

# Field Tests on RC Buildings of Hsin-Tseng Junior High School in Taiwan for Seismic Resistance


Yi-Hausn Tu

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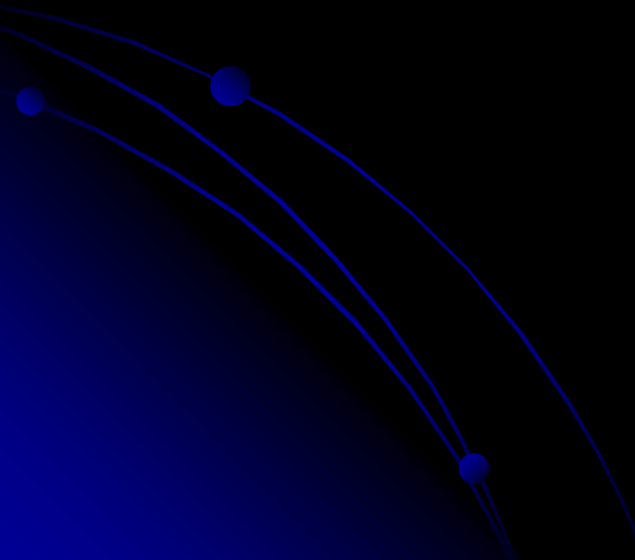
Shyh-Jiann Hwang



# Outline

- Introduction
  - Testing Plan
  - Lateral Load Test
  - Vertical Load Test
  - Future Study
- 

