

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

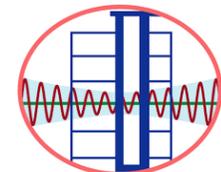


Tokyo Tech



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NCREE



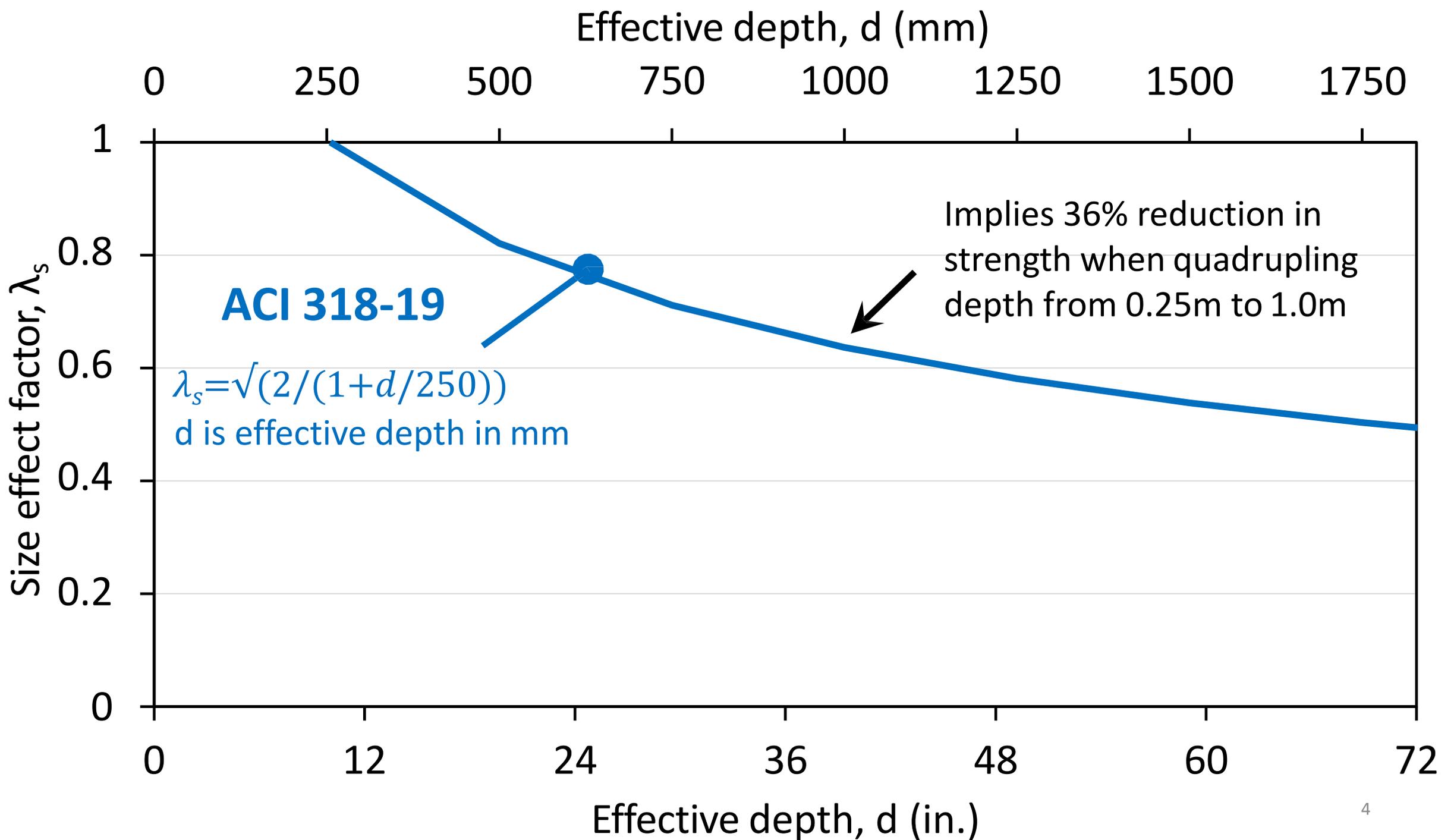
# Overview

- 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.

