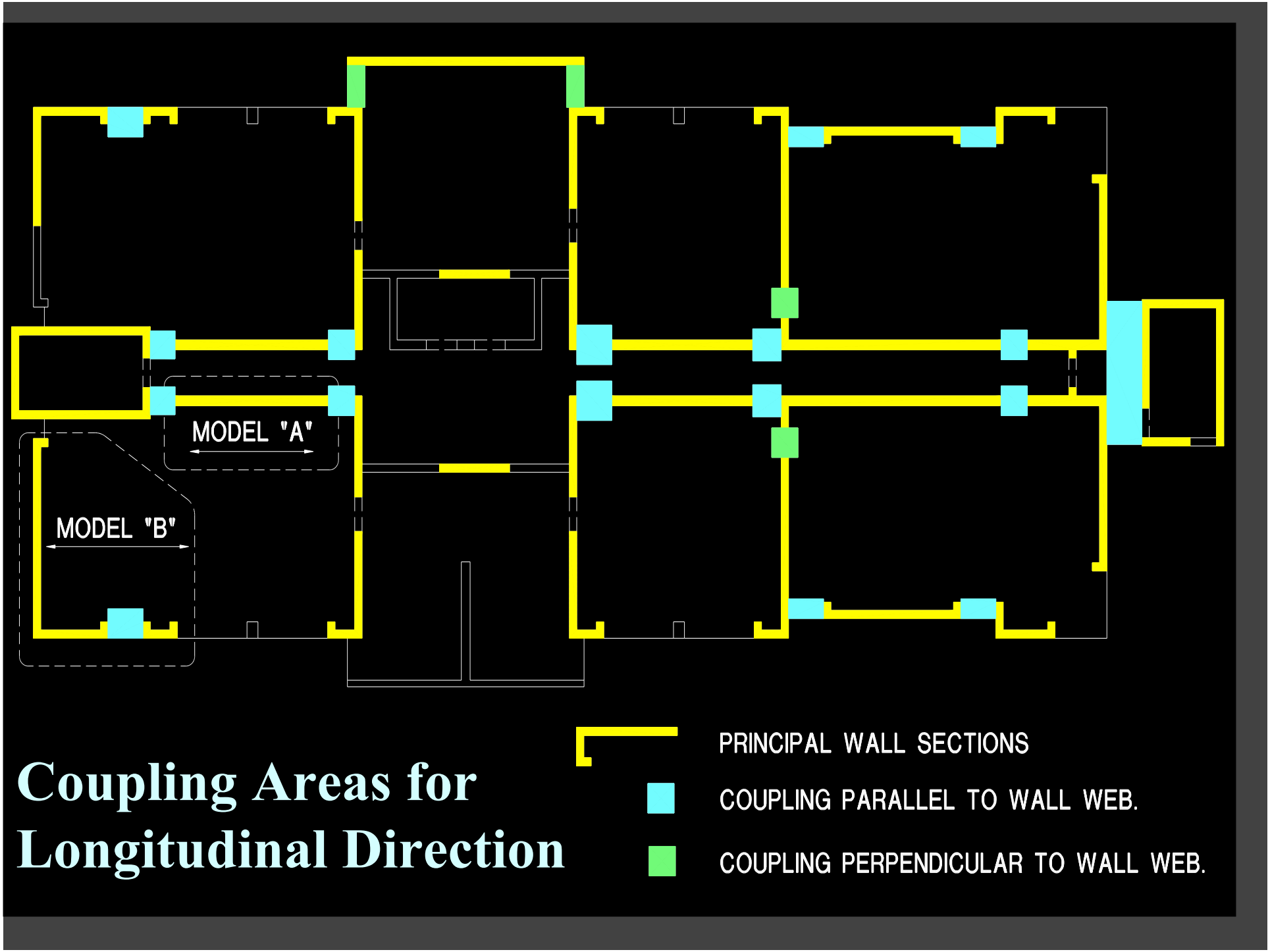
Fiber Overlay Before Finish Plaster

Wall Discontinuities



Flexure / Bar buckling

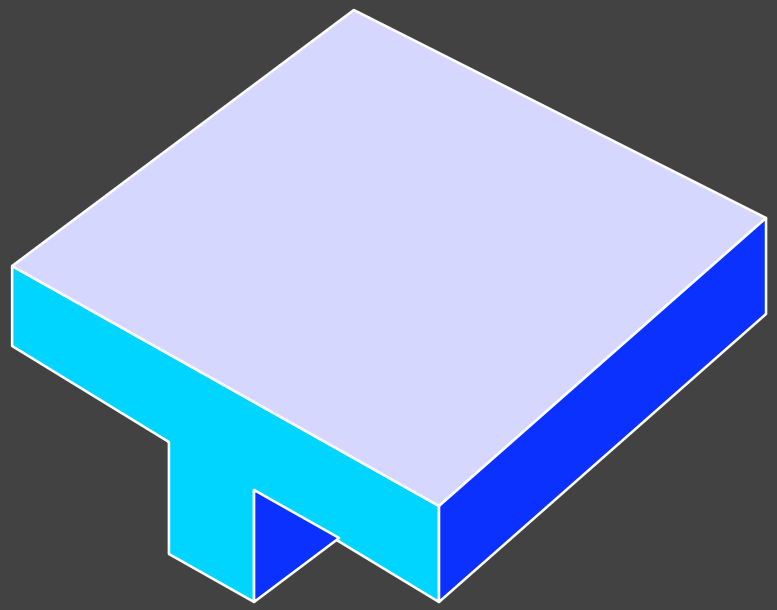
Buckled wall reinforcement



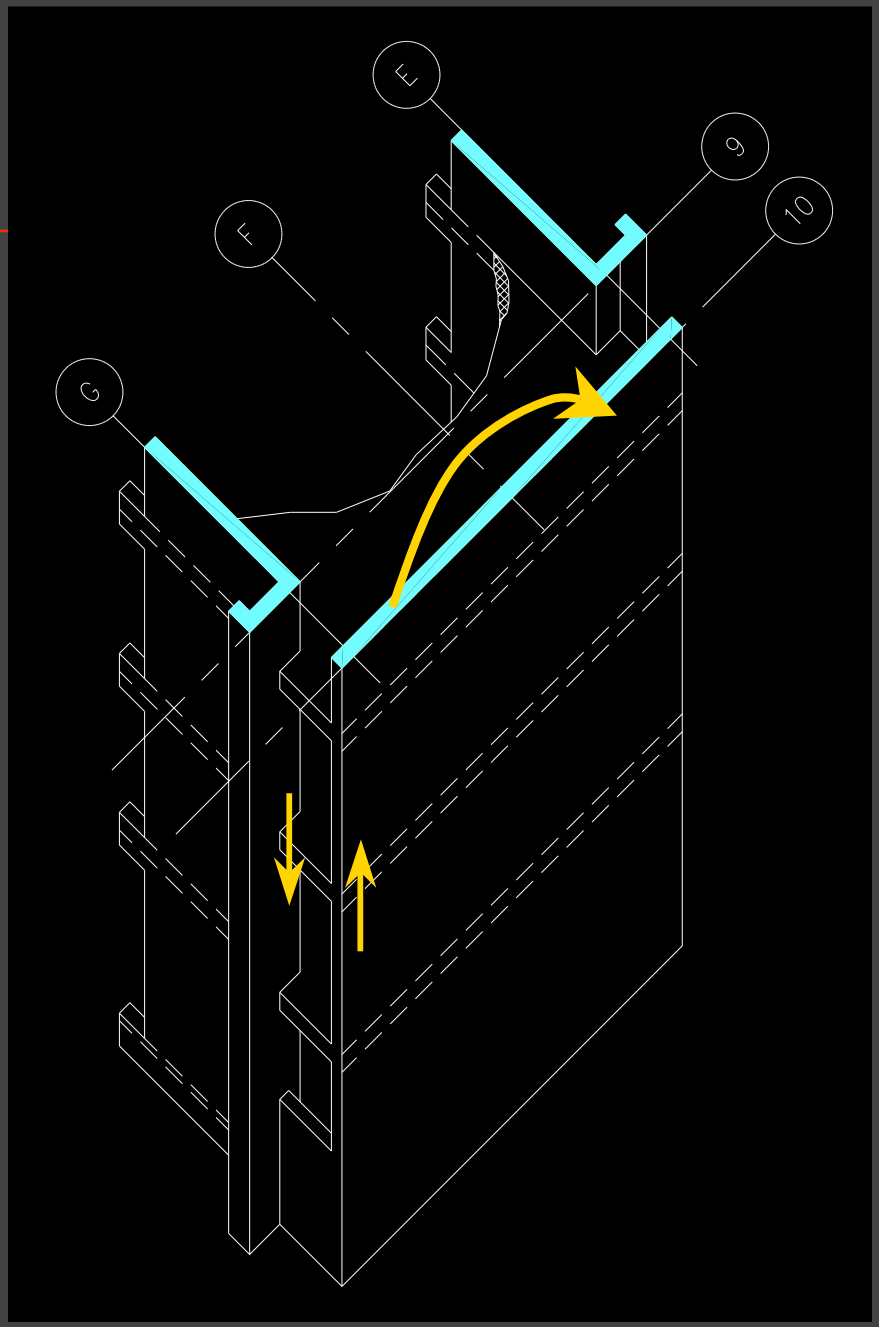
Coupling Areas for Longitudinal Direction

Coupling Beams and Slab Coupling

- Effective slab width = 1/2 l_n each side of wall web.
- Consider flexural strength and upper and lower bound shear strength.
- Consider coupling both parallel and transverse to wall web.



