

# Large Scale Experimental Tests of Size Effect in Pile Caps Loaded in Two-Way Shear

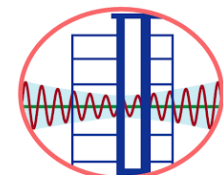


Tokyo Tech



**ACI Spring Convention**  
San Francisco, CA | April 2023

**LA Laughery, T Ichinose, K Kasai,**  
S Mogili, S-H Hwang



NCREE



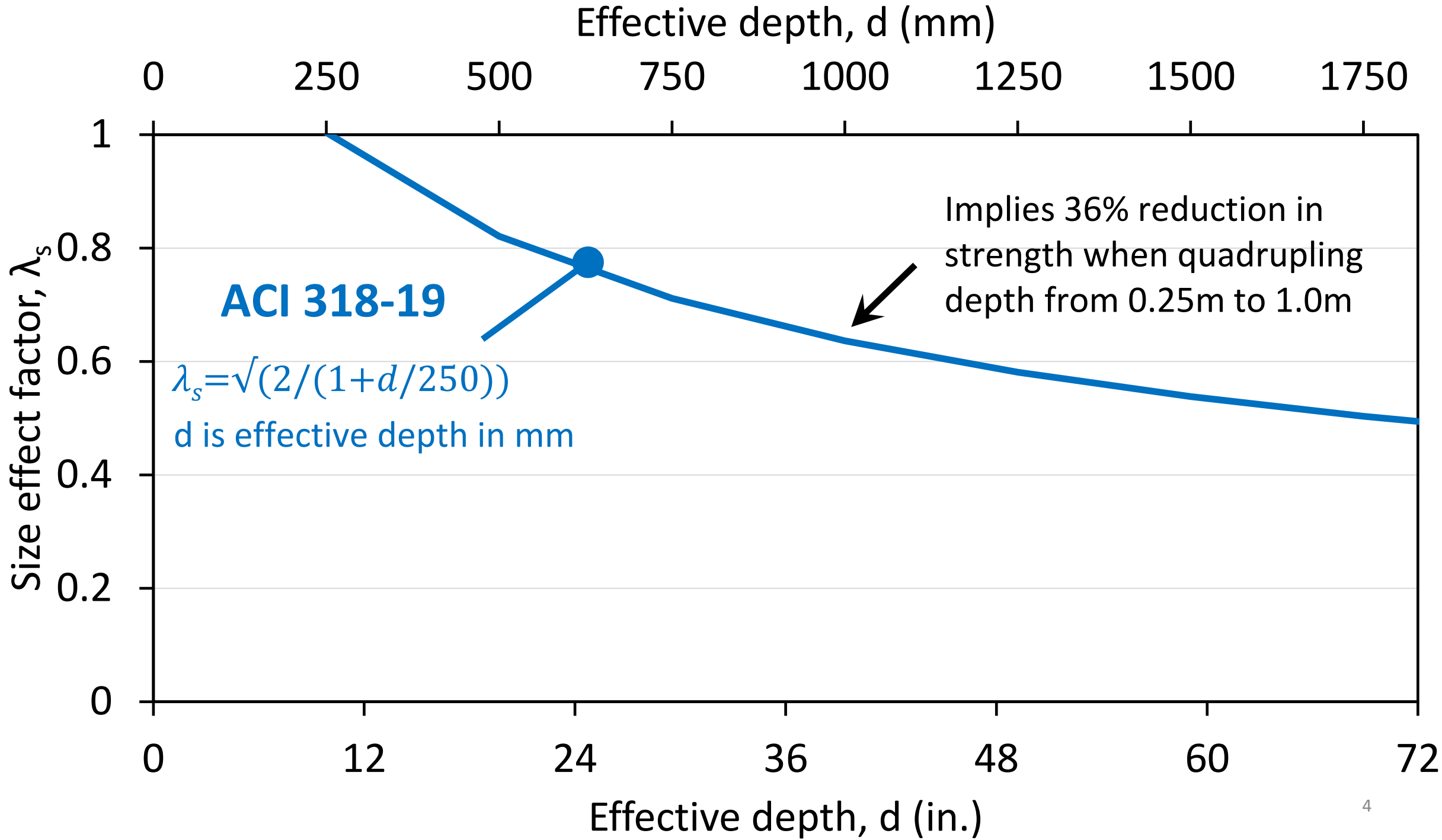
# Overview

- What is Size Effect?
- Current ACI Approach
- Experimental Program
  - Specimen Design
  - Test Setup
- Experimental Results
- Conclusions

# Size Effect

A decrease in concrete unit shear strength with increasing effective depth.

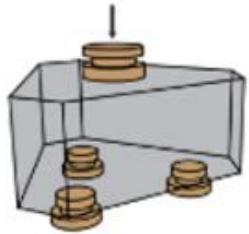
Phenomenon observed in one-way shear since at least 1970s by Kani, Codified in ACI 318-19