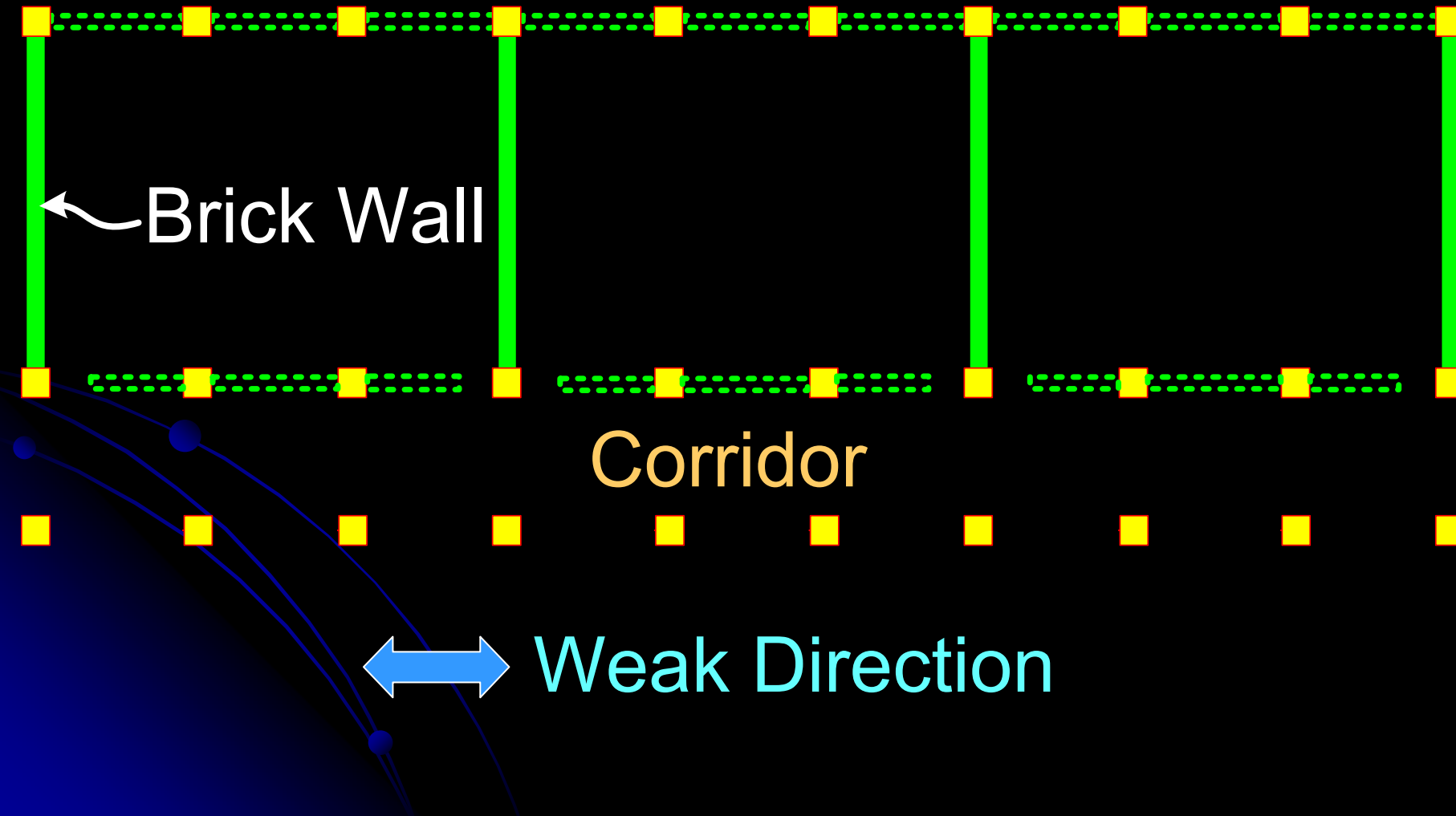
# Introduction



# 921 Chi-Chi Earthquake



# Typical Plan of School Buildings



# Collapse in the Weak Direction



# Typical Elevation of School Buildings



Window Sills and Captive Columns

# Column Failures but No Collapse

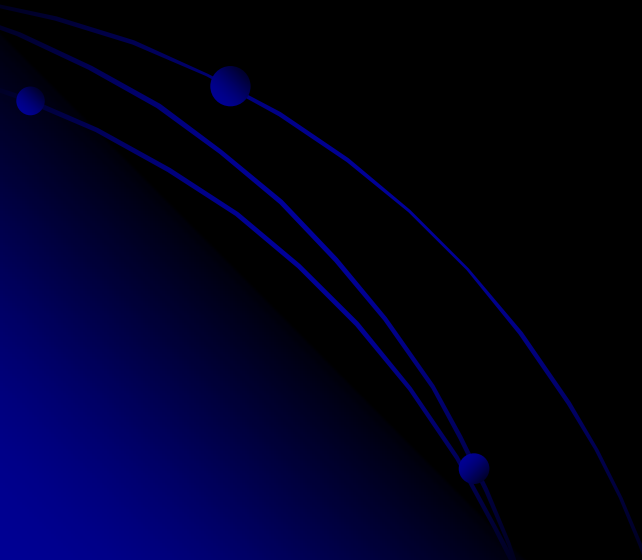




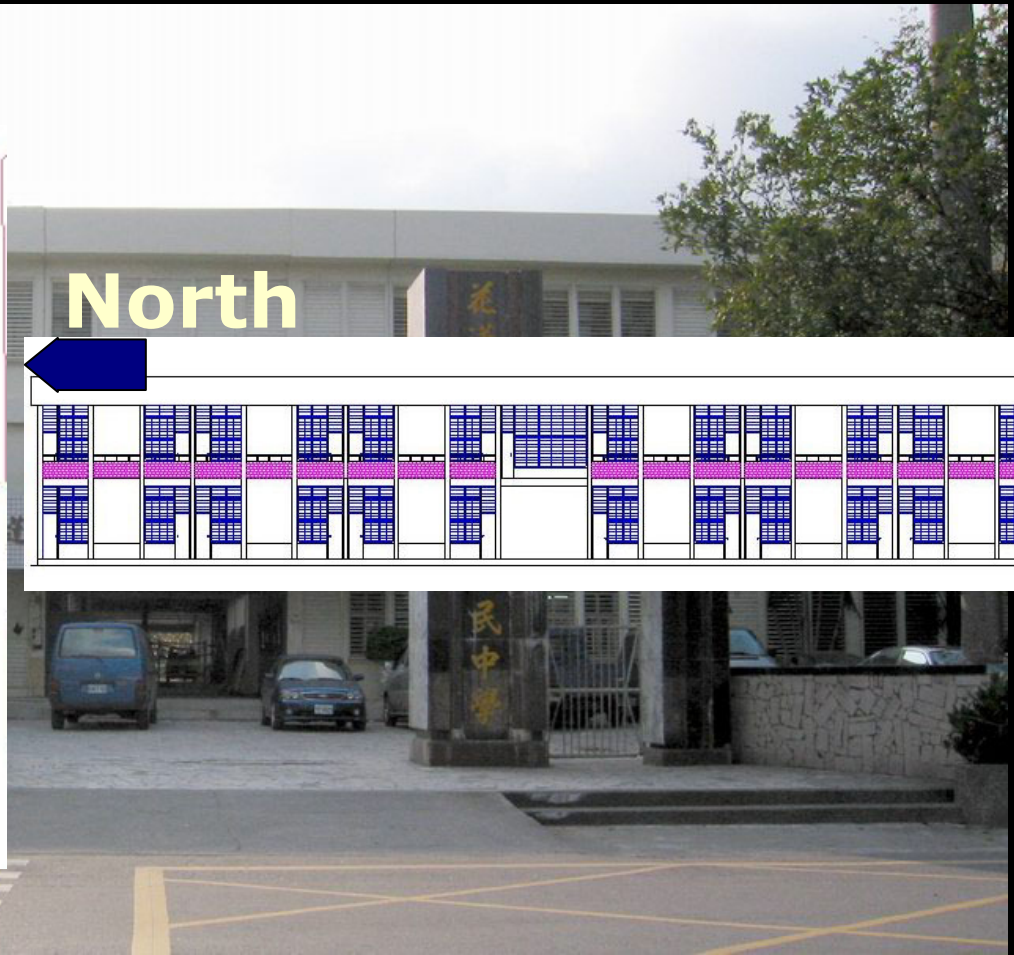
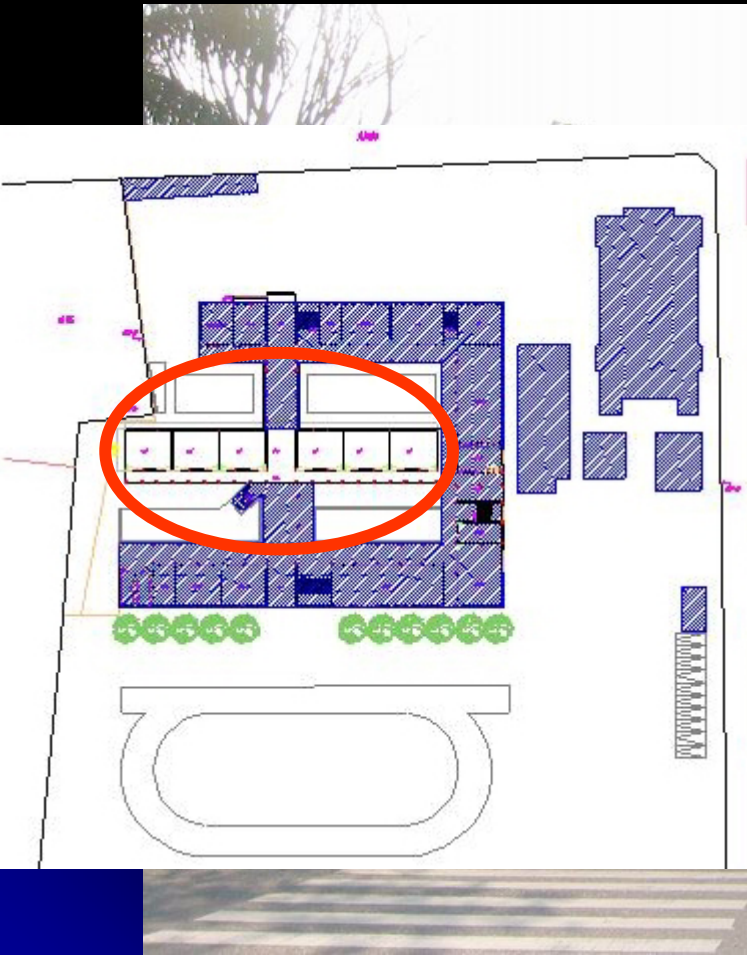
# Field Investigation



# Testing Plan

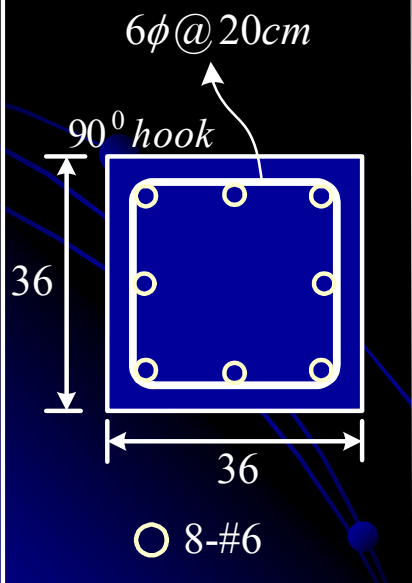
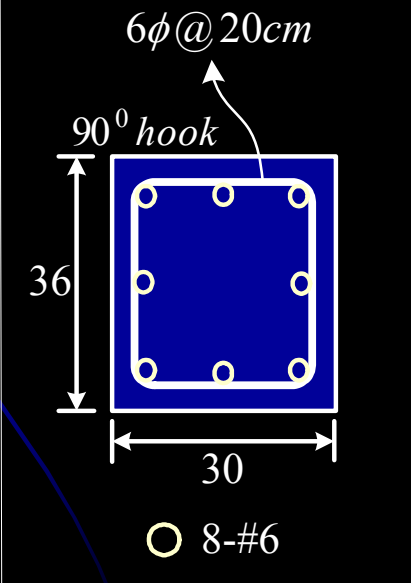
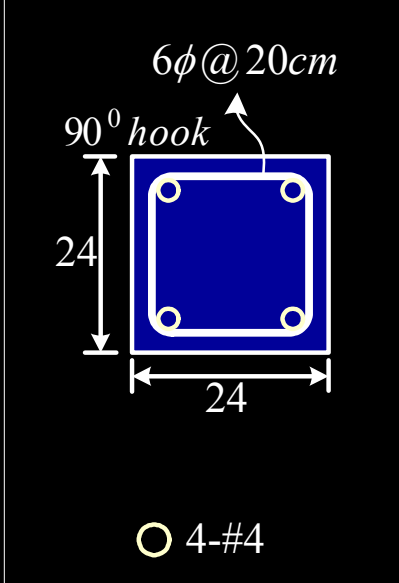
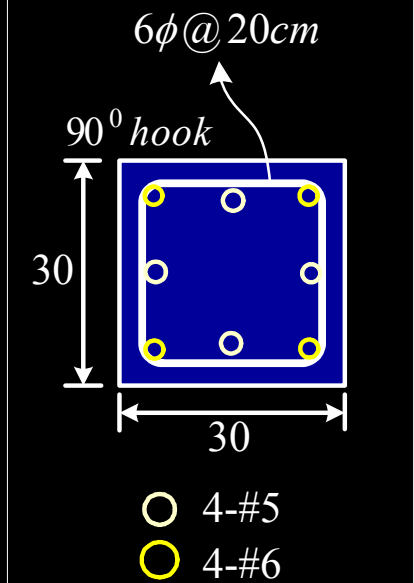


# Hsin-Tseng Junior High School Hualien County, Taiwan

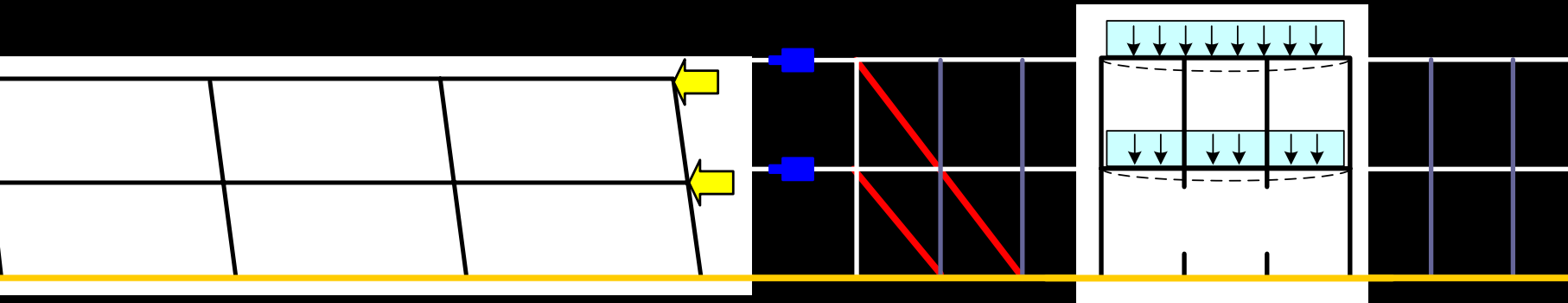


# Material Properties and Column Reinforcement

$$f'_c = 26MPa \quad f_y = 320MPa$$

C1	C2	C3	C4
<p style="text-align: center;"><math>6\phi@20cm</math></p> <p style="text-align: center;"><math>90^\circ</math> hook</p>  <p style="text-align: center;">36</p> <p style="text-align: center;">36</p> <p style="text-align: center;">○ 8-#6</p>	<p style="text-align: center;"><math>6\phi@20cm</math></p> <p style="text-align: center;"><math>90^\circ</math> hook</p>  <p style="text-align: center;">36</p> <p style="text-align: center;">30</p> <p style="text-align: center;">○ 8-#6</p>	<p style="text-align: center;"><math>6\phi@20cm</math></p> <p style="text-align: center;"><math>90^\circ</math> hook</p>  <p style="text-align: center;">24</p> <p style="text-align: center;">24</p> <p style="text-align: center;">○ 4-#4</p>	<p style="text-align: center;"><math>6\phi@20cm</math></p> <p style="text-align: center;"><math>90^\circ</math> hook</p>  <p style="text-align: center;">30</p> <p style="text-align: center;">30</p> <p style="text-align: center;">○ 4-#5 ● 4-#6</p>