Coupling Transverse to Wall Web

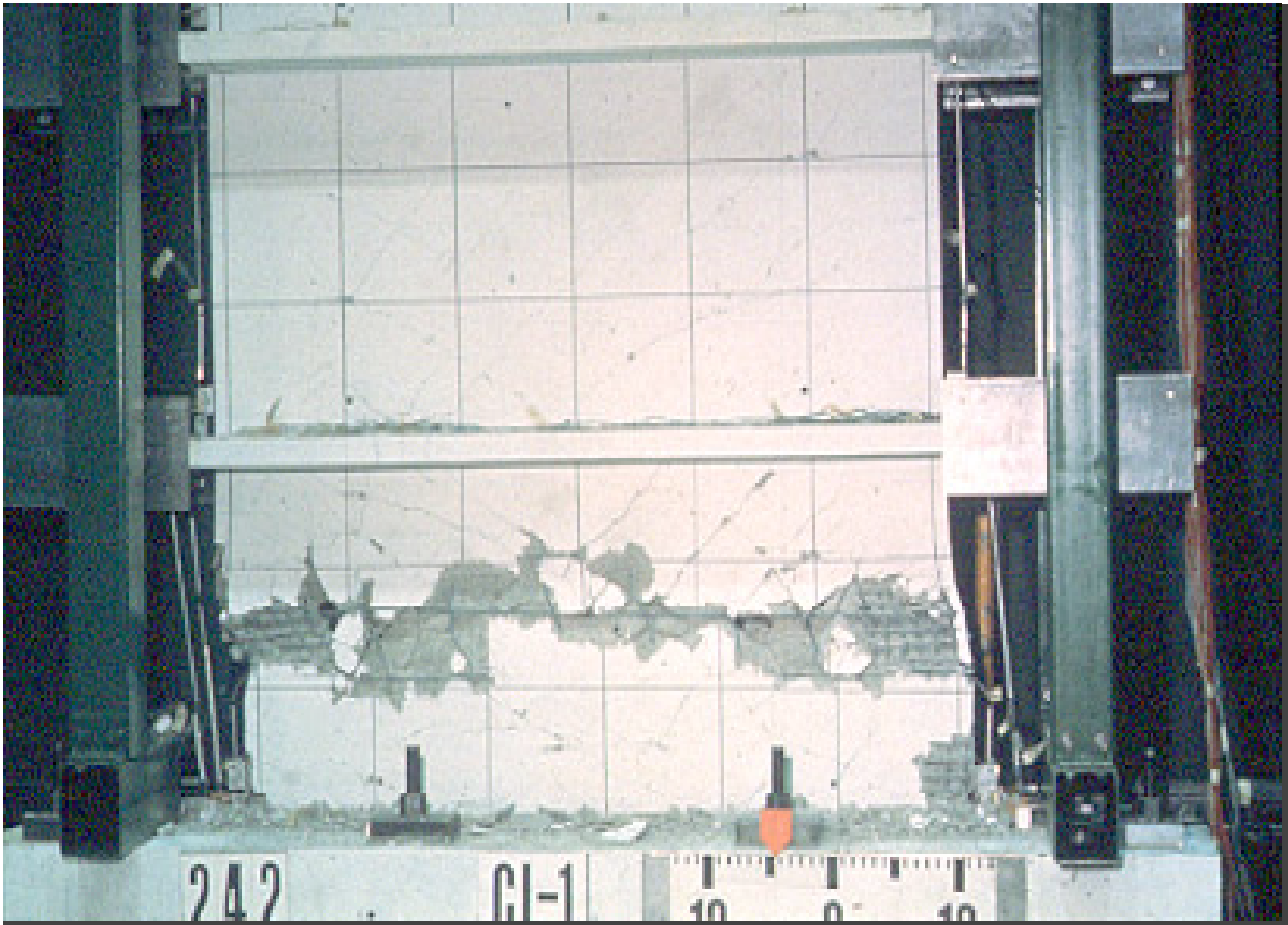


13-Story Building in Yeremca

More heavily damaged than three nearly identical neighboring buildings

Coupling of Walls by Slabs in Flexure

Behavior Mode: Flexure/ Sliding Shear



Sliding shear failure

Flexural yielding above curtailed reinforcement

Inelastic displaced shape

Administrative Building Retrofit

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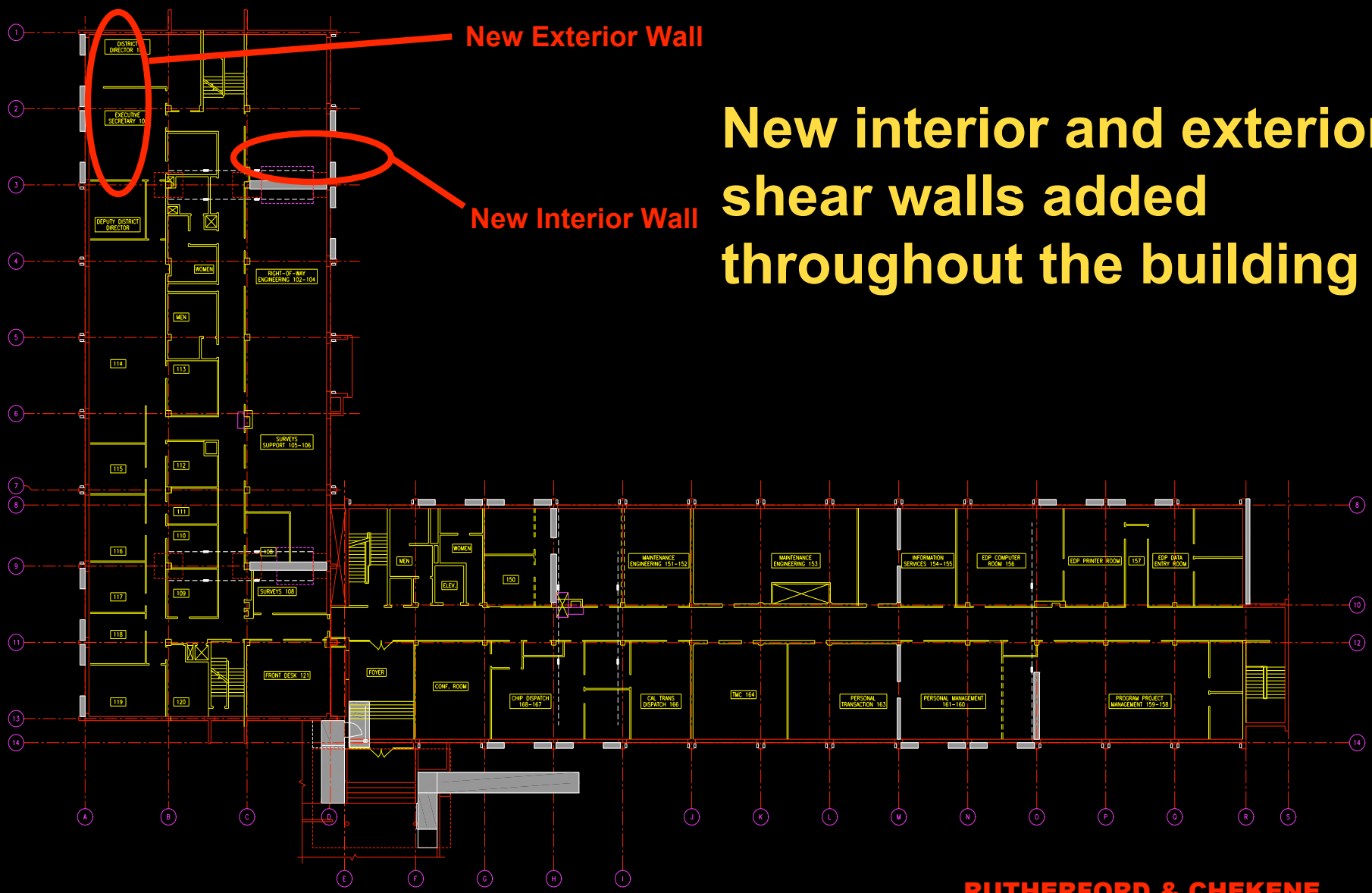
Retrofit Solution