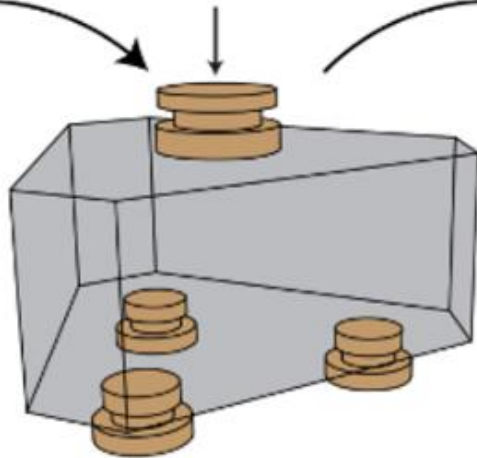
S

M

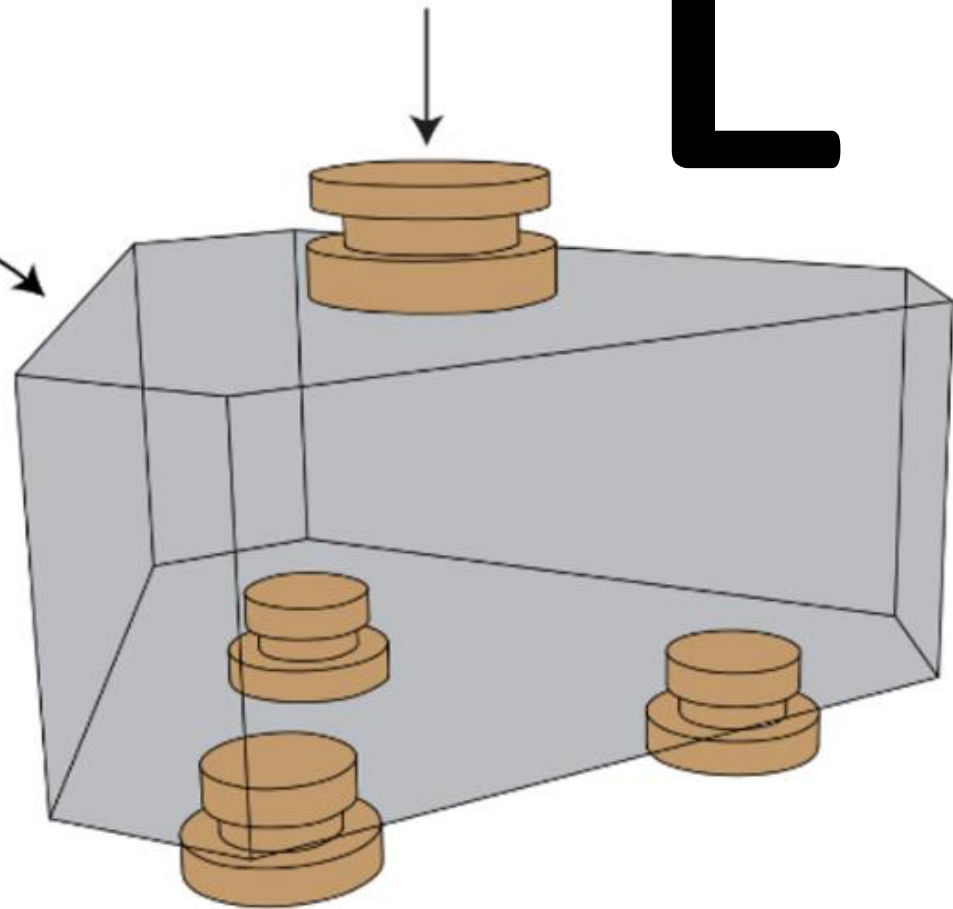
L



$a=d=250\text{mm}$   
(9.84in.)



$a=d=500\text{mm}$   
(19.7in.)



$a=d=1000\text{mm}$   
(39.4in.)

Scaled geometry

Constant maximum aggregate size

Constant nominal compressive strength\*

Control group over-reinforced to induce shear failure

# Specimen Details

$d_{\text{bar}} = 9.5\text{mm}, 19.1\text{mm}, \text{ or } 38.1\text{mm}$  (#3, #6, #12)

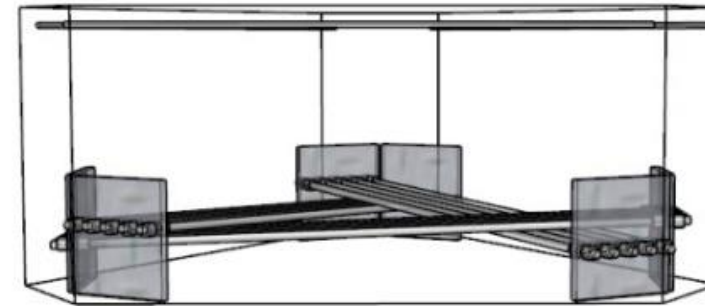
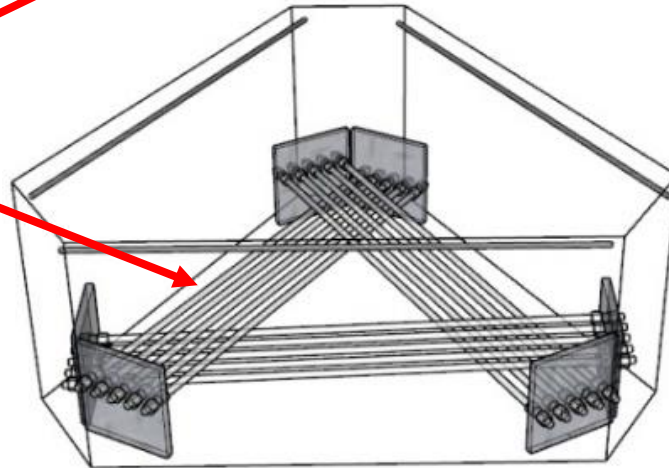
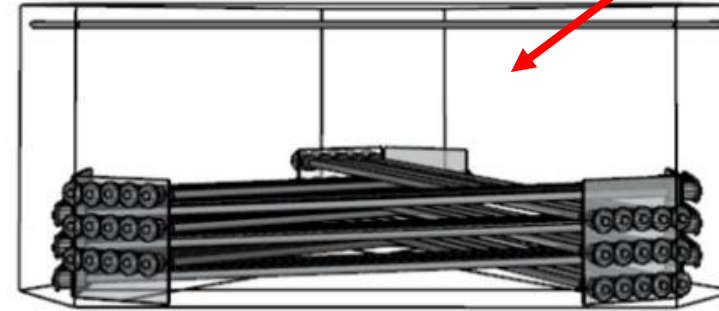
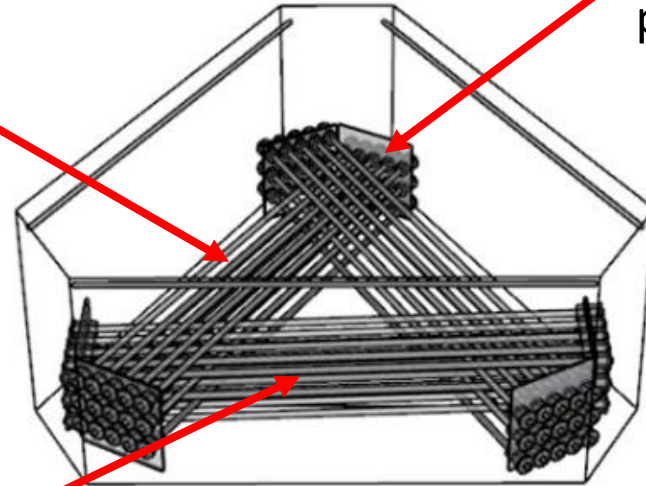
$f_{y,\text{min}} = 685\text{MPa}$  (100ksi)