# Testing Objectives



## Lateral Load Test

Seismic resistance  
along corridor direction

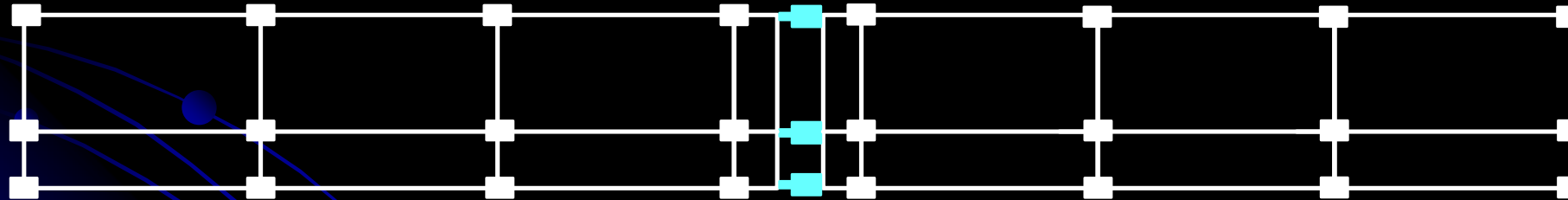
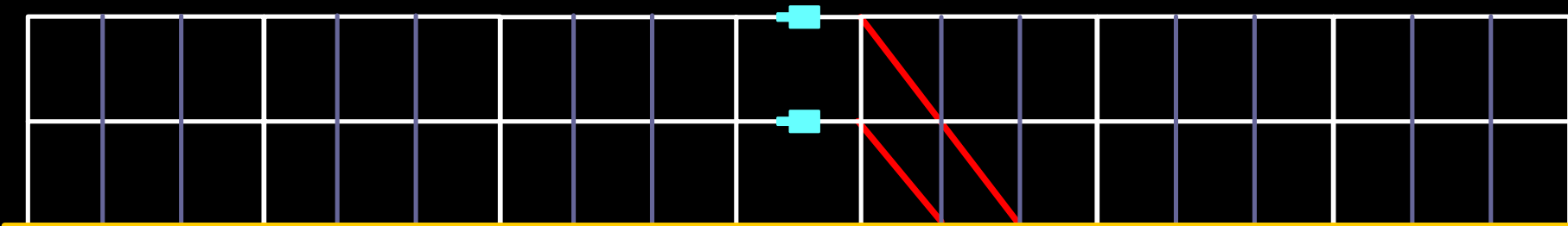
## Vertical Load Test