New interior and exterior shear walls added throughout the building

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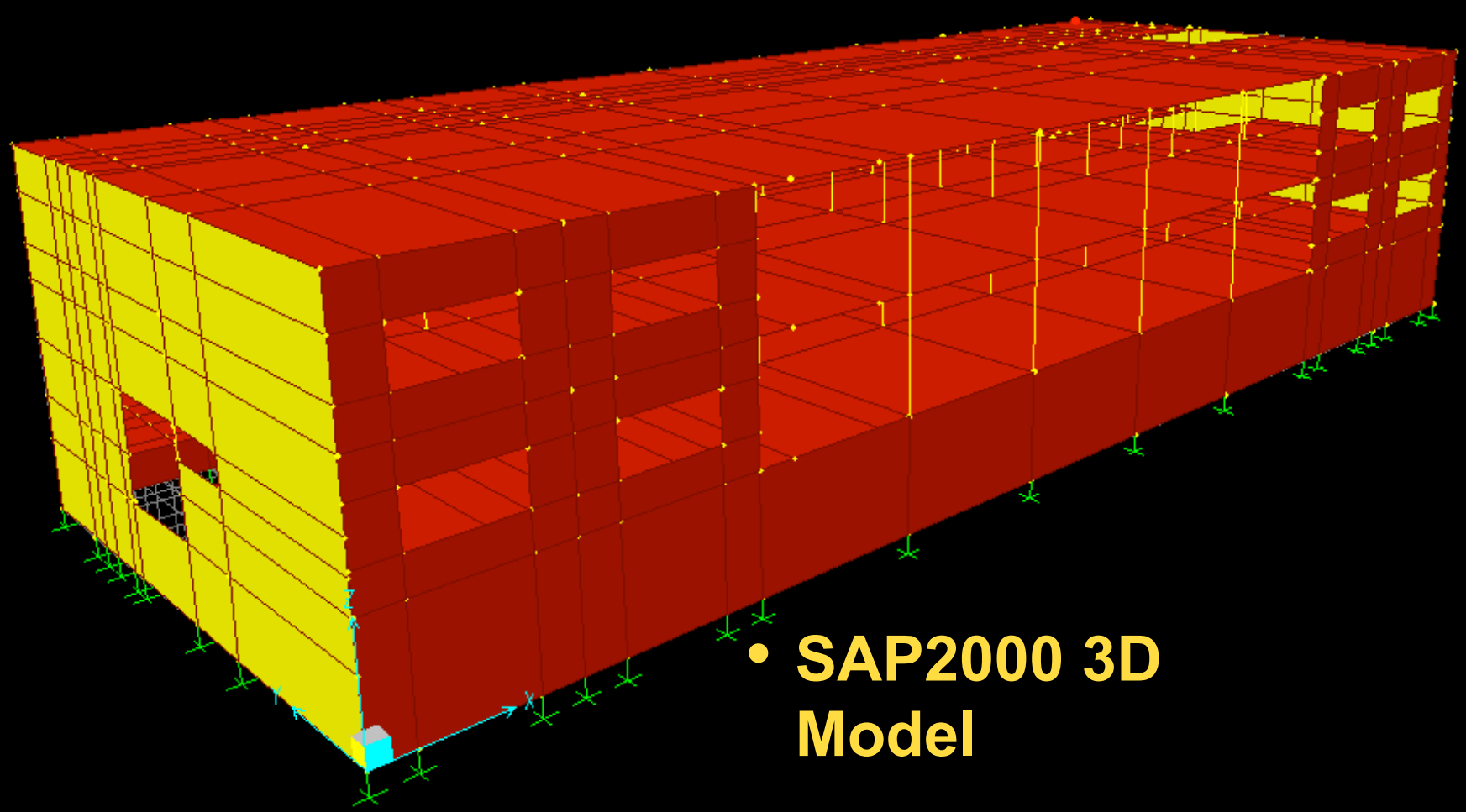
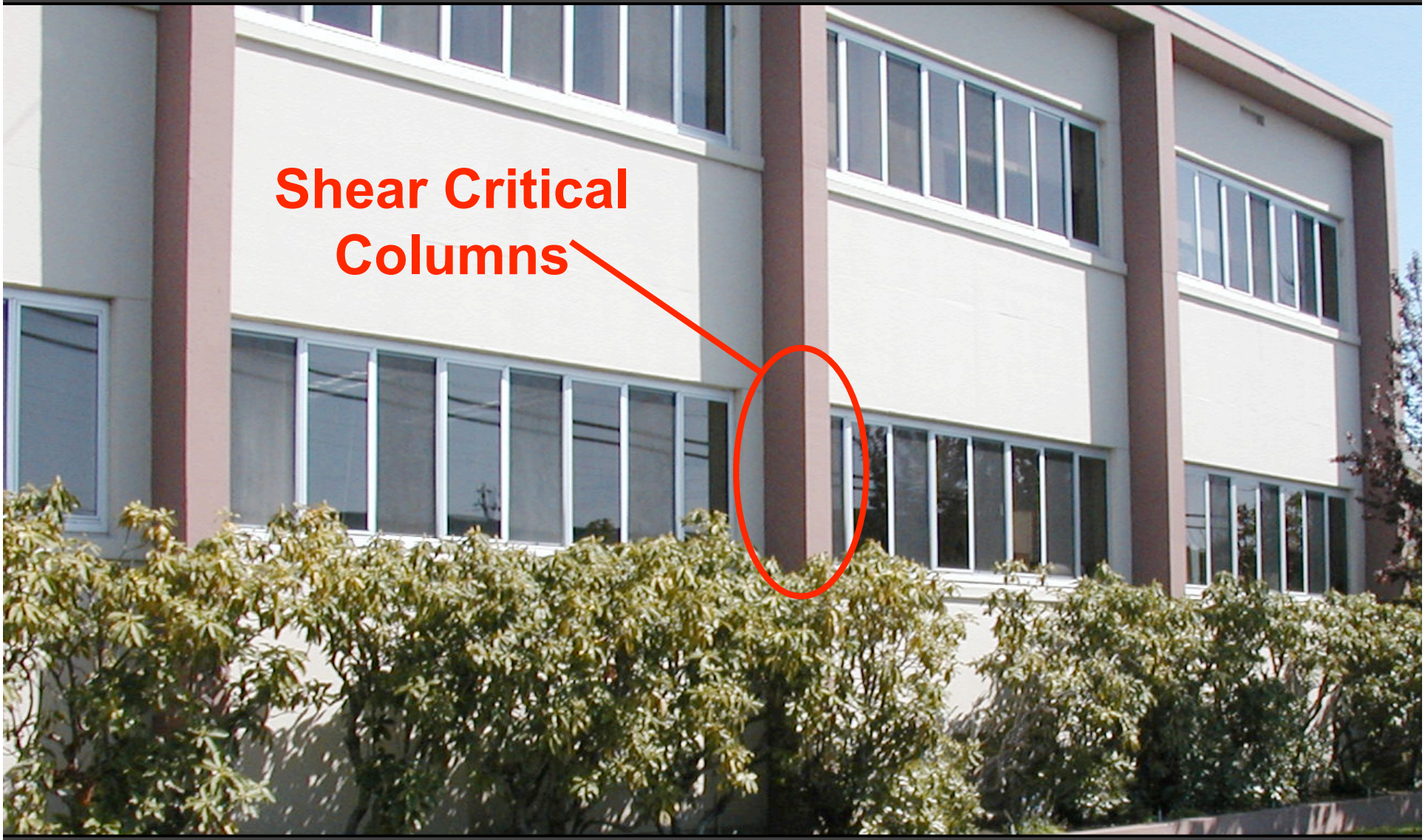
Analysis model



- SAP2000 3D Model

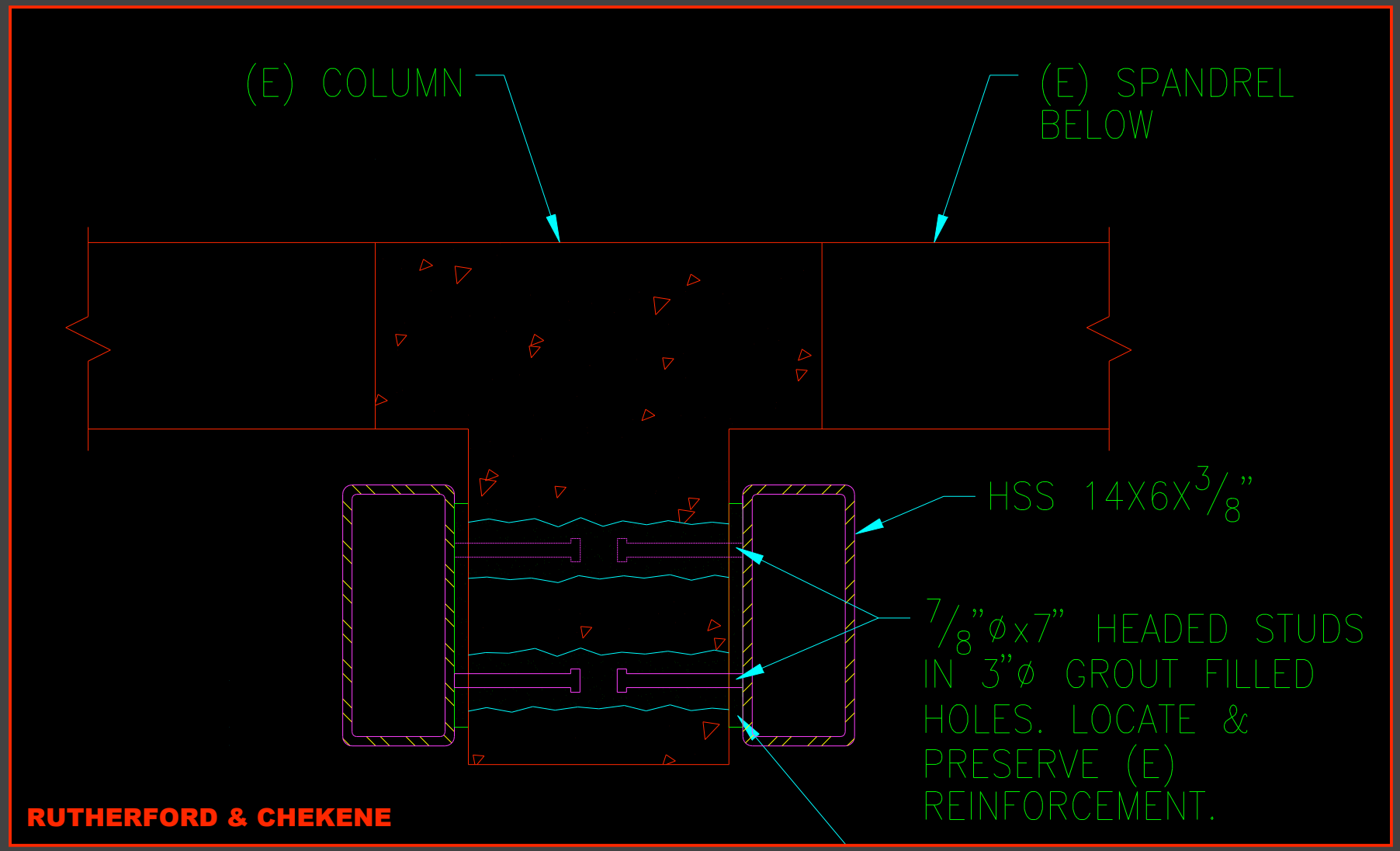
“Gravity” Columns



Acceptance limits for shear-critical columns

- 1% plastic rotation in FEMA 273, revised to 0.3% plastic rotation in FEMA 356 .
- Research by Moehle et al.
- But how reliably can we estimate the displacement demand?