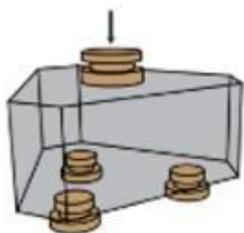
Phenomenon observed in one-way shear since at least 1970s by Kani, Codified in ACI 318-19



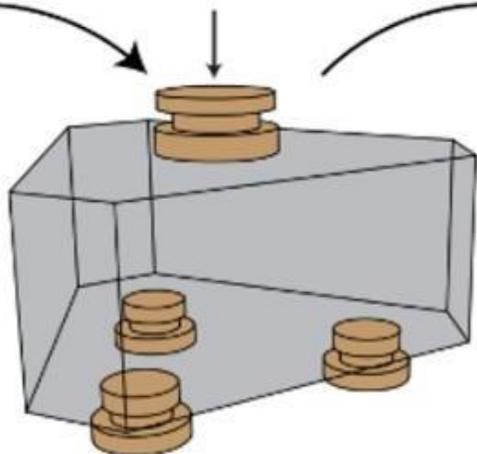
S

M

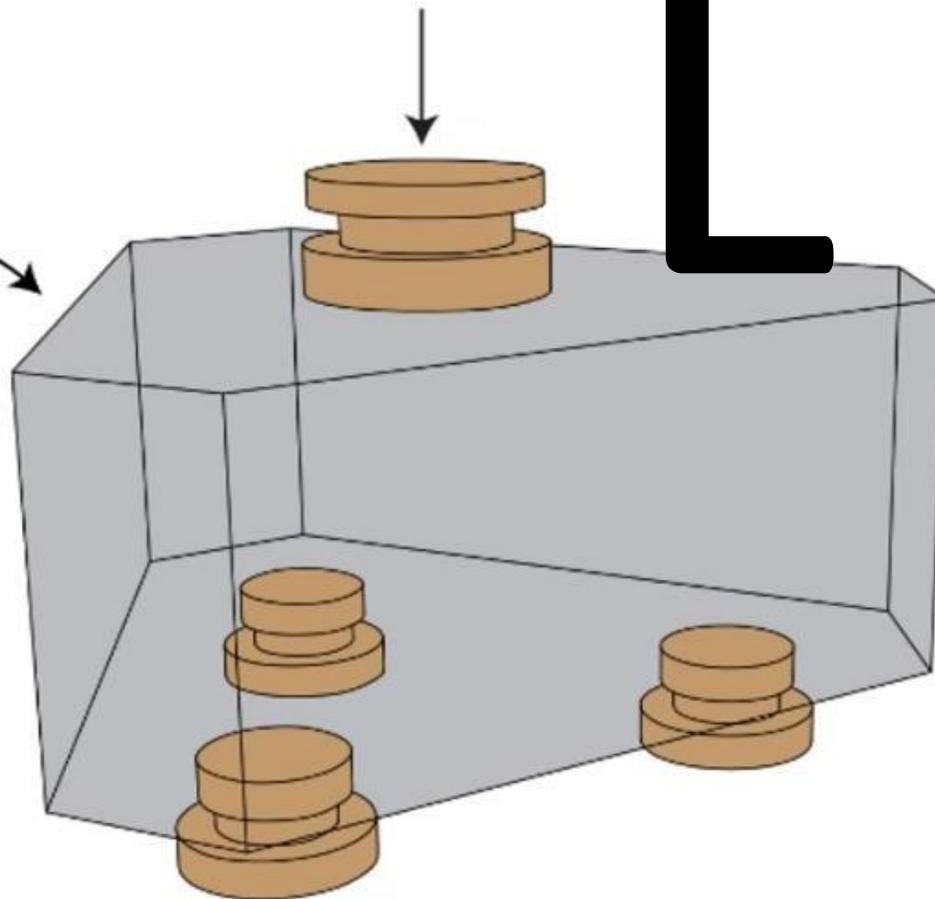
L



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

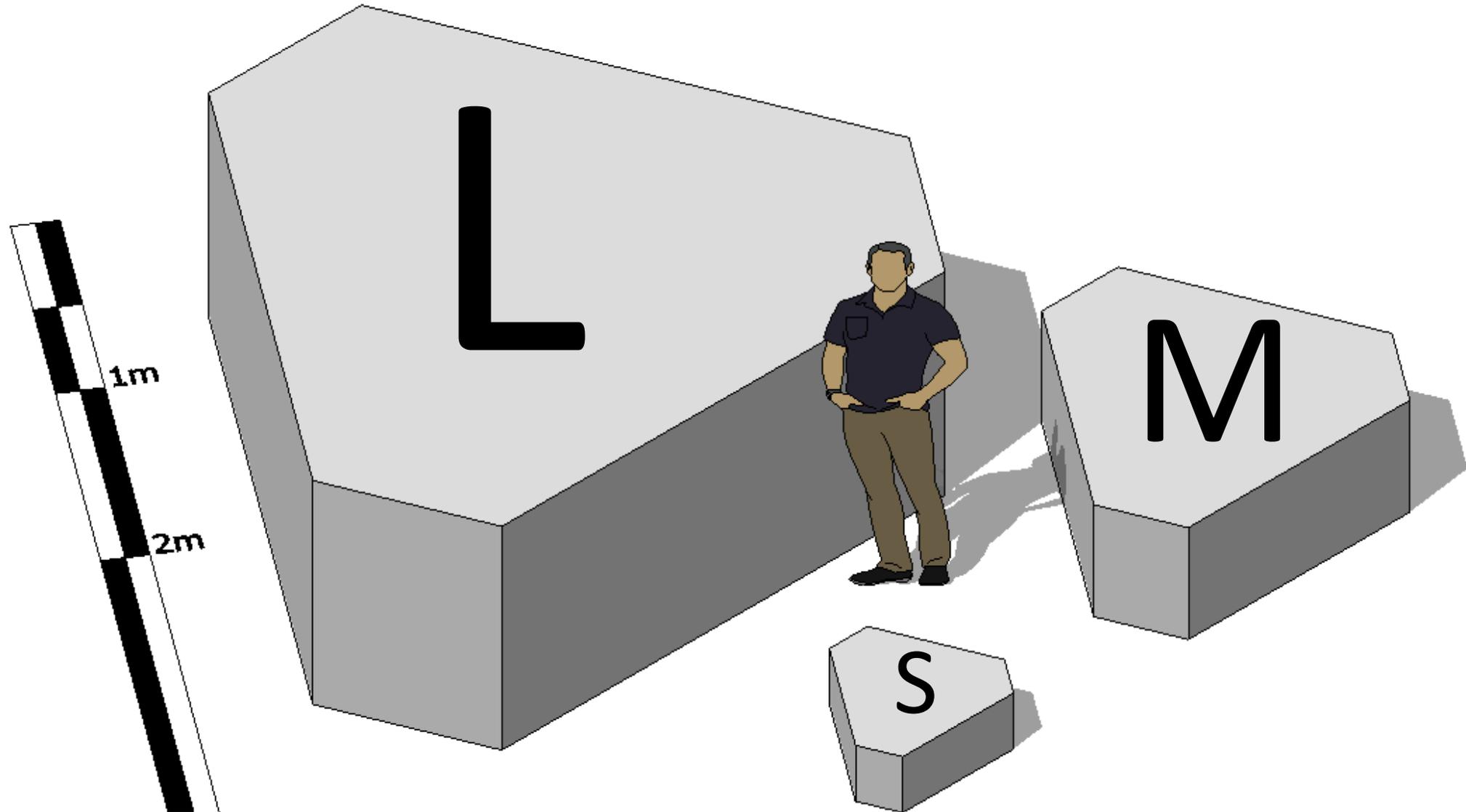


$a=d=500\text{mm}$   
(19.7in.)