3 rows of 5 bars  
per span ( $\rho_f = 1.5\%$ )

-or-

1 row of 5 bars  
per span ( $\rho_f = 1.5\%$ )

End anchorage  
plates



$f'_c = 40\text{MPa}$  typ.  
(5,800 psi)  
60 MPa in L3H

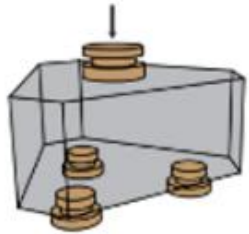
$d_{\text{agg}} = 10\text{mm}$  (0.39in.)

$d = 250\text{mm}$  S  
500mm M  
1000mm L

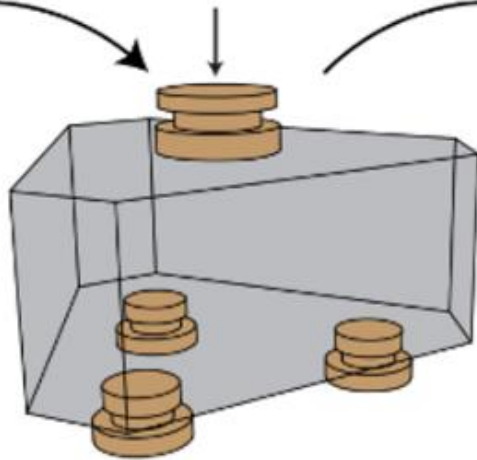
S

M

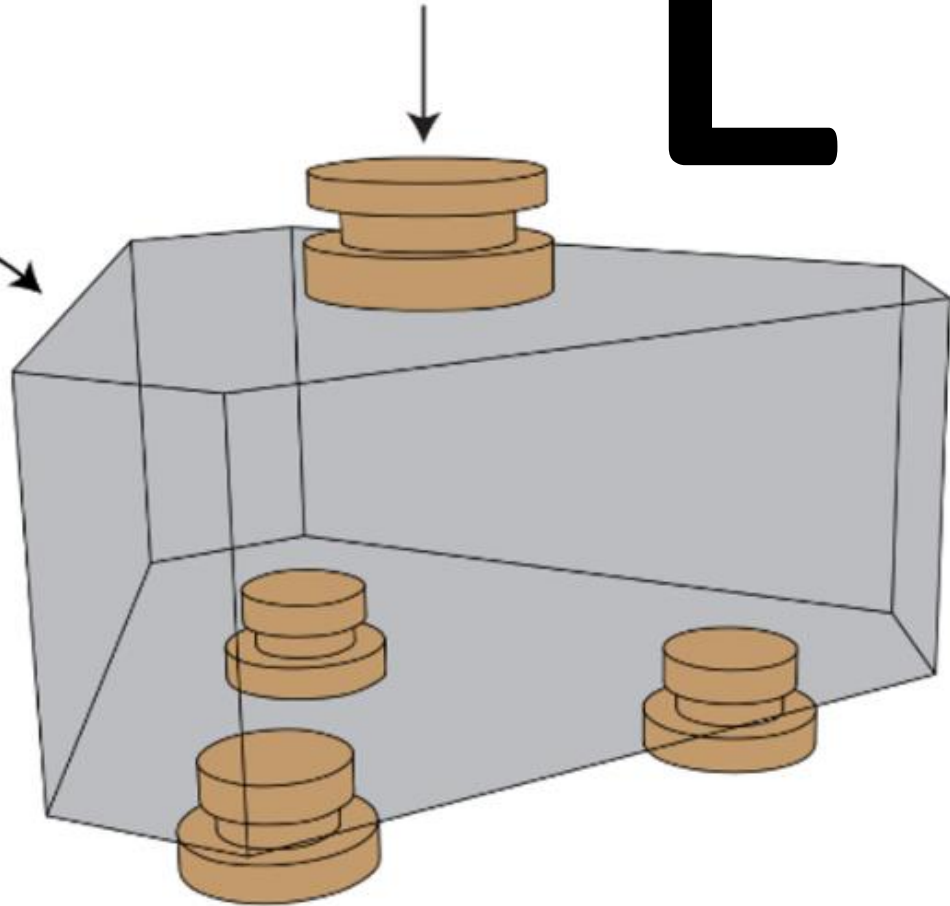
L



S1, S3a,  
S3b, S3c