Supplemental Support at exterior columns



Wurster Hall
UC Berkeley

RUTHERFORD & CHEKENE

Steel columns backing up existing precast concrete exterior columns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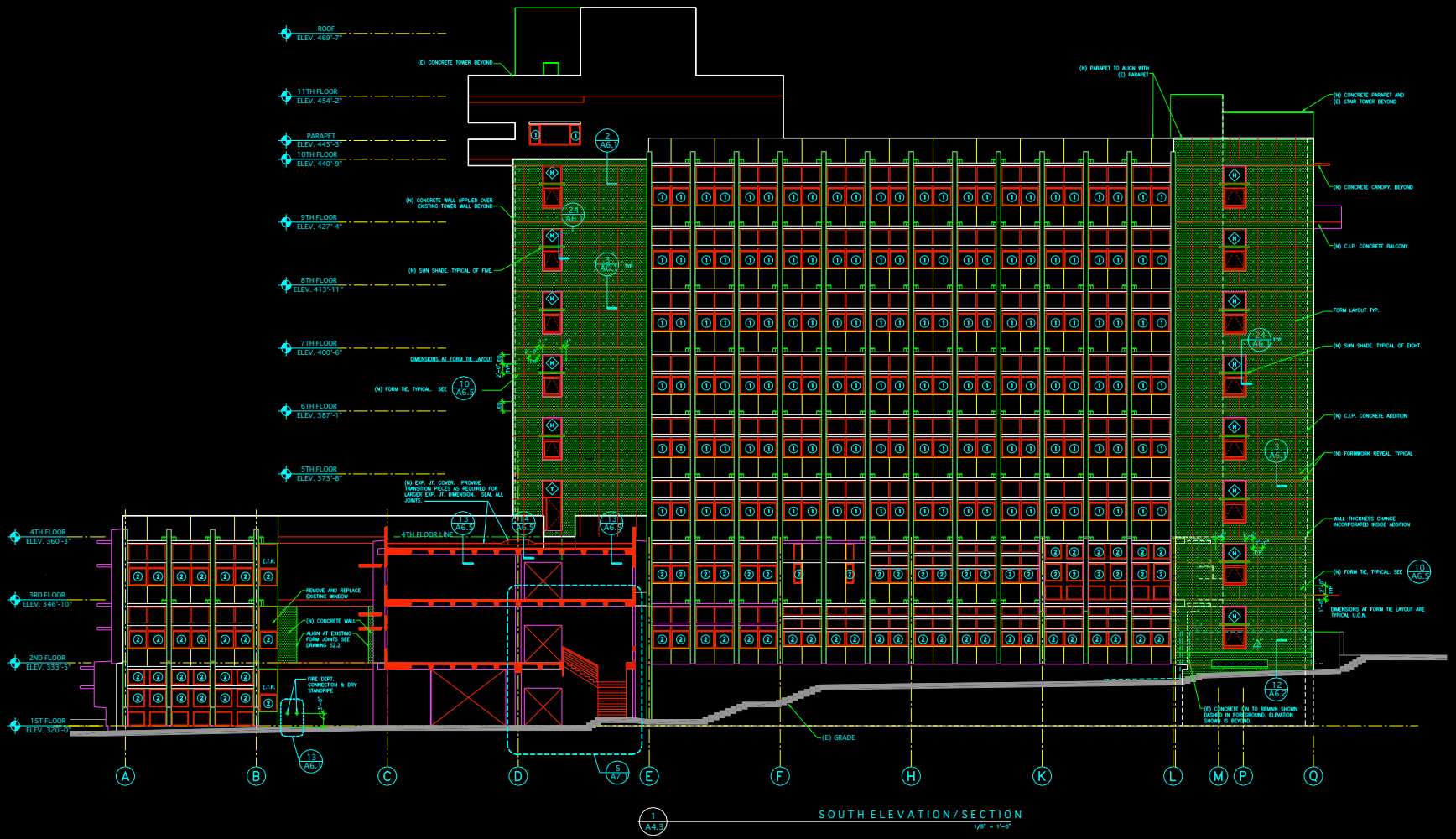
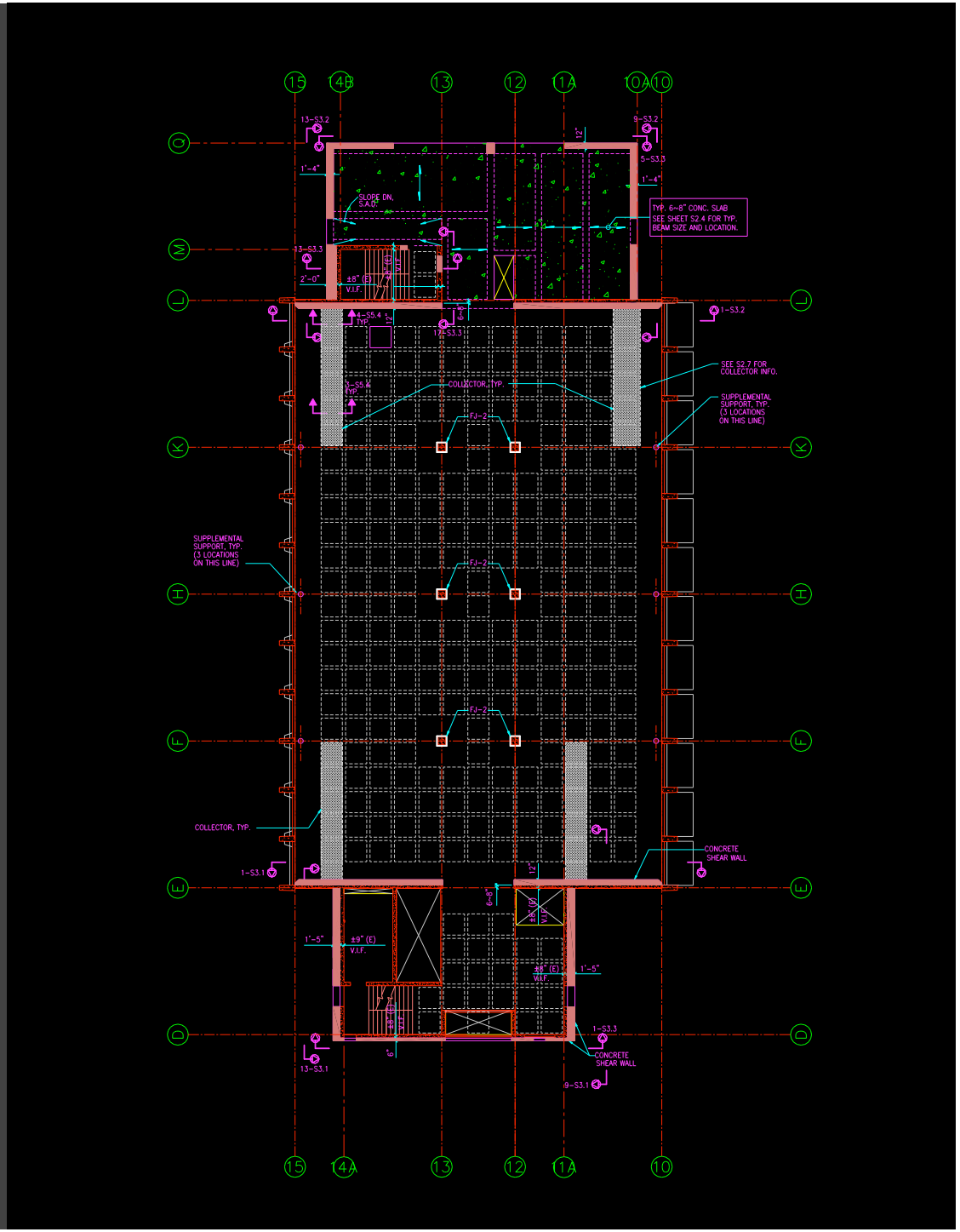
Elevation


ROOF
ELEV. 469'-7"
(E) CONCRETE TOWER BEYOND
11TH FLOOR
ELEV. 454'-2"
PARAPET
ELEV. 445'-3"
10TH FLOOR
ELEV. 440'-9"
(N) CONCRETE WALL APPLIED OVER EXISTING TOWER WALL BEYOND
9TH FLOOR
ELEV. 427'-4"
(N) SUN SHADE, TYPICAL OF FIVE
8TH FLOOR
ELEV. 413'-11"
7TH FLOOR
ELEV. 400'-6"
DIMENSIONS AT FORM TIE LAYOUT
(N) FORM TIE, TYPICAL. SEE
6TH FLOOR
ELEV. 387'-1"
5TH FLOOR
ELEV. 373'-8"
(N) EXP. JT. COVER. PROVIDE TRANSITION PIECES AS REQUIRED FOR LARGER EXP. JT. DIMENSION. SEAL ALL JOINTS.
4TH FLOOR
ELEV. 360'-3"
4TH FLOOR LINE
3RD FLOOR
ELEV. 346'-10"
2ND FLOOR
ELEV. 333'-5"
1ST FLOOR
ELEV. 320'-0"
E.T.R.
REMOVE AND REPLACE EXISTING WINDOW
(N) CONCRETE WALL
ALIGN AT EXISTING FORM JOINTS SEE DRAWING S2.2
FIRE DEPT. CONNECTION & DRY STANDPIPE
(N) PARAPET TO ALIGN WITH (E) PARAPET
(N) CONCRETE PARAPET AND (E) STAIR TOWER BEYOND
(N) CONCRETE CANOPY, BEYOND
(N) C.I.P. CONCRETE BALCONY
FORM LAYOUT TYP.
(N) SUN SHADE, TYPICAL OF EIGHT.
(N) C.I.P. CONCRETE ADDITION
(N) FORMWORK REVEAL, TYPICAL
WALL THICKNESS CHANGE INCORPORATED INSIDE ADDITION
(N) FORM TIE, TYPICAL. SEE
DIMENSIONS AT FORM TIE LAYOUT ARE TYPICAL U.O.N.
(E) CONCRETE TO REMAIN SHOWN DASHED IN FOREGROUND. ELEVATION SHOWN IS BEYOND.
(E) GRADE
A
B
C
D
E
F
H
K
L
M
P
Q
SOUTH ELEVATION/SECTION
1/8" = 1'-0"