Vertical load  
carrying mechanism  
after column failures

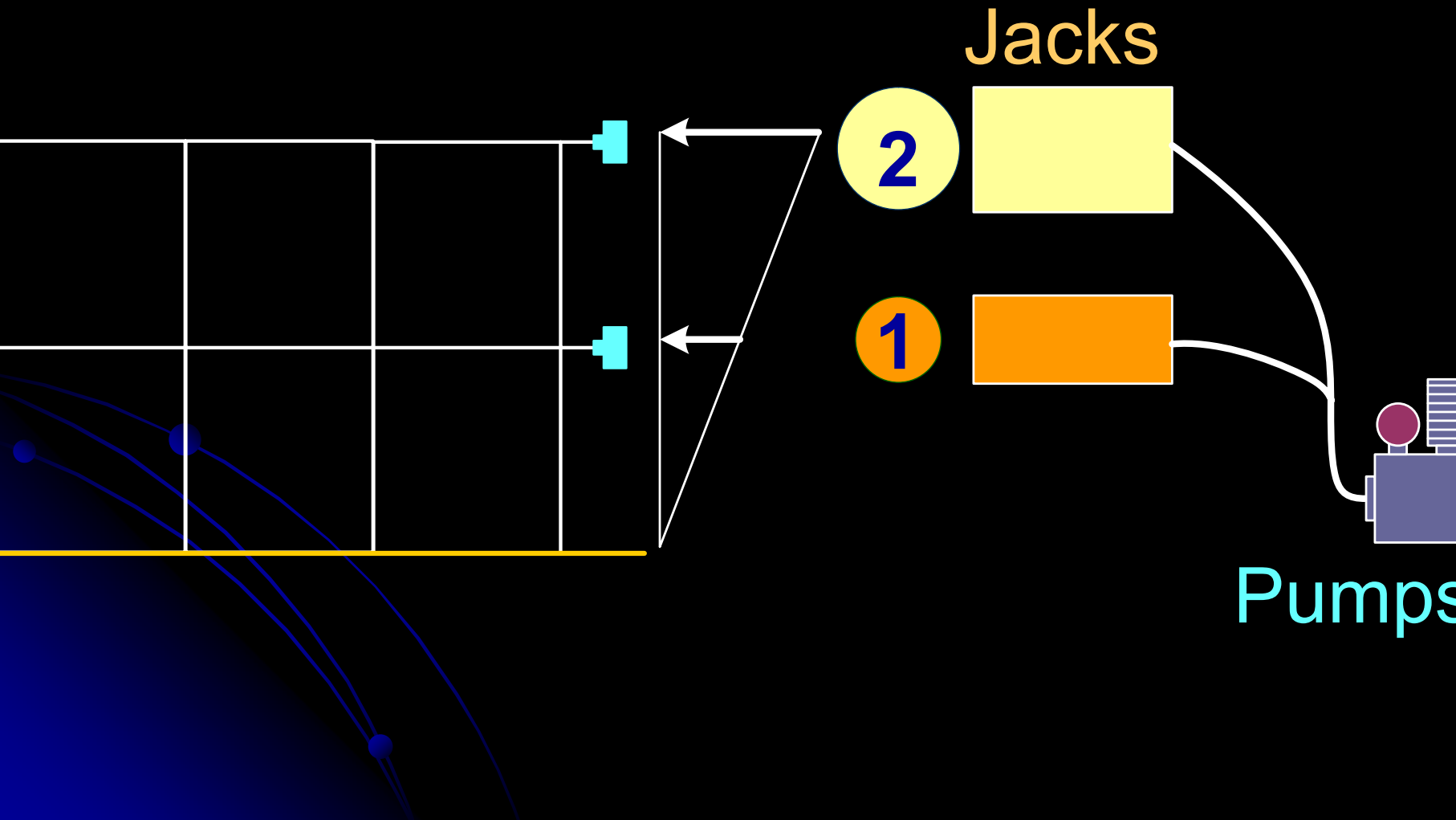
# Lateral Load Test



# Test Setup



# Loading System





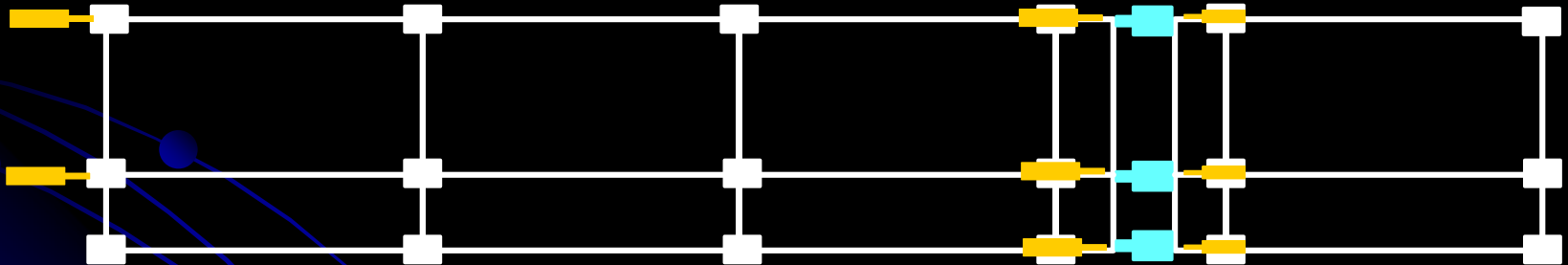
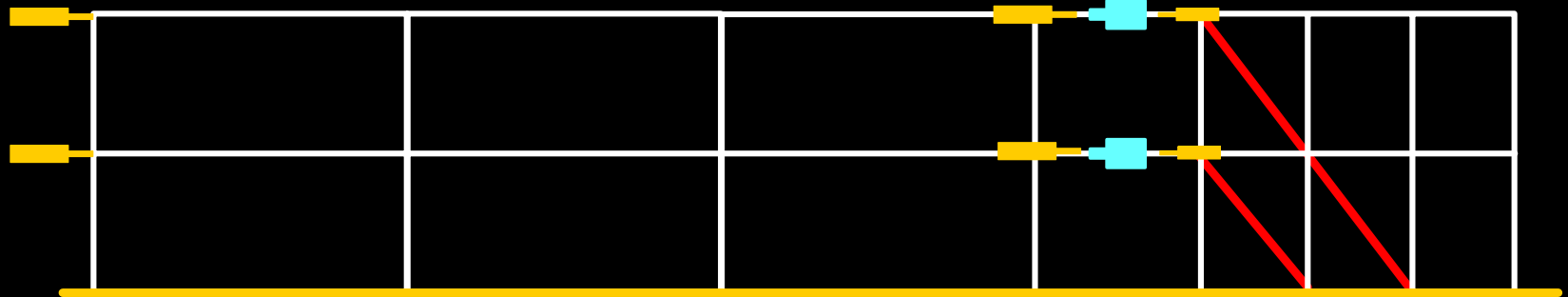
# Braces and Jacks



# Instrumentation

Free End

Loaded End



Displacement Gauge: 

# Lateral Displacement

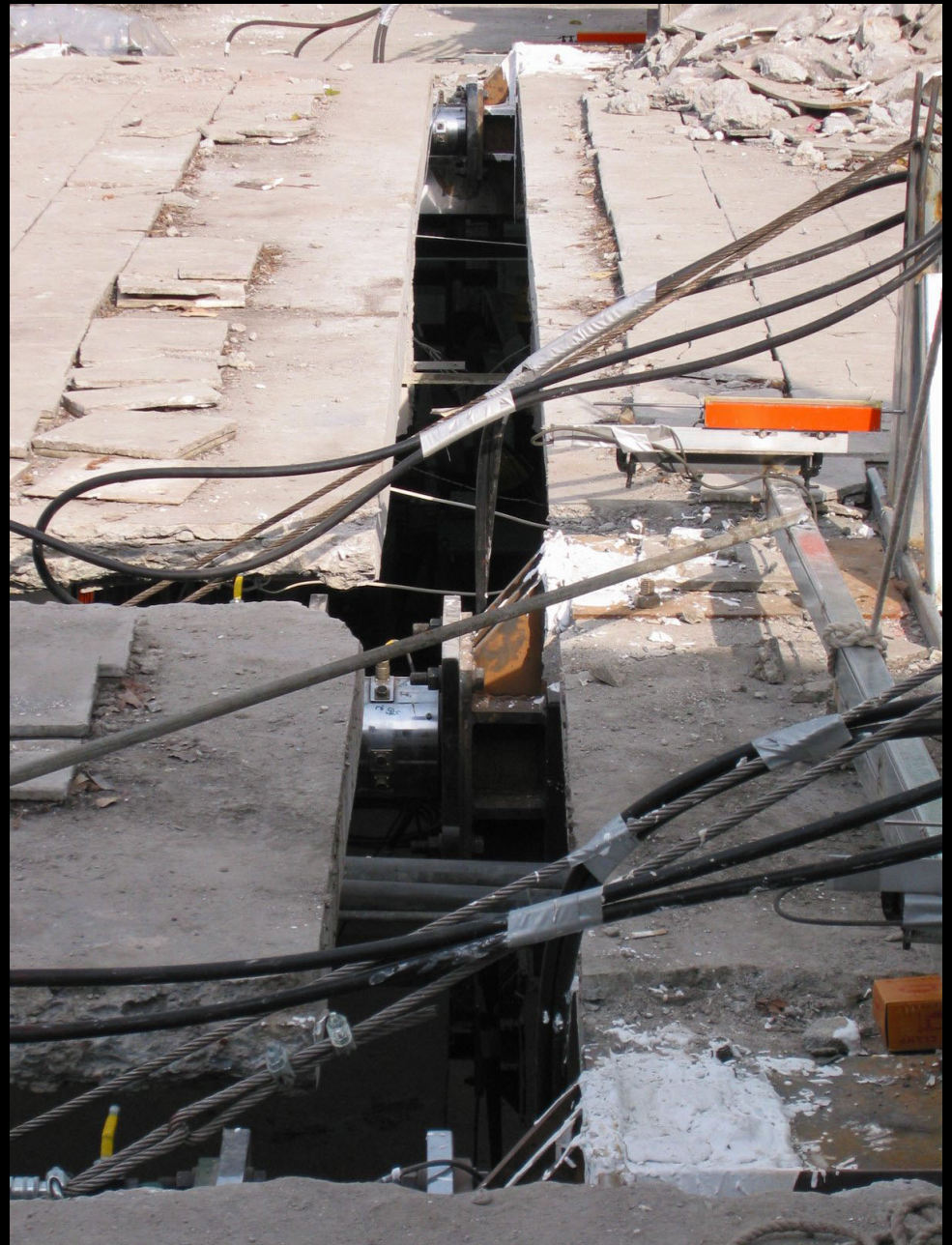


Loaded End

Free End

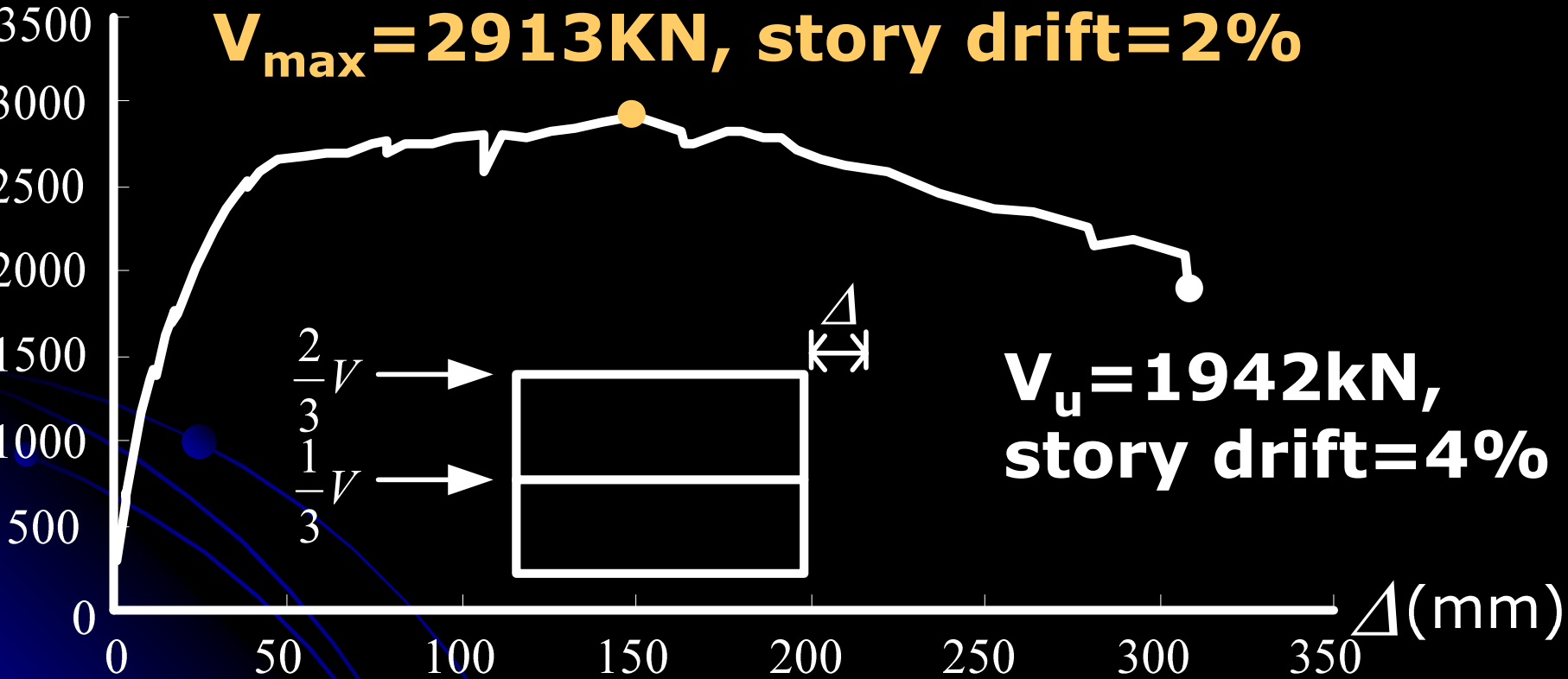
# Loading Process

Roof  
Displacement  
= 30cm  
Drift = 4%



# Test Results

$V$  (kN)