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

# Sizes



Scaled geometry

Constant maximum aggregate size

Constant nominal compressive strength\*

Control group over-reinforced to induce shear failure

# Specimen Details

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

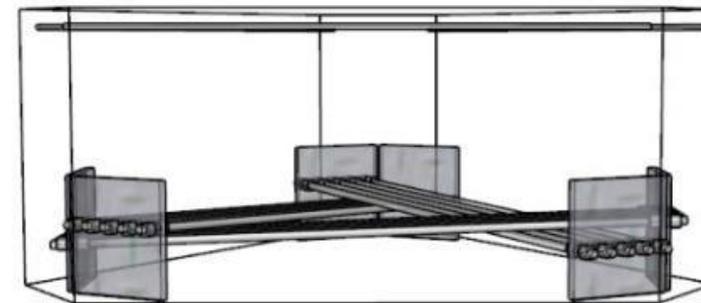
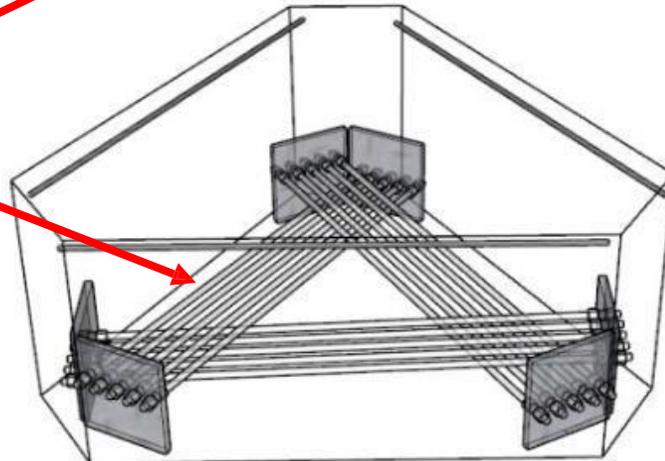
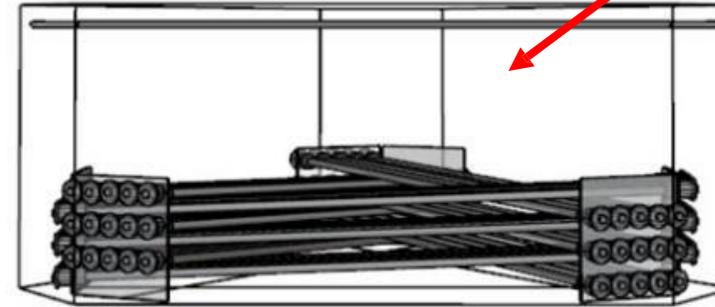
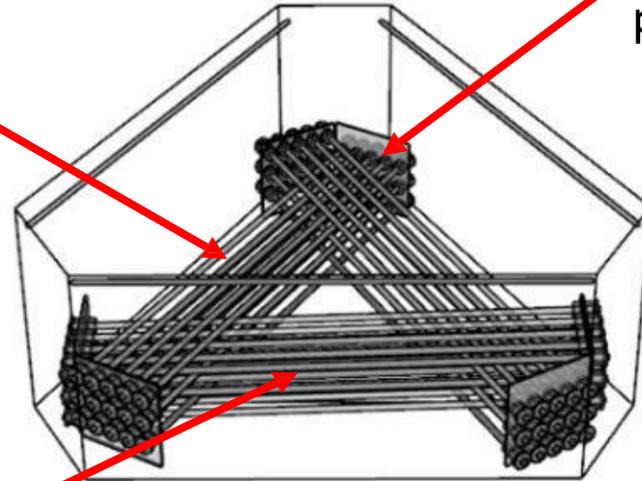
$f_{y,\text{min}}=685\text{MPa} (100\text{ksi})$