Retrofit Plan



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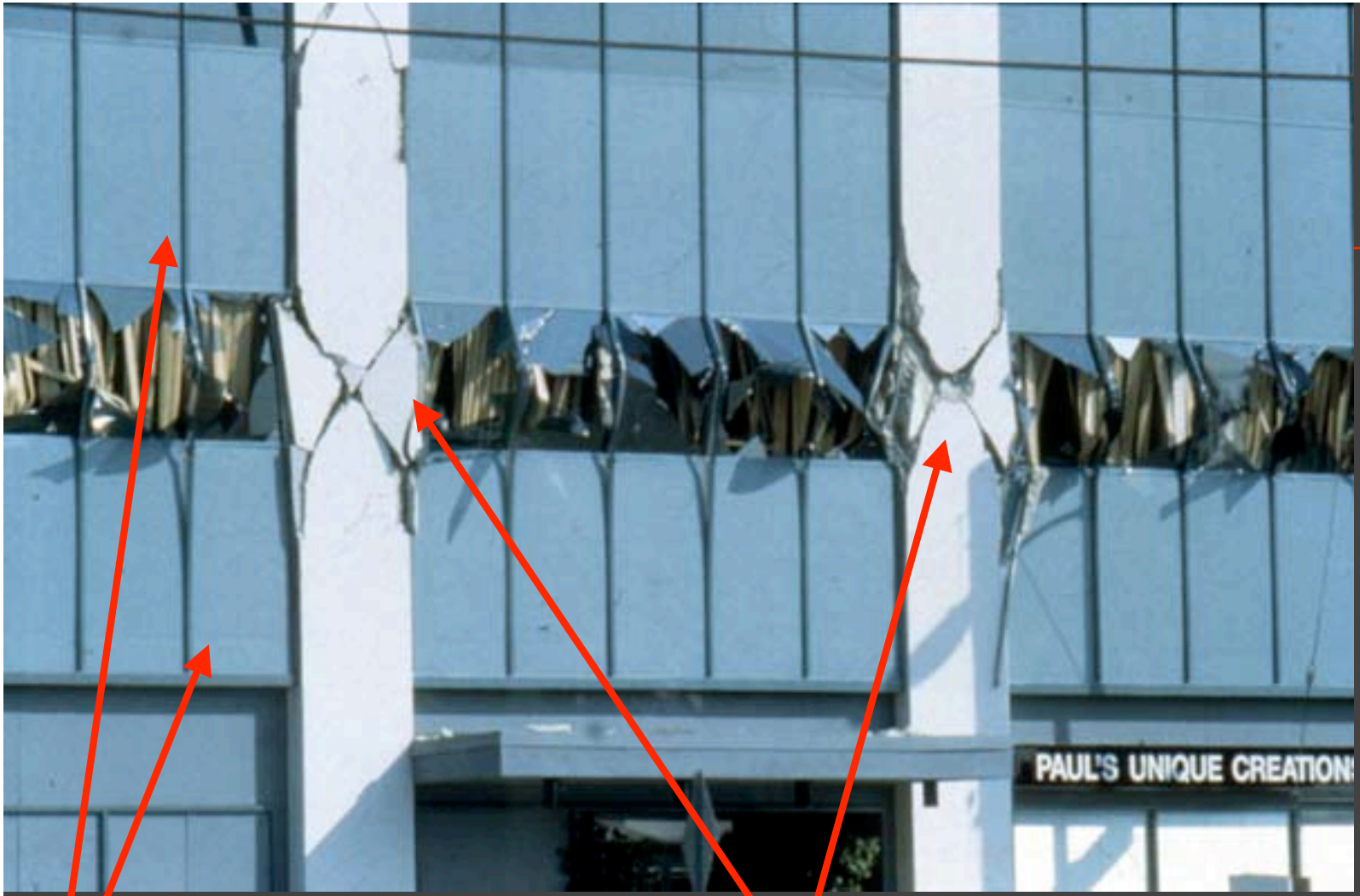
Steel plate collectors

Column shear failures

Behavior Mode: Foundation Rocking (Overturning)



Stronger Spandrel

Preemptive diagonal tension

Private high school, constructed 1897-1906

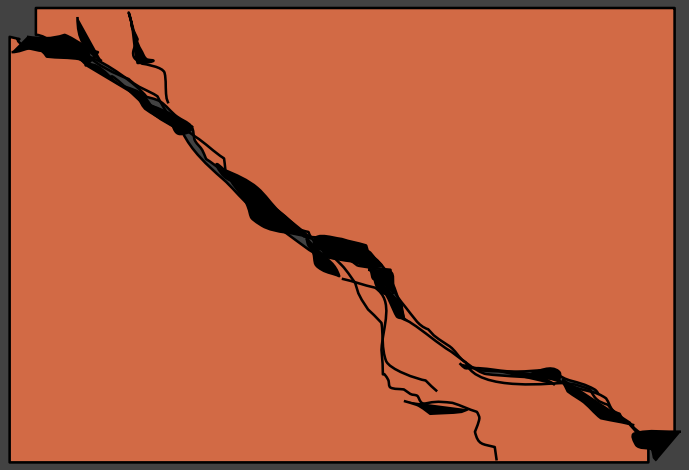
1897 Unreinforced brick school

Strength of:

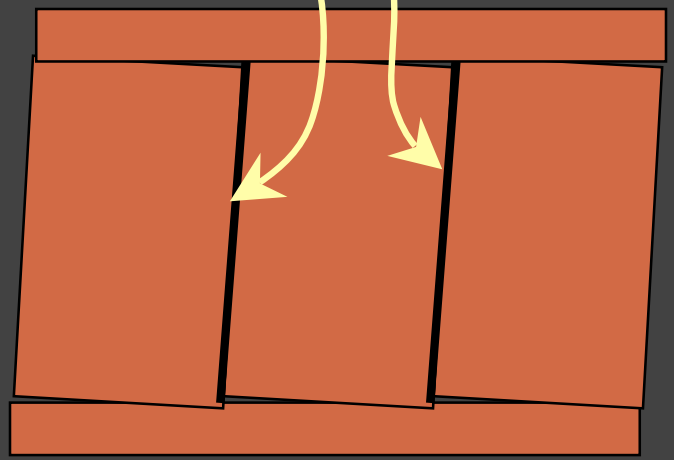
- **Wall-to-roof and wall-to-floor connections**
- **Brick walls and new steel braces in-plane**

>

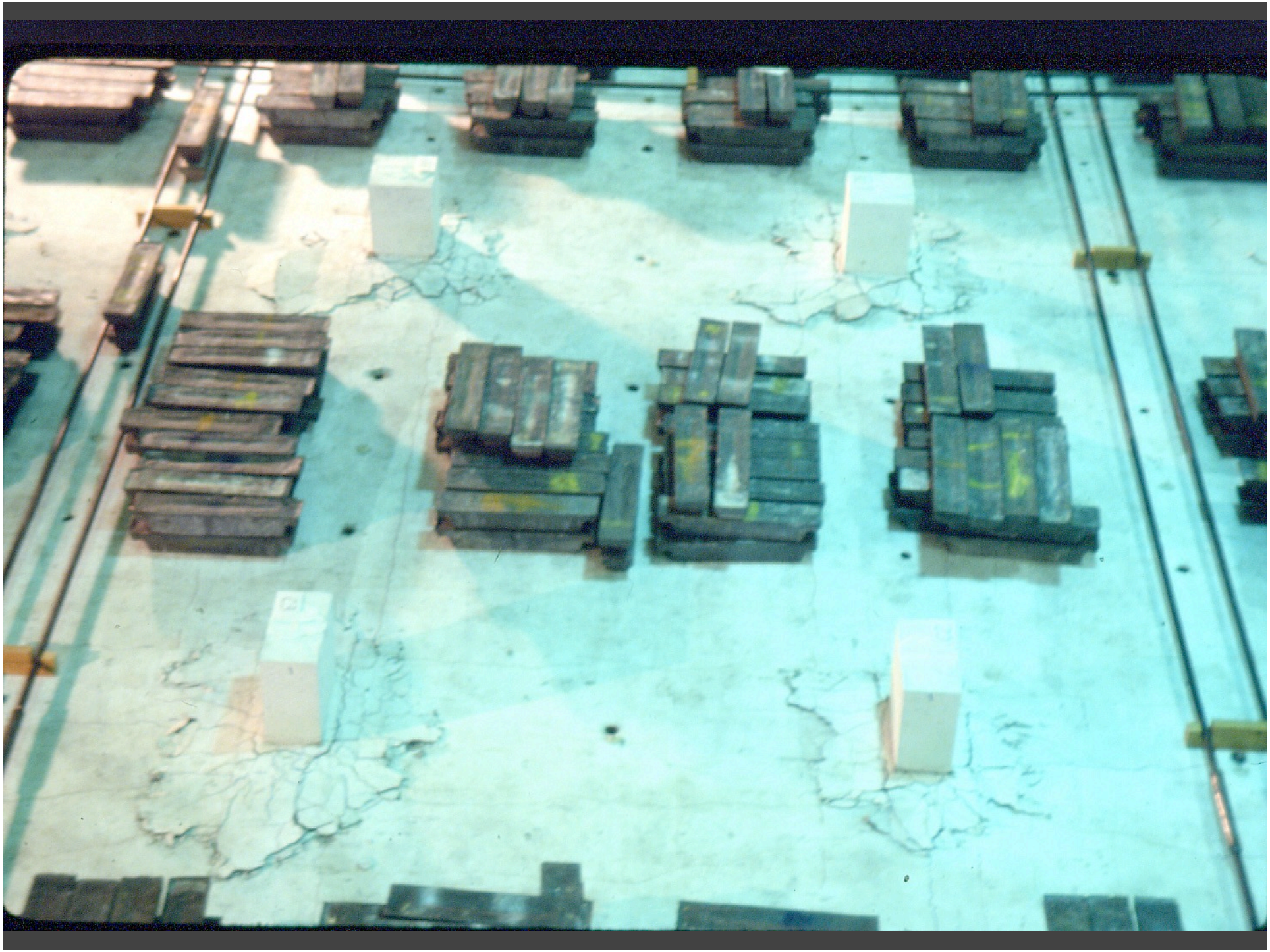
Strength of wood floor and roof diaphragms yielding.