# Failure Mode 1 Flexural



Column

top

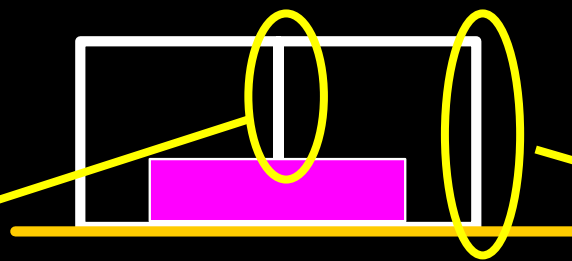
bottom

# Failure Mode 2 Flexural Shear



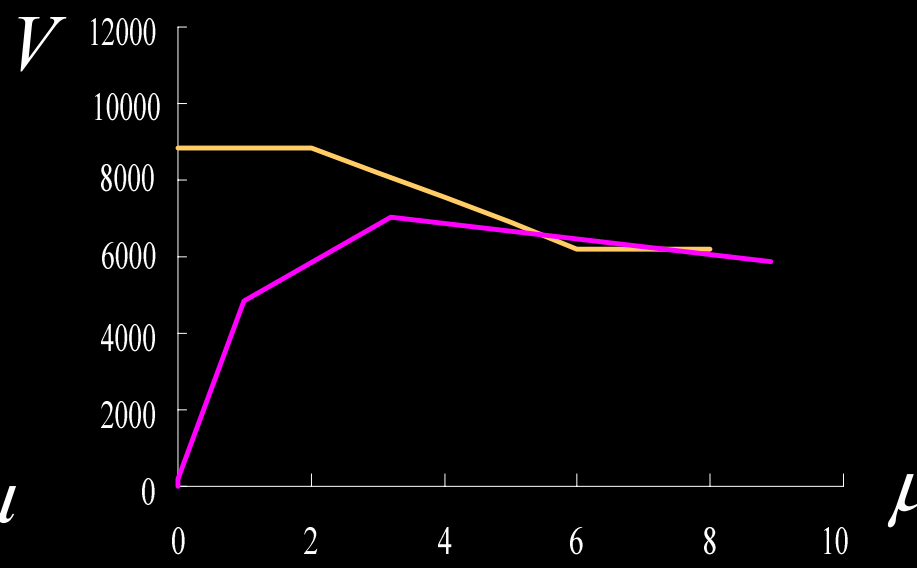
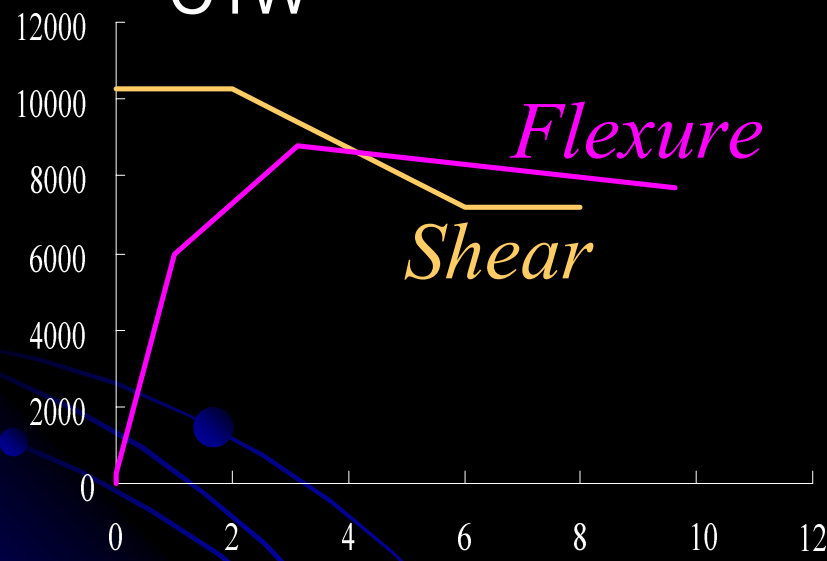
Captive  
Column

# Degradation of Shear Strength



C1W

C1



$$V_n = V_s + V_c = k \frac{A_v f_y d}{s} + k \left( \frac{6\sqrt{f'_c}}{a/d} \sqrt{1 + \frac{P}{6\sqrt{f'_c} A_g}} \right) 0.8 A_g \text{ (psi)}$$

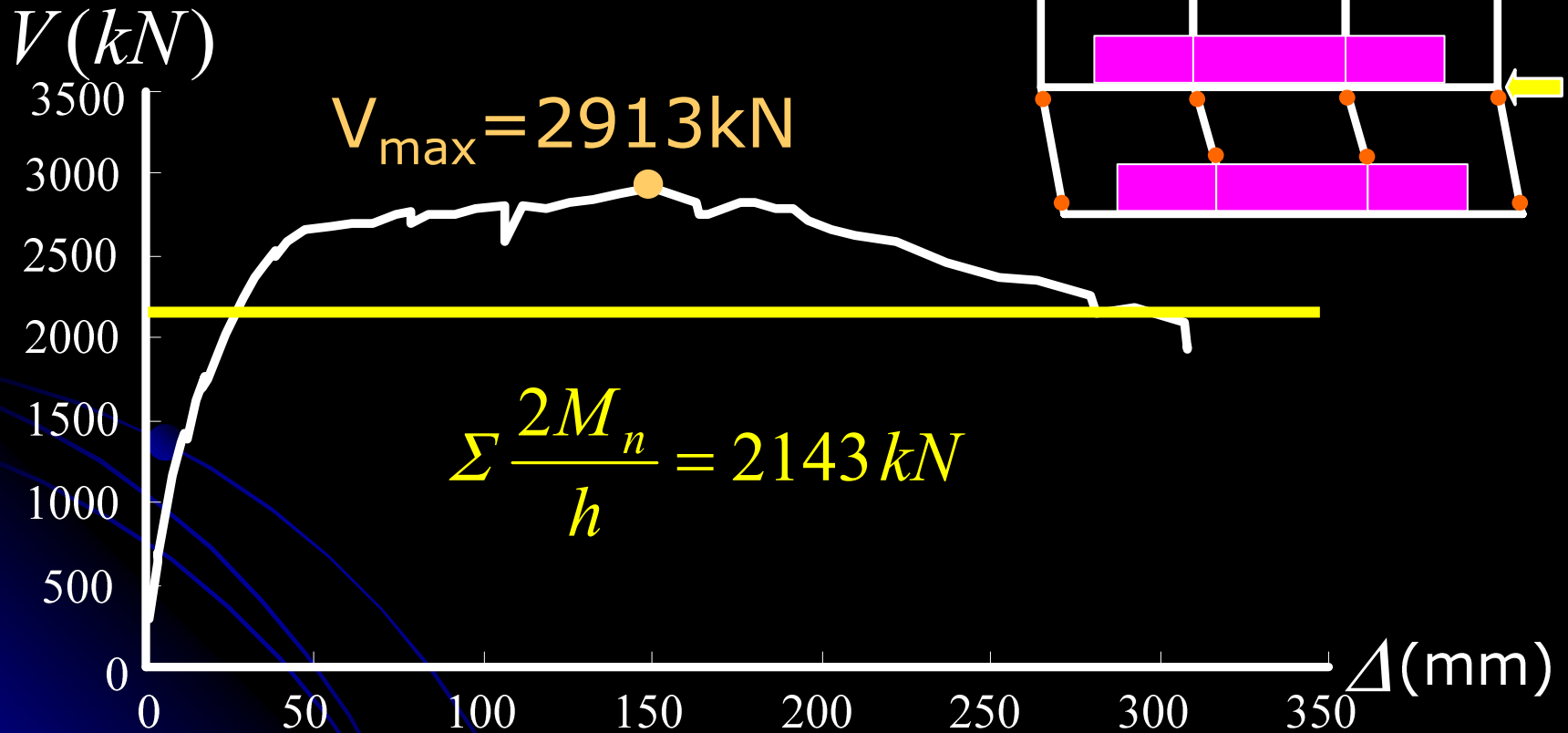
Sezen and Moehle (ASCE 2004)

Shear Strength Model for Lightly Reinforced Concrete Columns



# Discussion

- Strength Prediction



Participation of **Other Elements**?