M1, M3a,  
M3b, M3c



L1, L3a,  
L3b, L3H



S







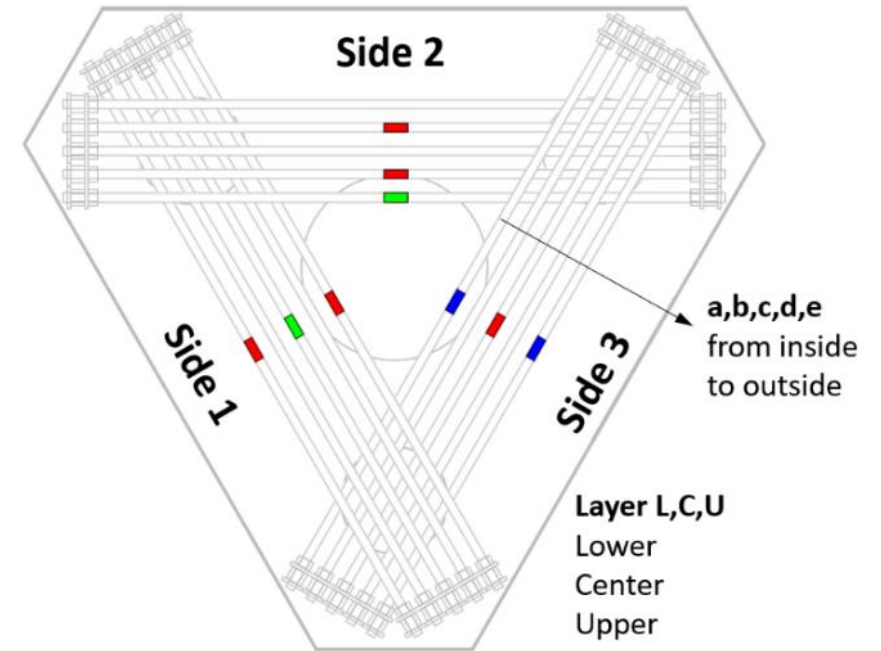
S

L



# Instrumentation & Setup

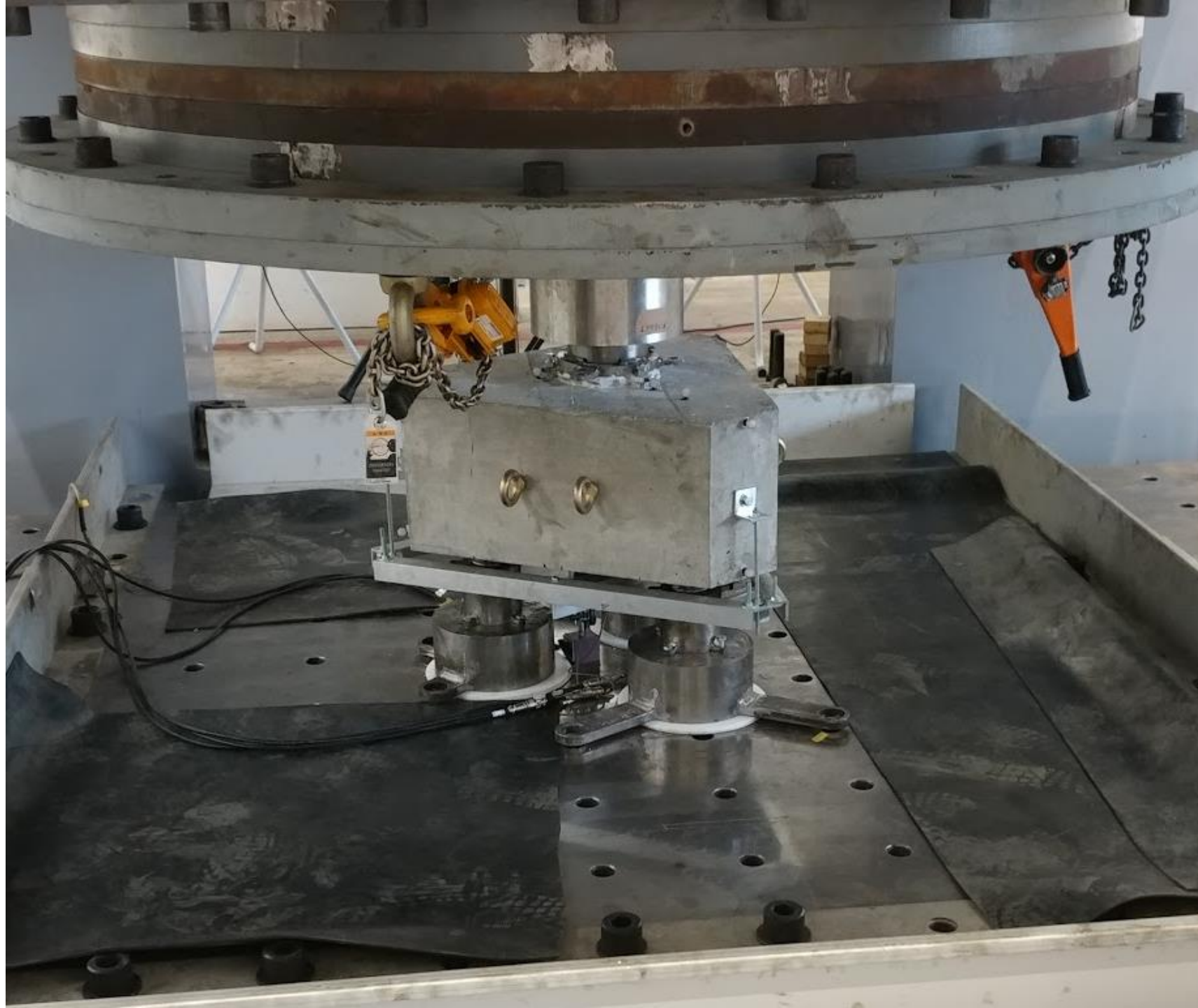
- **Sensors**
  - Displacement gauges
  - Strain gauges
  - Cameras
- **Loading**
  - Upper loading platen
  - Three lower platens each with 1/3 area
  - Monotonic to failure
- **Post-Testing Destructive Examination**
  - Saw cut to examine crack patterns