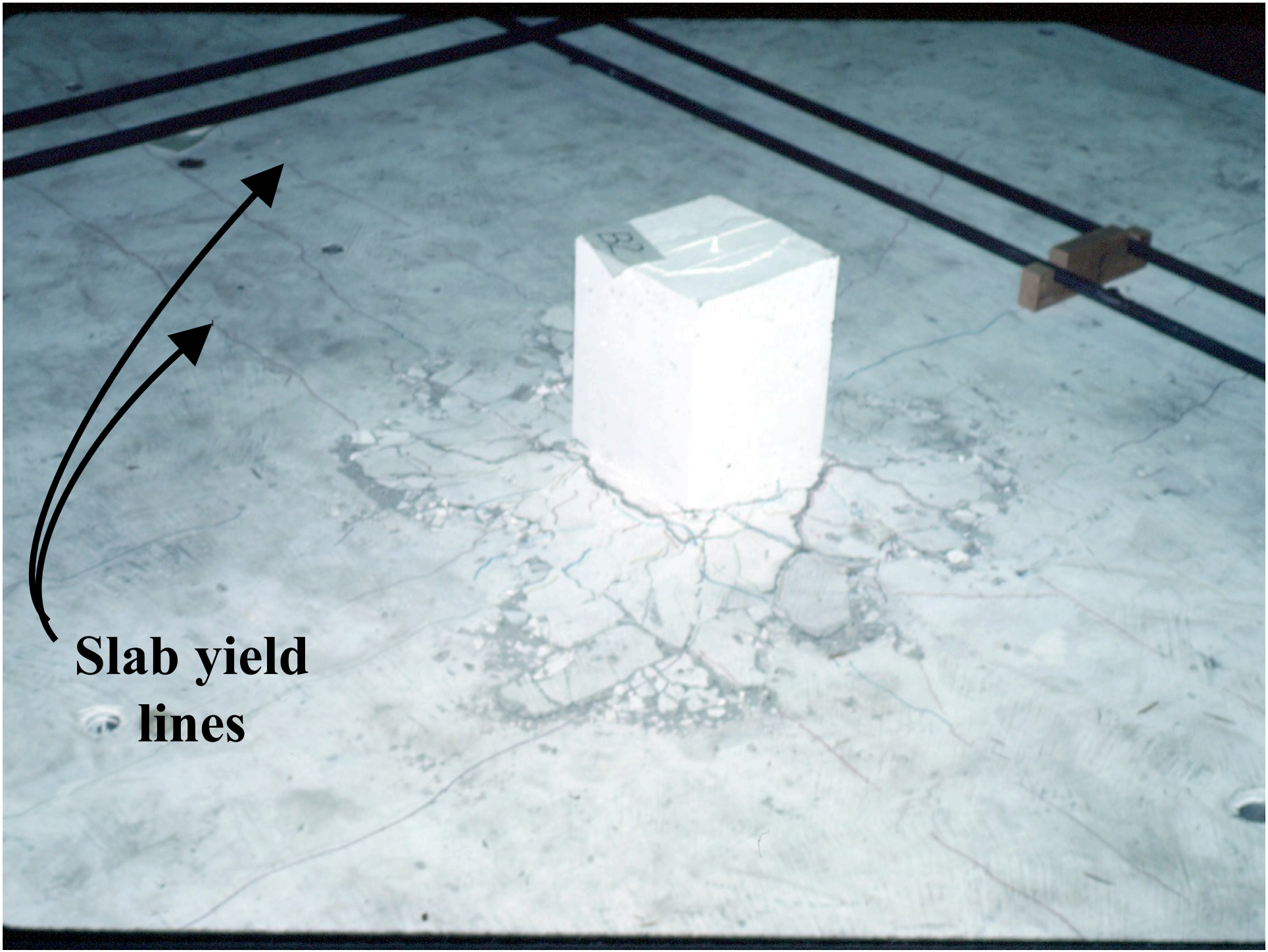


Vertical saw cut of walls



Northridge, punching shear damage




Slab yield
lines

Punching shear and slab collapse

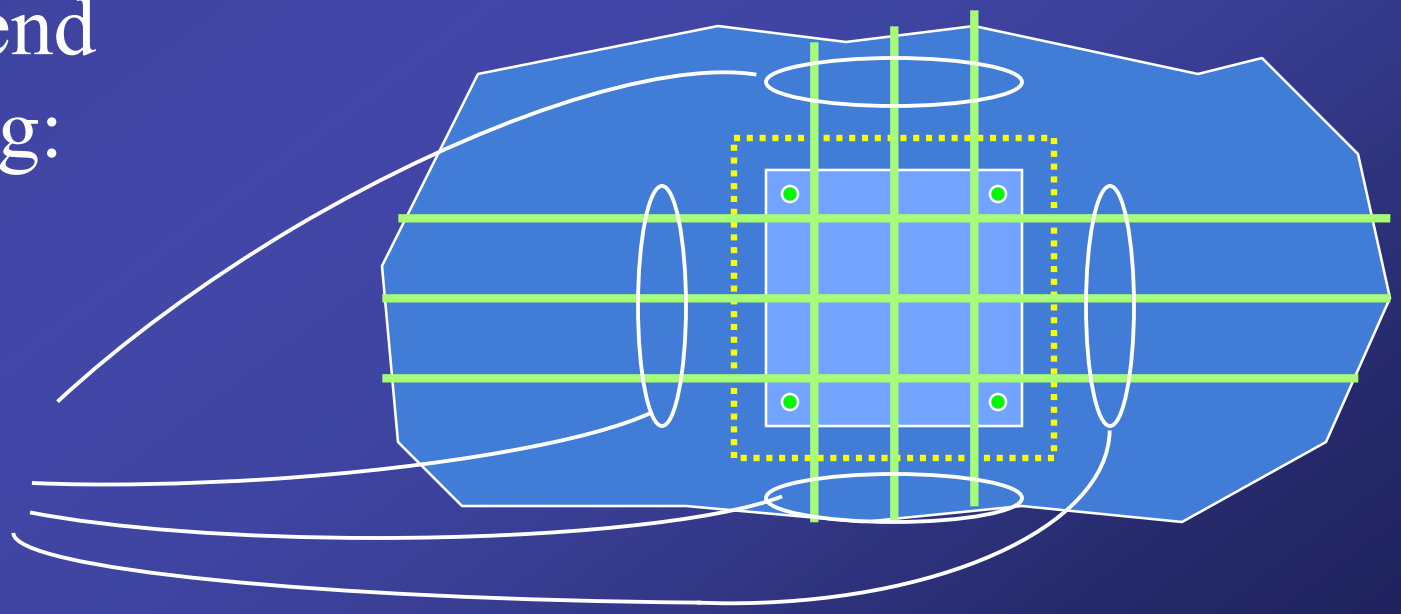
“Integrity” reinforcement

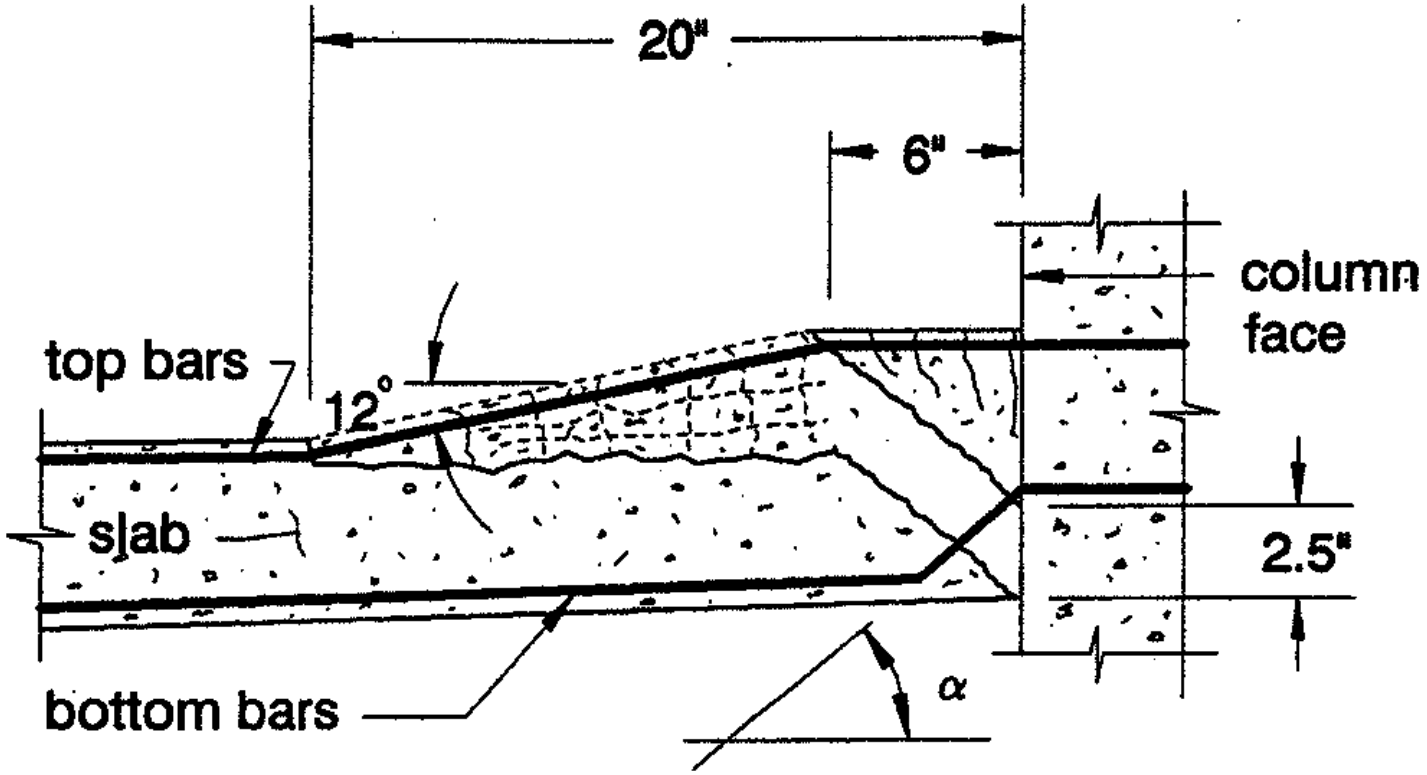
13.3.8.5 Requires two bottom bars through the column core.