- Contributions of Brick Walls



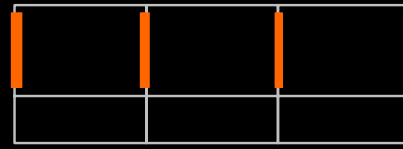
Frame 3 Brick Wall



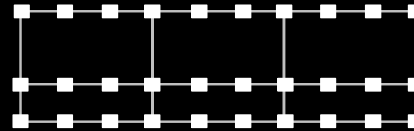
Frame 2 Brick Wall

# Contributions of Brick Walls

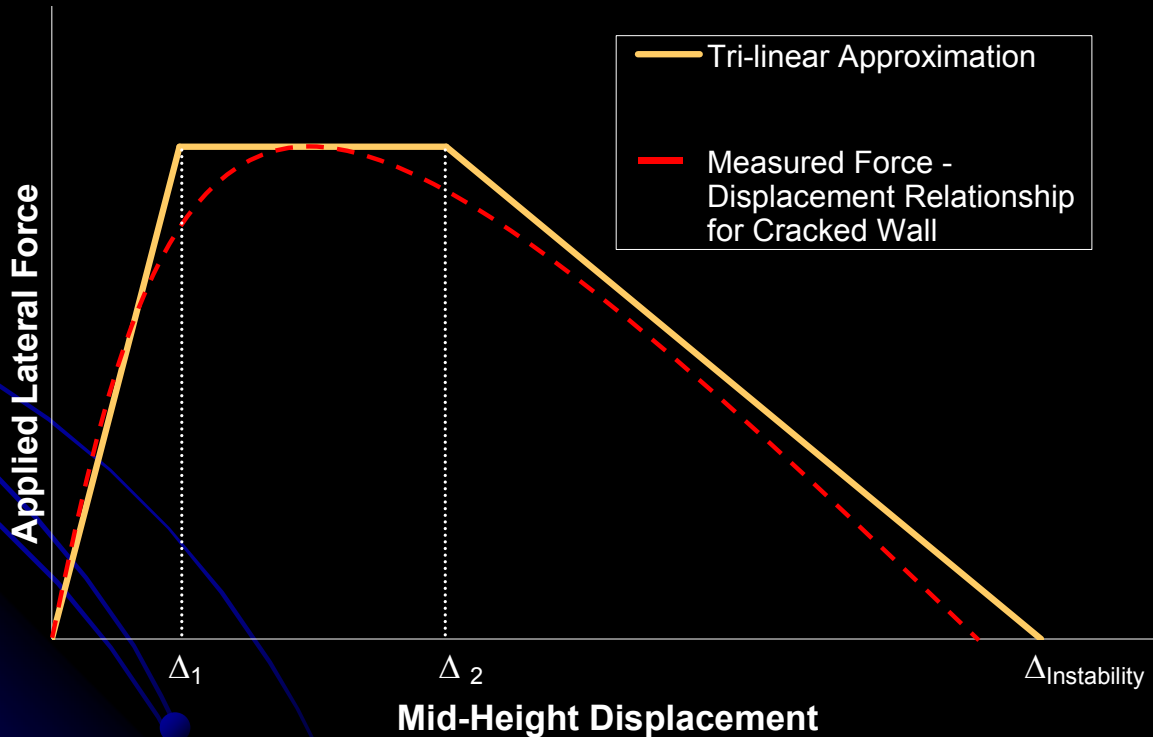
Area of  
Brick Walls



Area of  
Columns

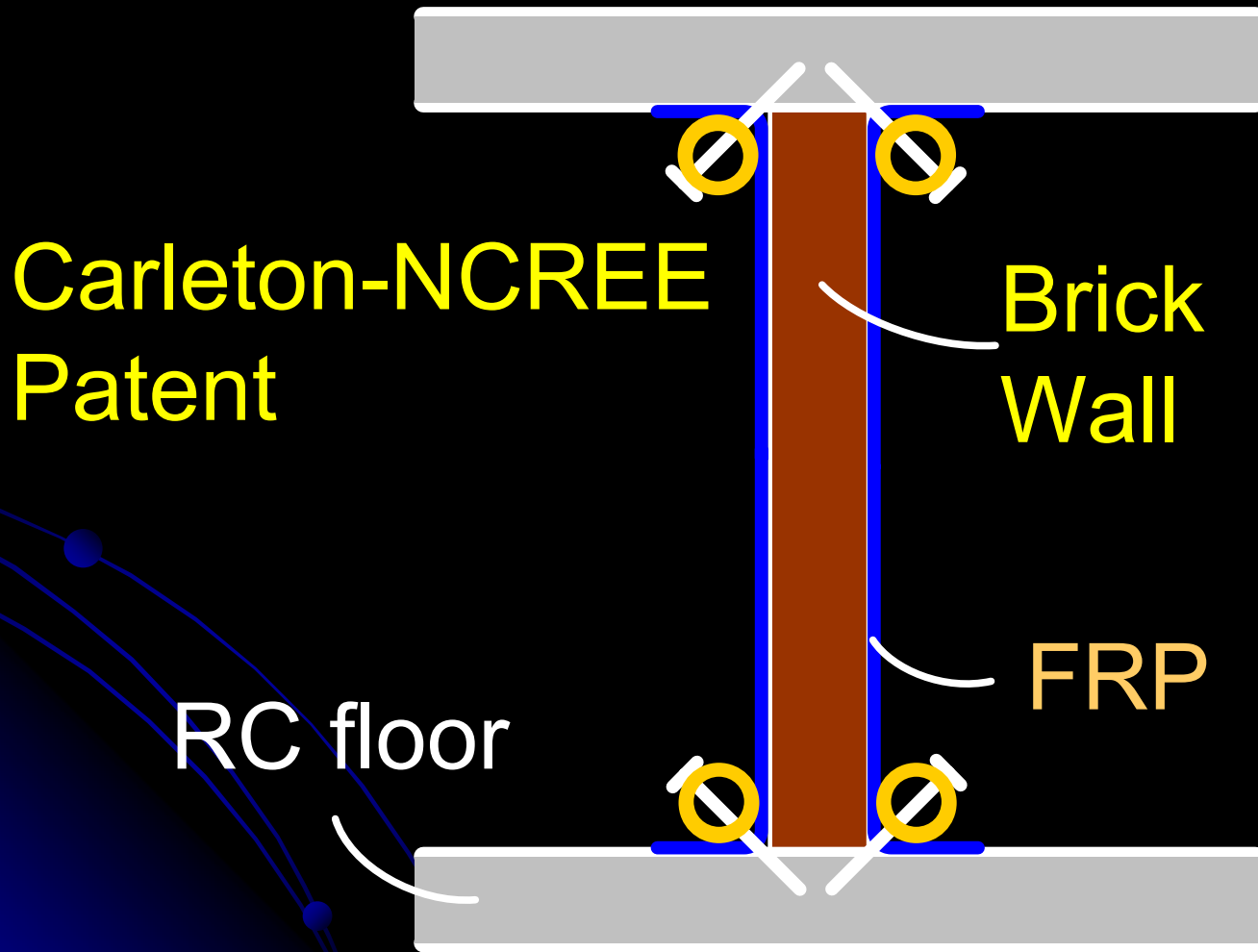


$\approx 3$



Tri-linear Stiffness Model (adapted from Doherty, 2000)