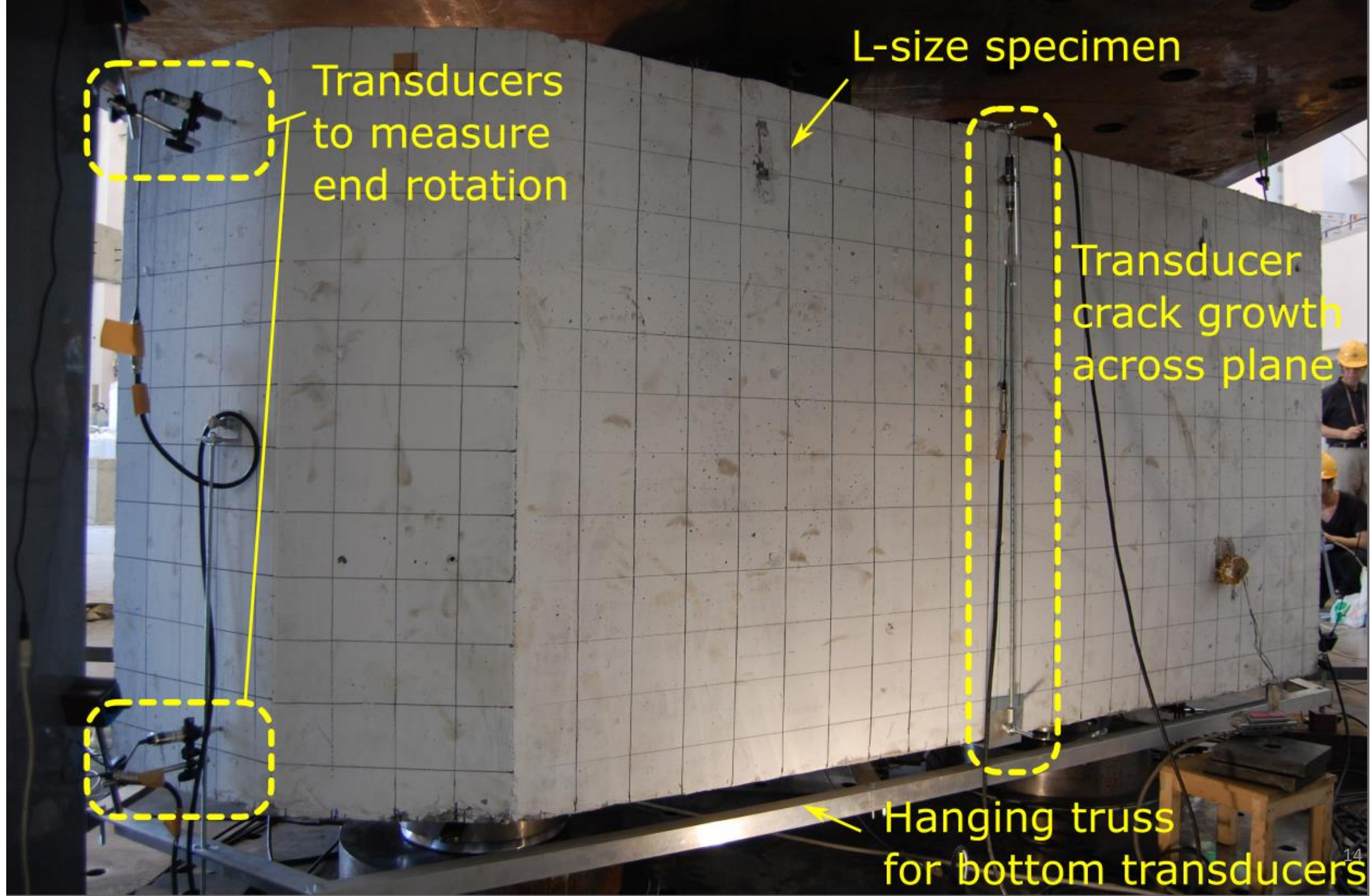
# BATS

雙軸向動態試驗系統









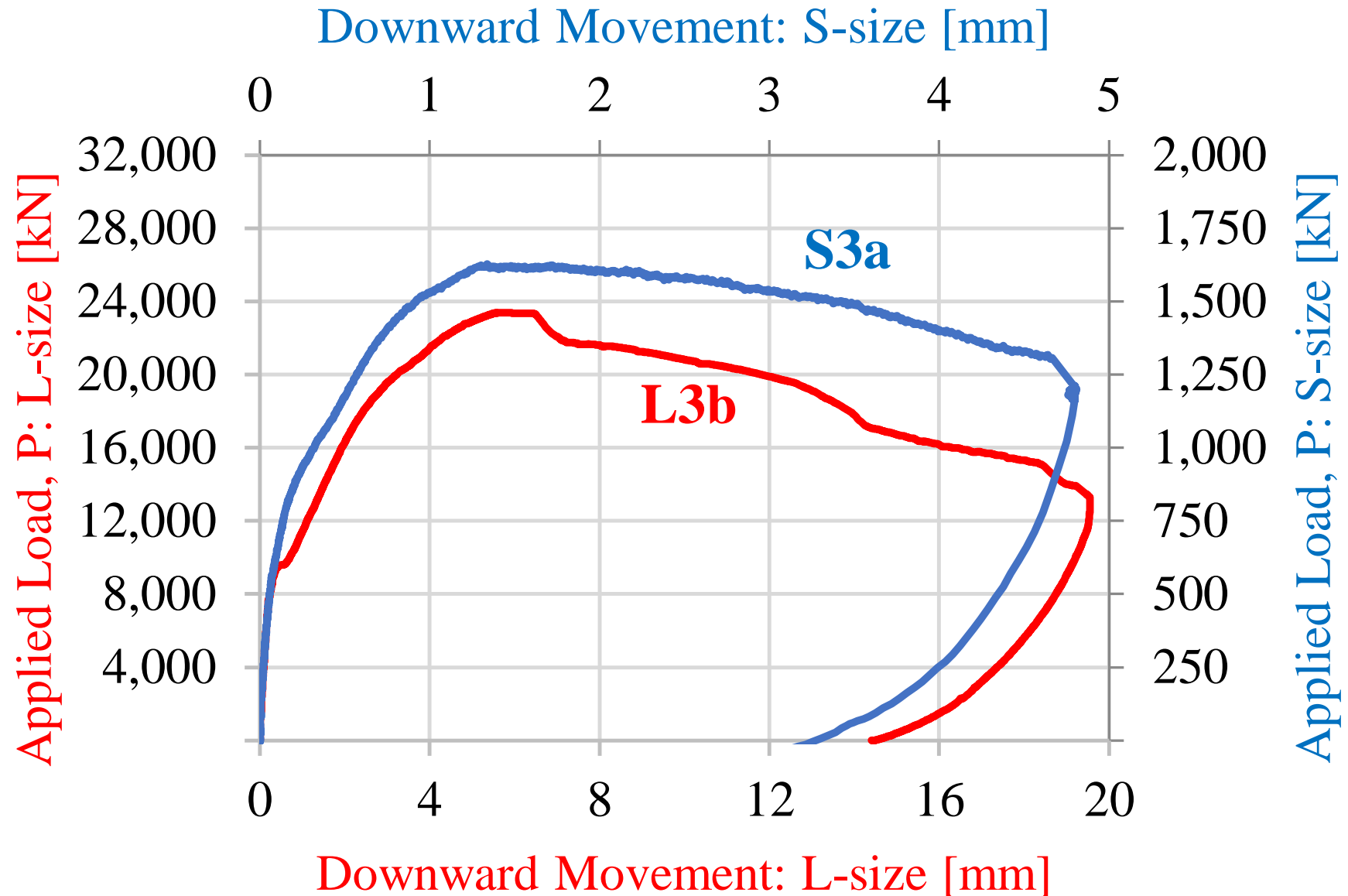
L-size specimen