Recommend calculating:

$\square A_{s,integrity}$

$\geq 2V_u/f_y$





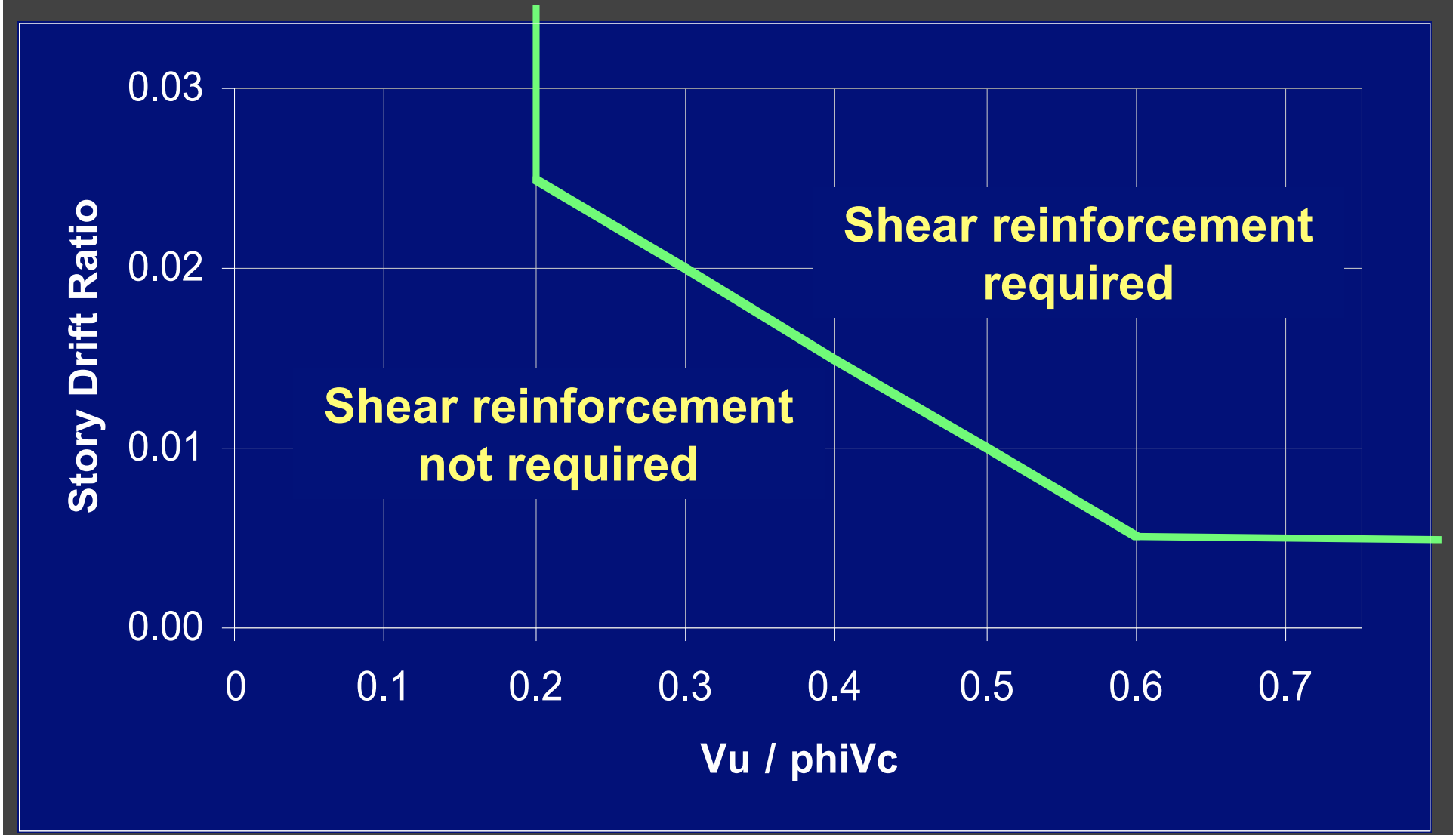
Slab vertical displacement of 2.5" inferred from equal vertical movement of column after punching.

Inclination of top slab bars deduced from extent of spalling, vertical column movement, and average slab inclination prior to punching.

Fig. 9—Post-punching behavior of slab-column connections (1 in. = 25.4 mm)

Pan & Moehle 1992

Proposed criteria



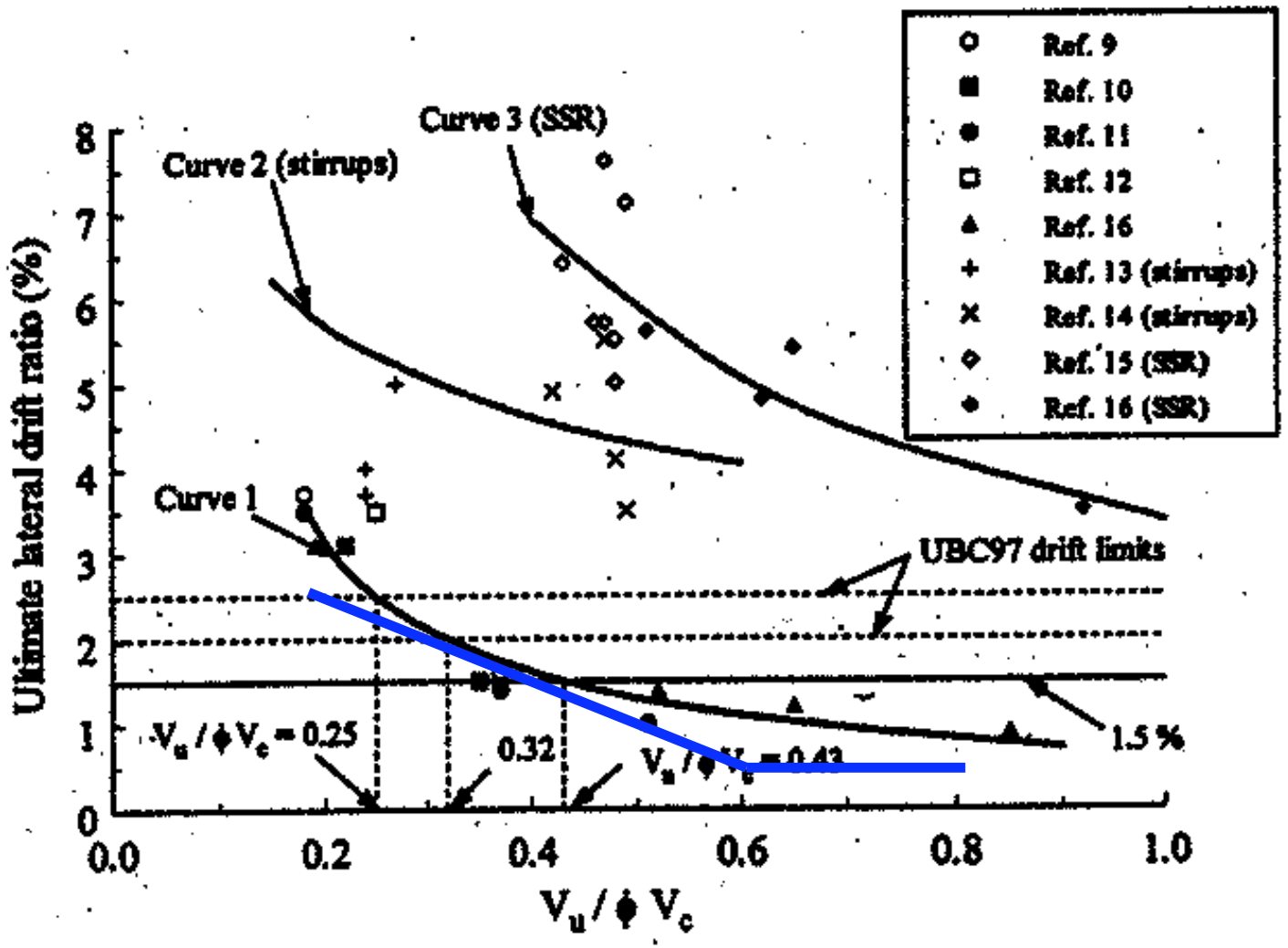


Fig. 1—Effect of gravity loads on lateral drift capacity of interior slab-column connections.