# Retrofitting of Brick Walls



Carleton-NCREE  
Patent

Brick  
Wall

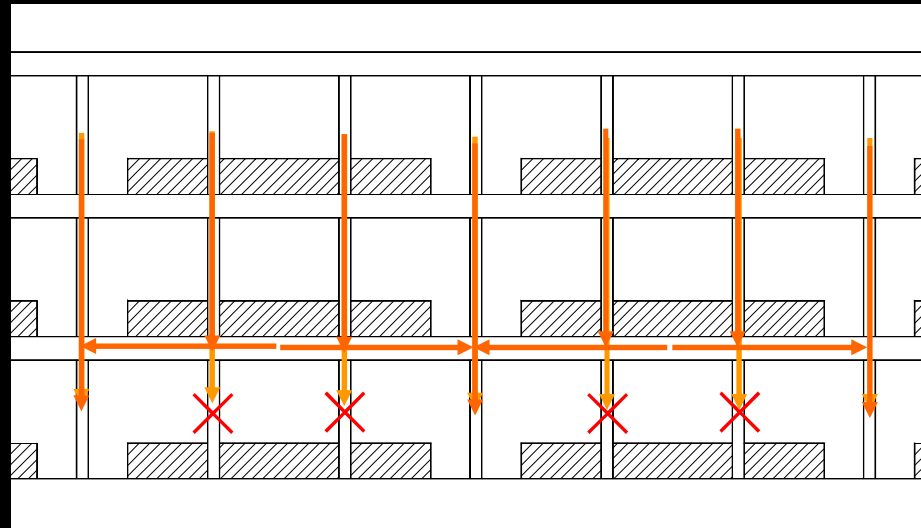
FRP

RC floor

# Vertical Load Test

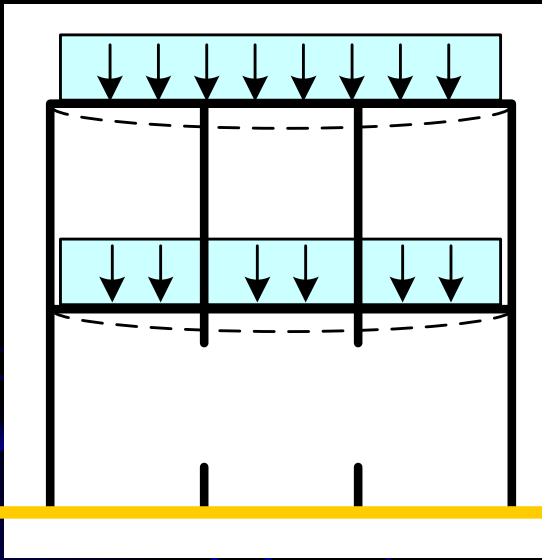


# Test Objective



Typical Column Failures  
of School Buildings

# Test Setup



# Instrumentation

Displacement  
Gauge





# Loading - Water Tanks

Weight of Water

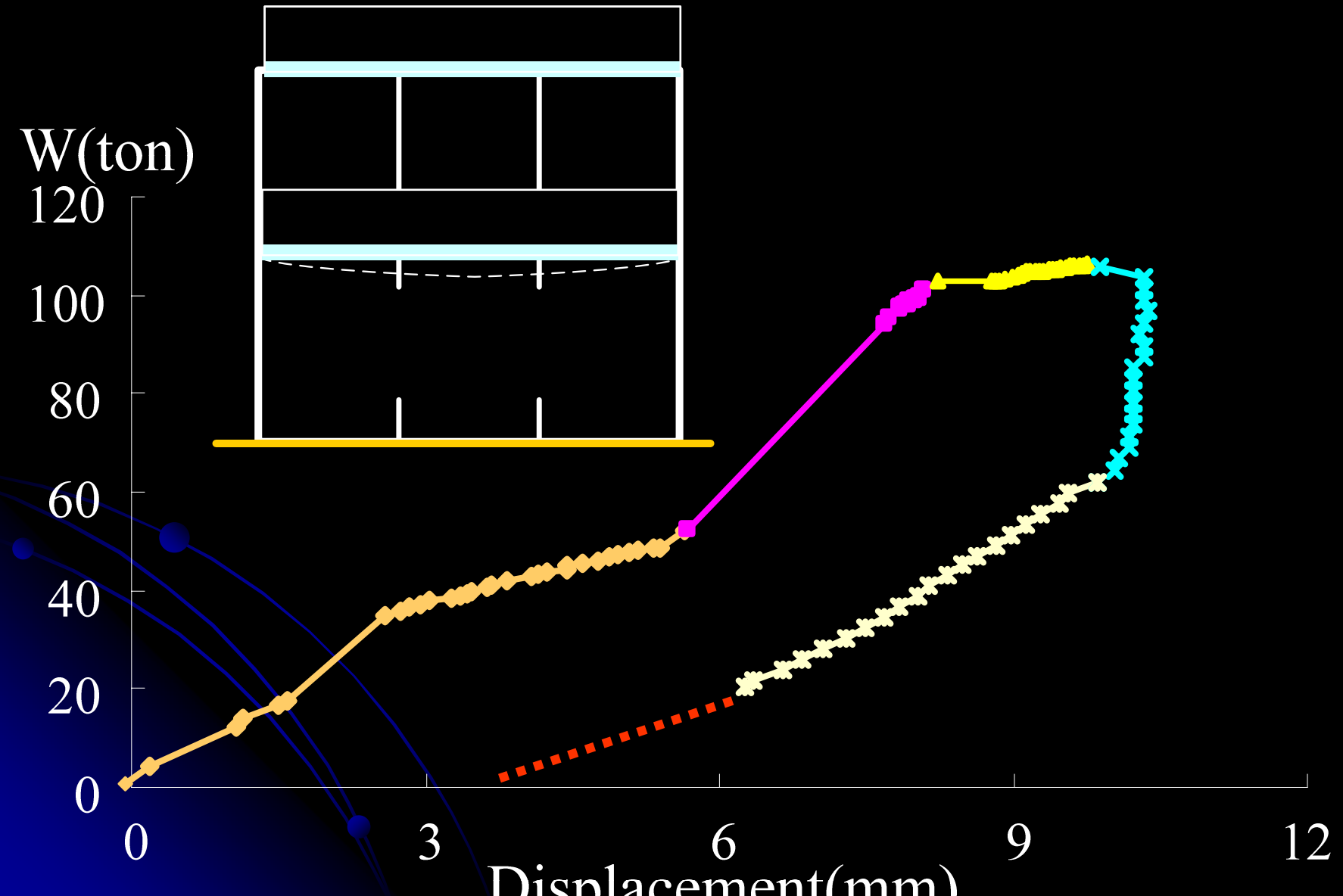
Weight of Building

$\cong 0.7$



Total Load of  
Water = 1040kN

# Test Results



# Crack Pattern – Flexural Cracks

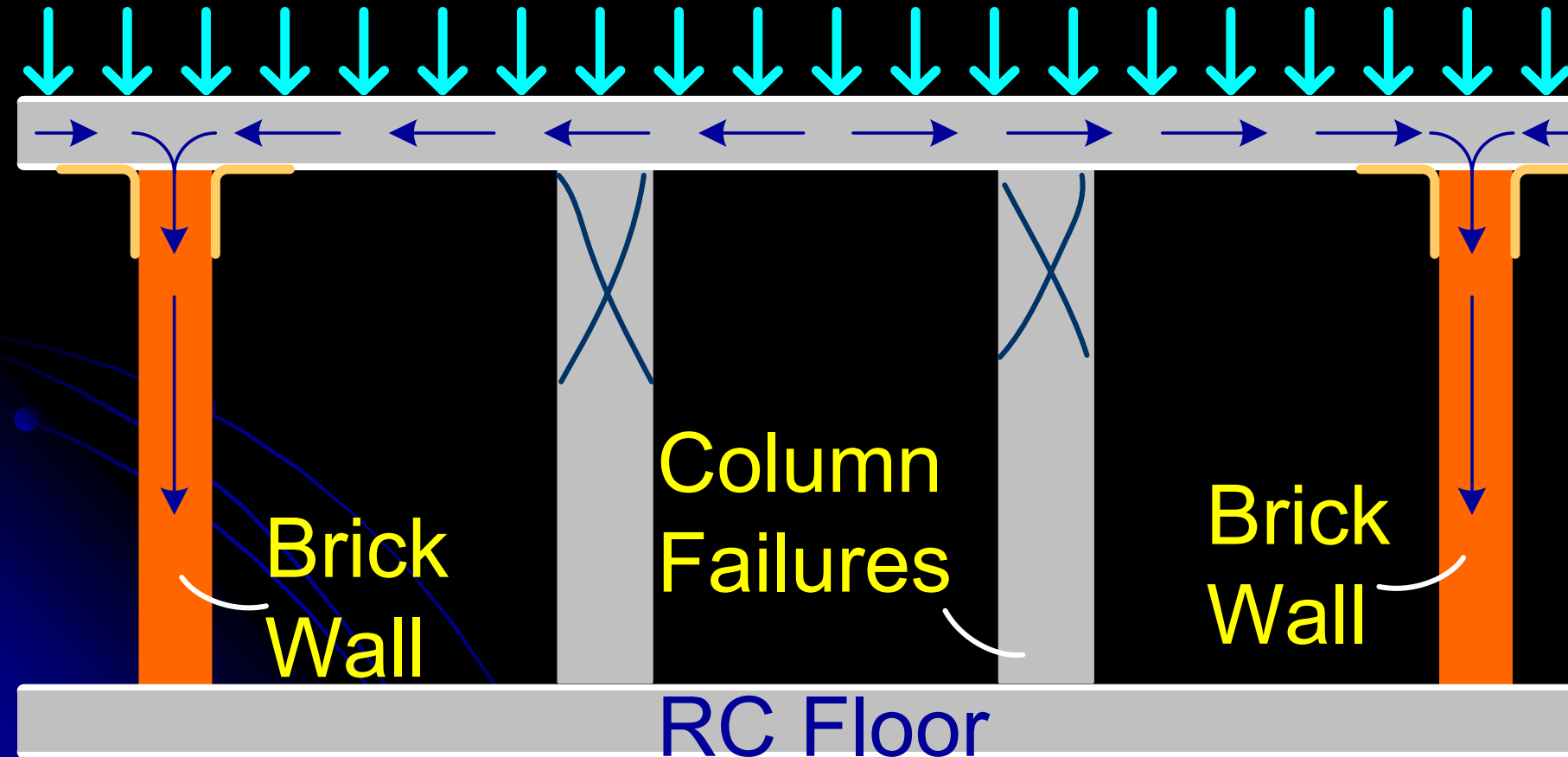
Loading  
Removed

Max. residual width  
of crack = 0.2mm




# Discussion

- Vertical Load Carrying Mechanism Exists