Transducers to measure end rotation

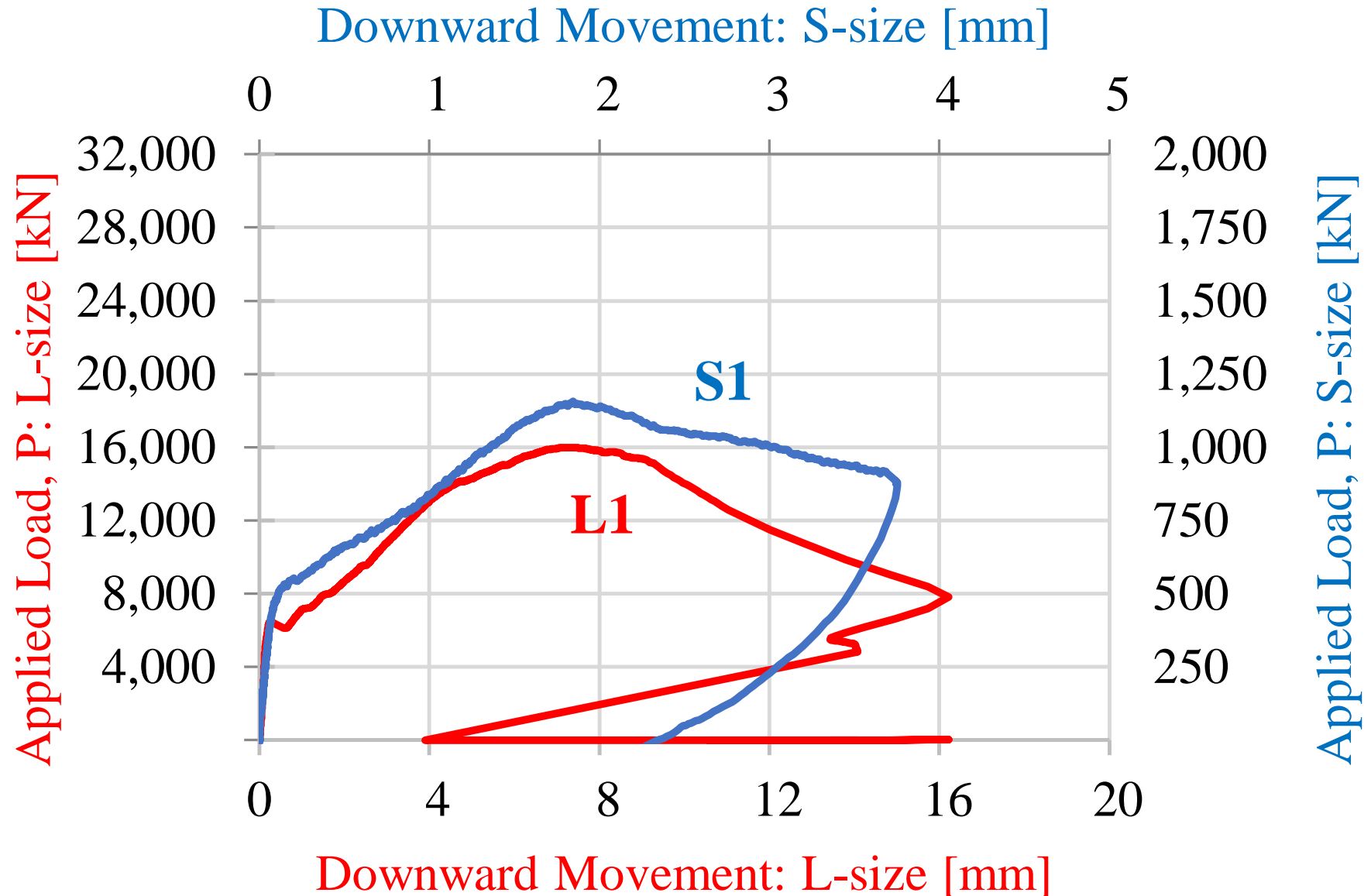
Transducer crack growth across plane

Hanging truss for bottom transducers