Megally & Ghali 2000

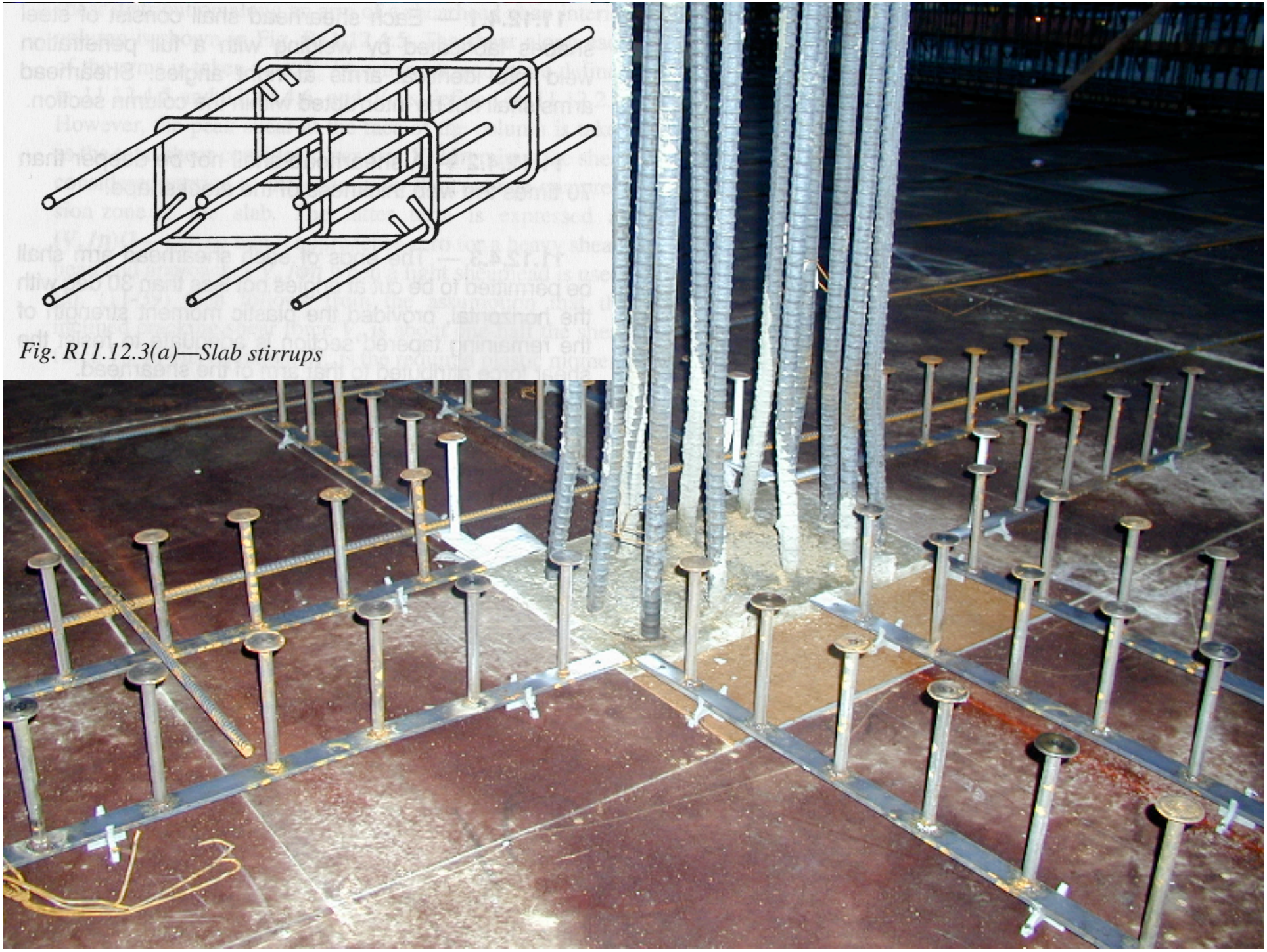
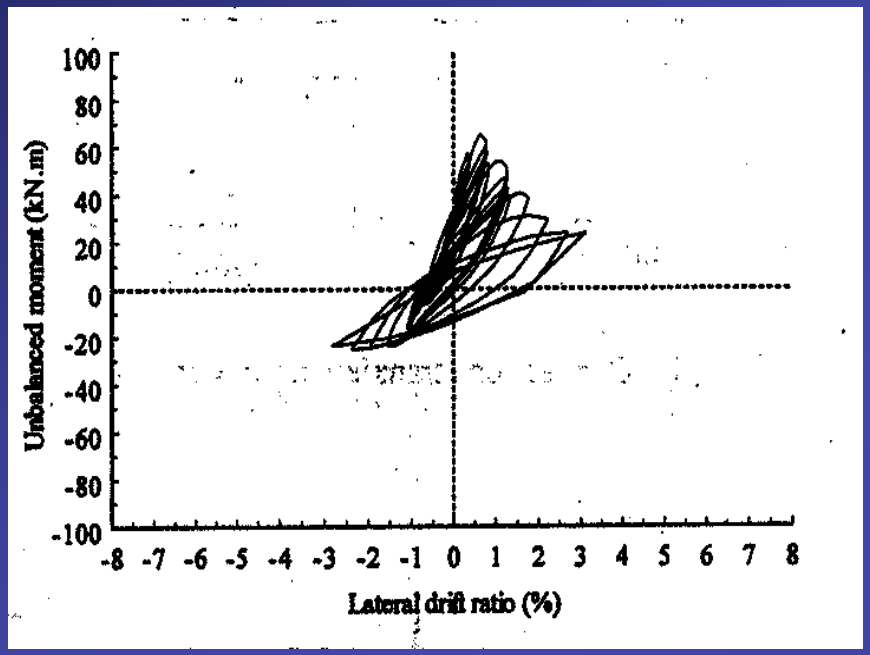
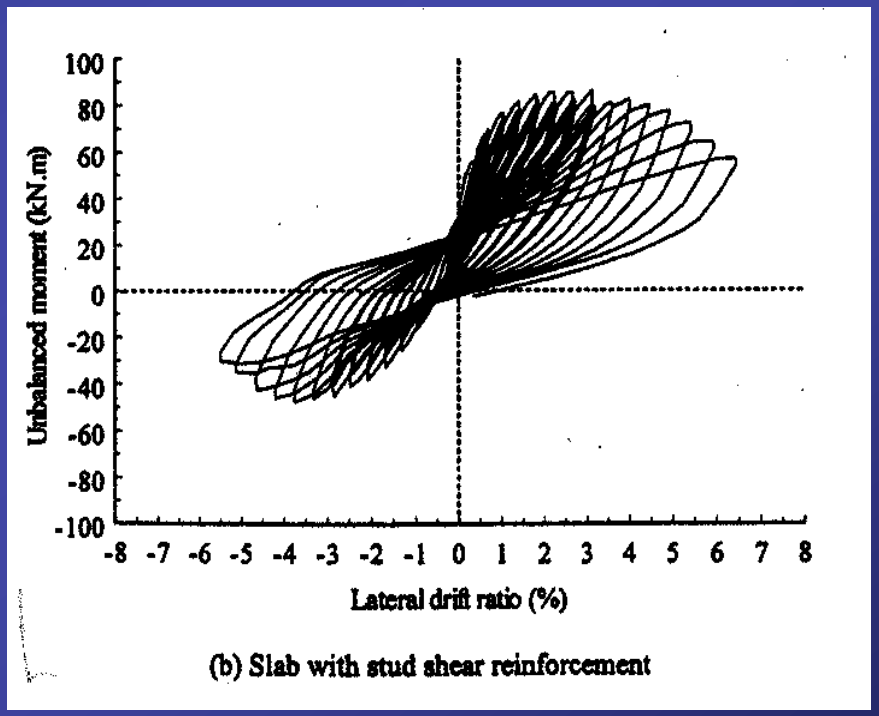


Fig. R11.12.3(a)—Slab stirrups





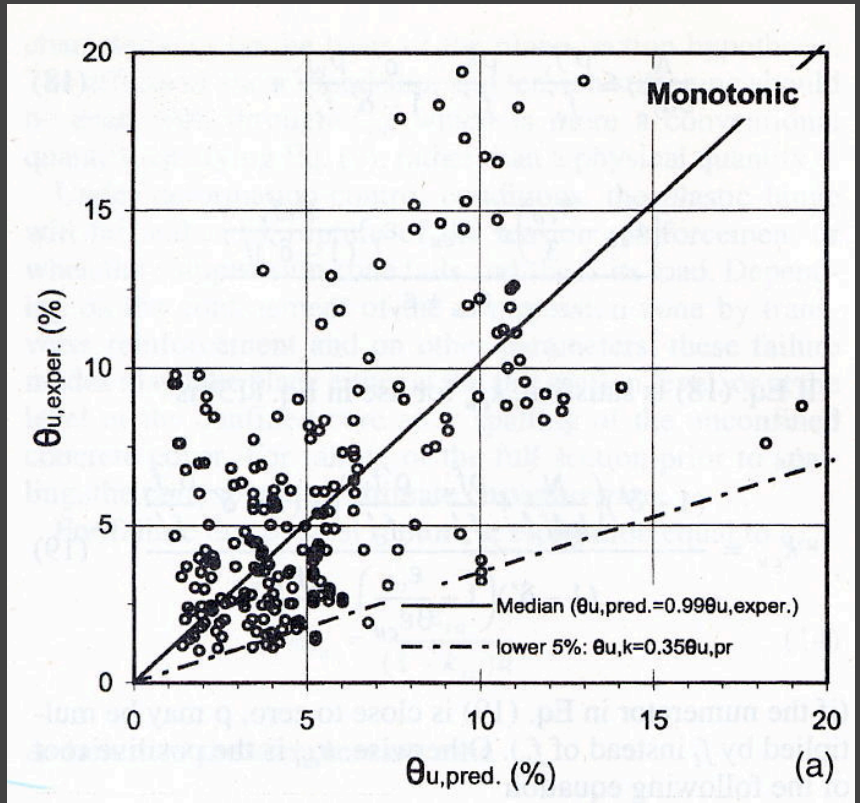
Megally & Ghali 2000

Conclusions

- Research has been very useful to practitioners.
- Development of research into easy to use guidelines needs much more work, particularly if guidelines are made into requirements or standards.

Conclusions

- **Summaries and comparisons of research, and investigations of previous data, are extremely valuable.**



Conclusions

- Clear and complete documentation of research methods and observations is essential.

Recommendations

Principles of scientific inquiry:

- **Explore thoroughly previous work in the same topic area, so that you build on it rather than repeating it.**
- **Document everything, so that your work could be independently duplicated.**