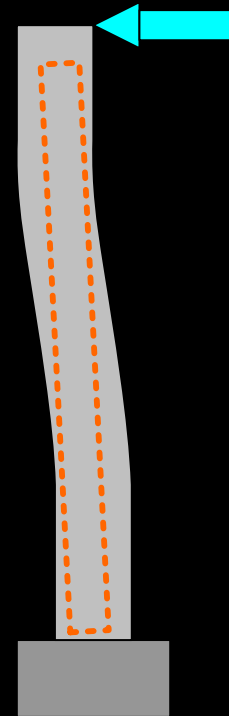
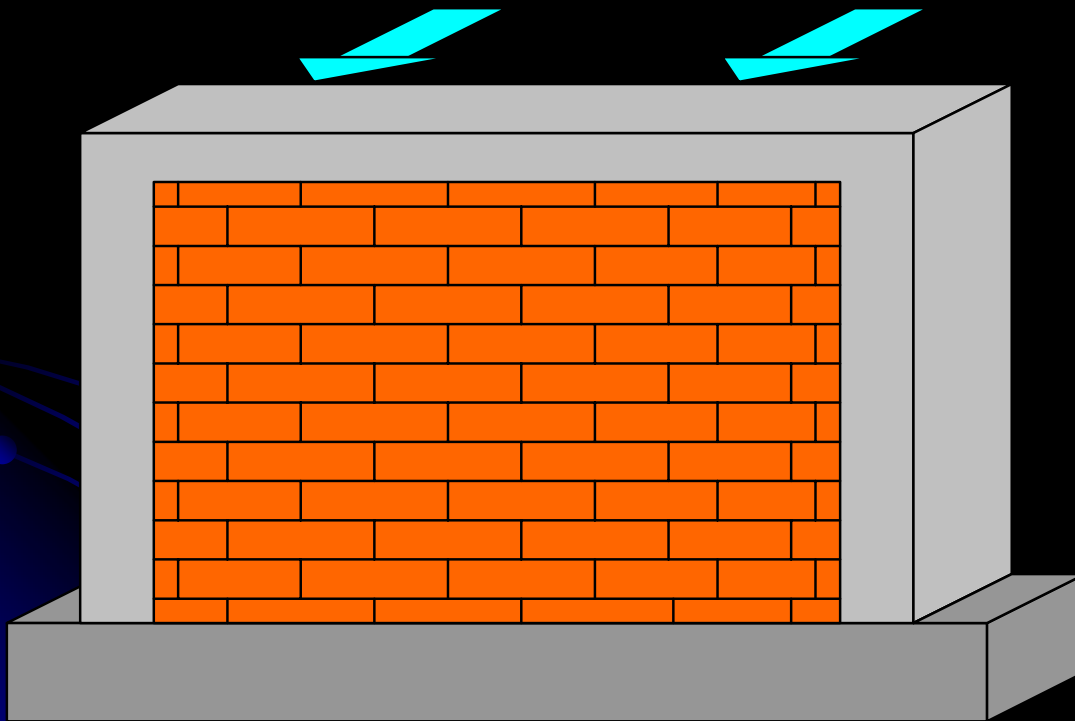


# Future Study

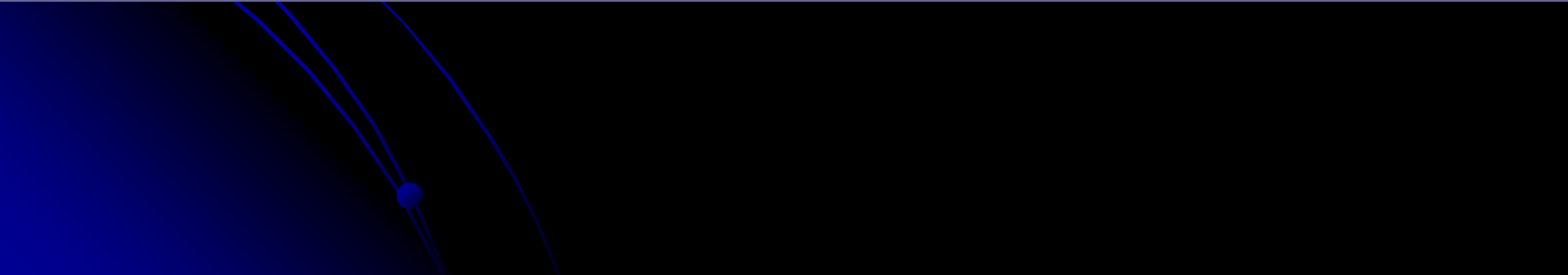
- **Out-of-Plane** Resistance of Brick Walls
  - **More Field Tests** of School Buildings
- 

# Test of Brick Walls


- Out-of-Plane Behavior



- **Field Tests – Kouhu Elementary School  
(Summer, 2005)**



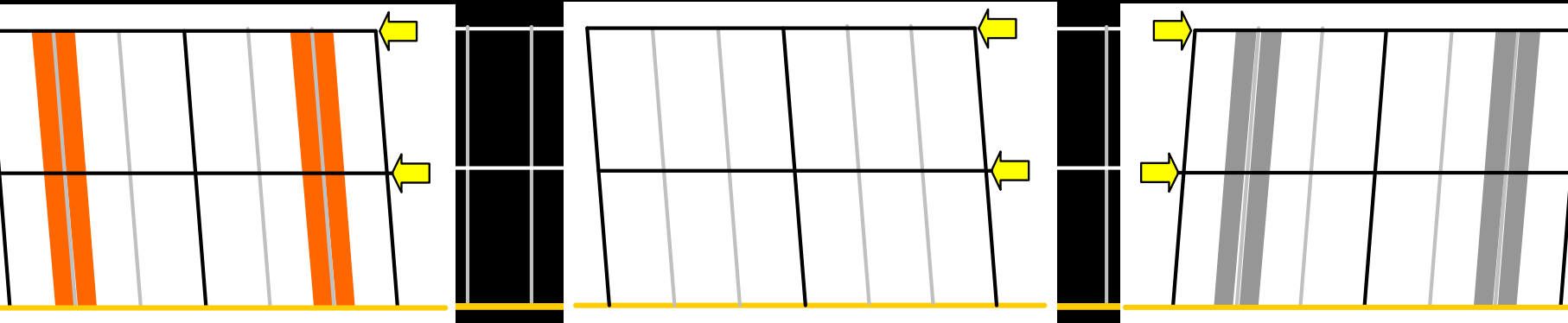
# Static Pushover Tests

1. More Axial Loads
  2. Effect of Retrofitting Using  
RC Wing Walls
  3. In-Plane Seismic Resistance  
of Brick Walls
- 



# Testing Plan

## Lateral Load Test



Seismic Resistance  
of Brick Walls

Pure Frame

Retrofitting  
Using  
RC Wing Walls

Thank you for your attention