# Behavior – S3 vs. L3

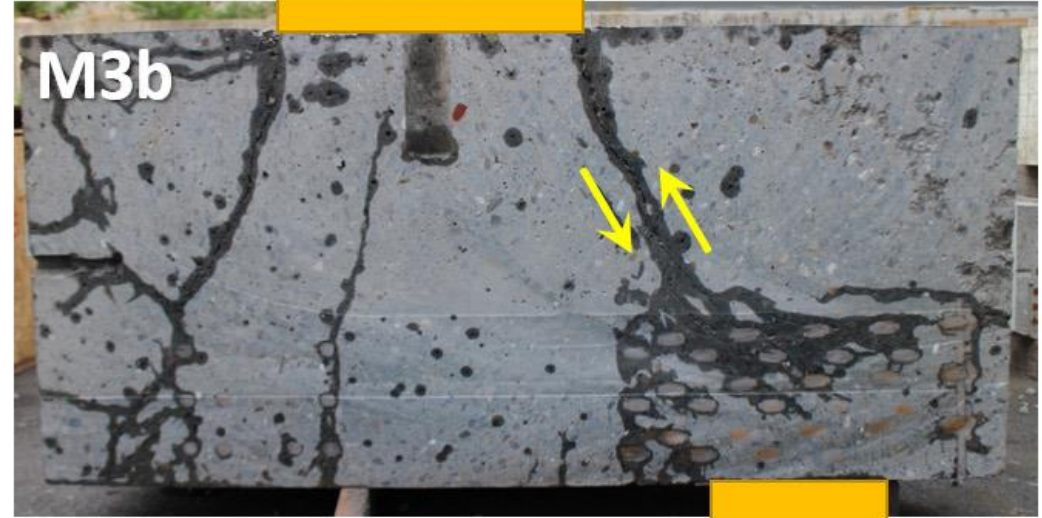
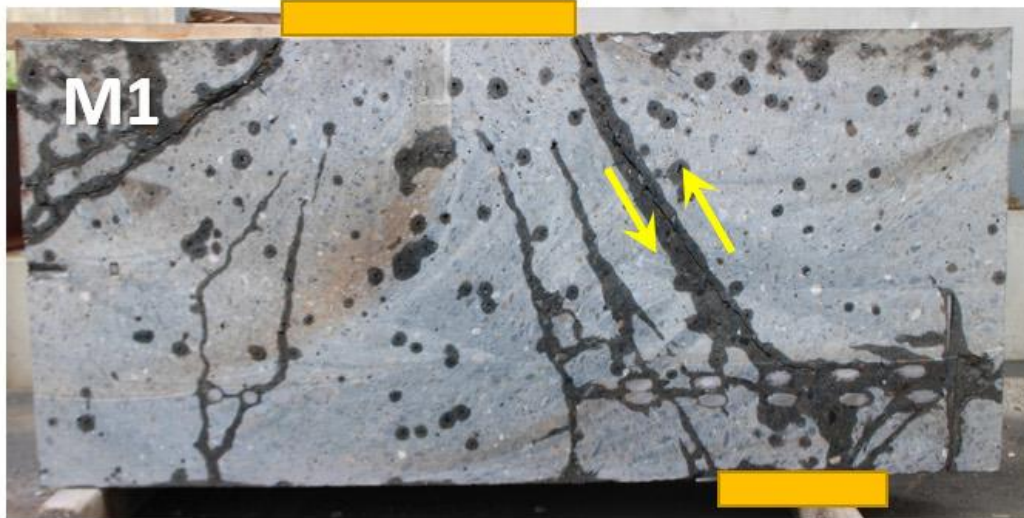
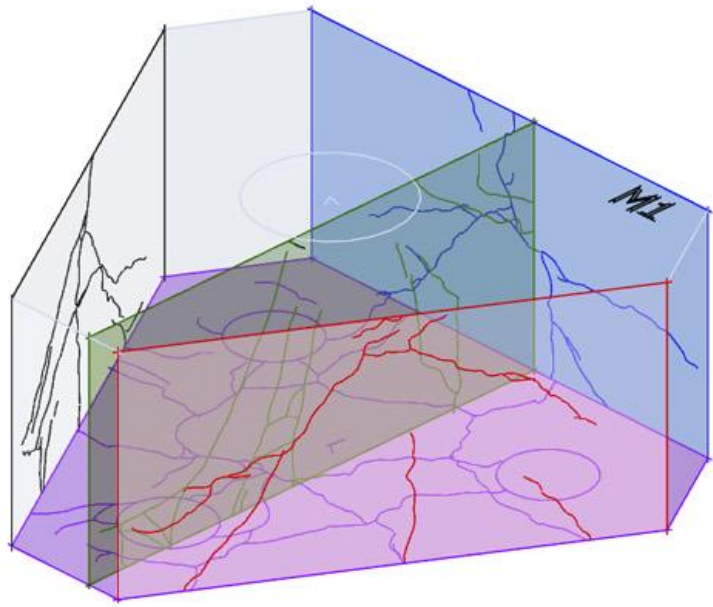


# Behavior – S1 vs. L1

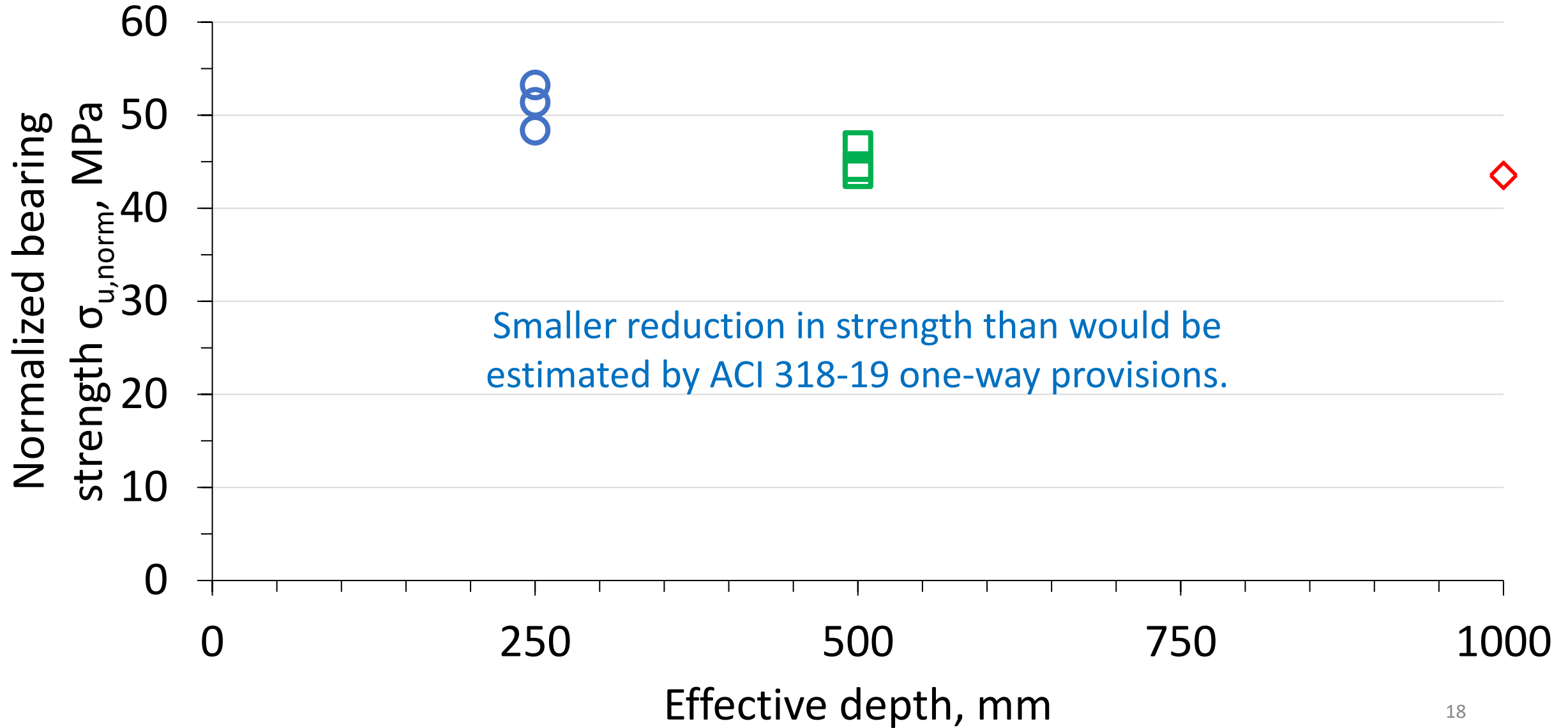




# Cross-Sections



# Strength



# Summary

- Tests of footings with effective depth ranging from 0.25m (9.84 in.) to 1.0 m (39.4 in.)
- Controlled geometry such that key ratios were constant
  - Bar diameter to effective depth
  - Bar diameter to cover
- Variables
  - Effective depth
  - Constant aggregate size, such that  $d/d_{agg}$  varied
  - Reinforcement ratio
  - Compressive strength (1 test)
- Observed reduction in unit strength was not as severe as would be predicted by ACI 318-19: about 20% vs. ACI 36%

**Thank You!**