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

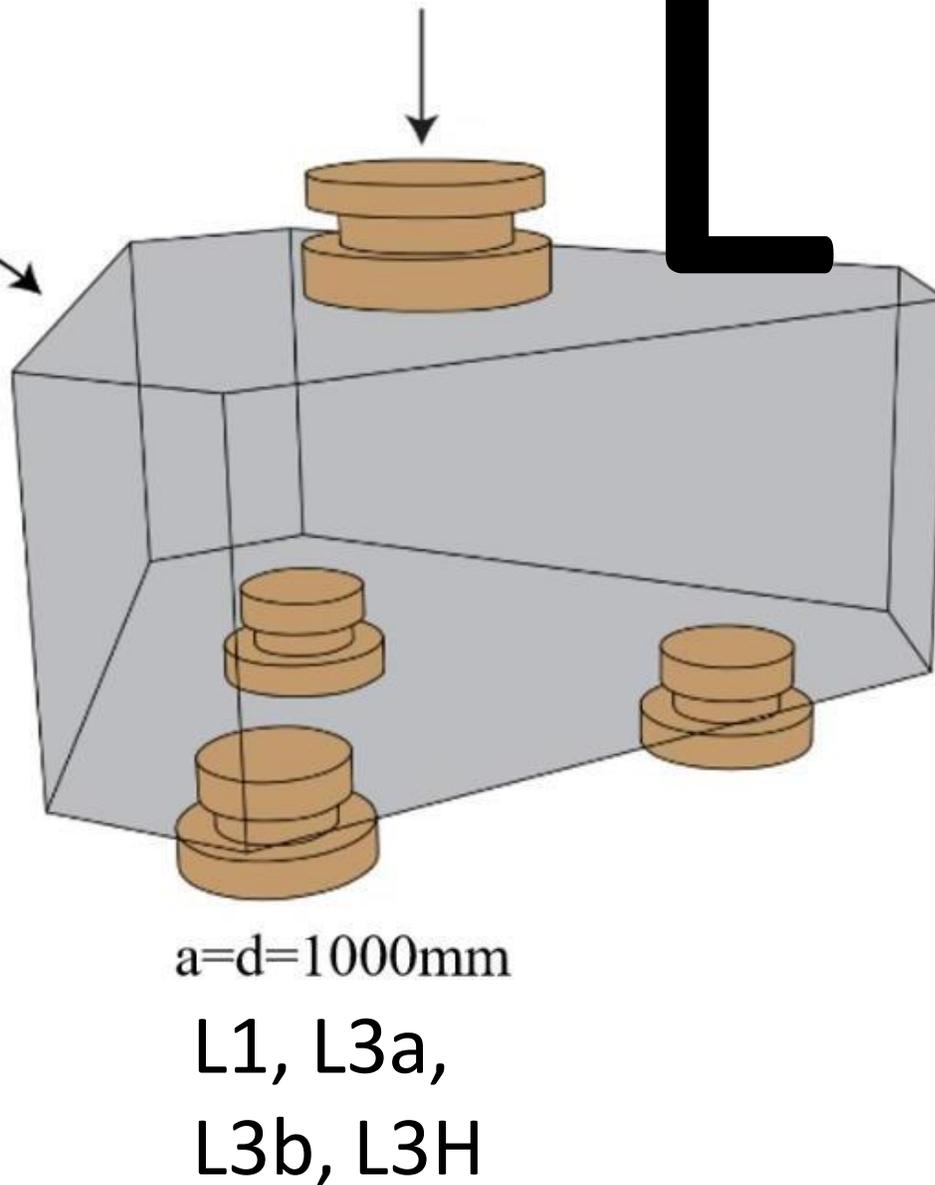
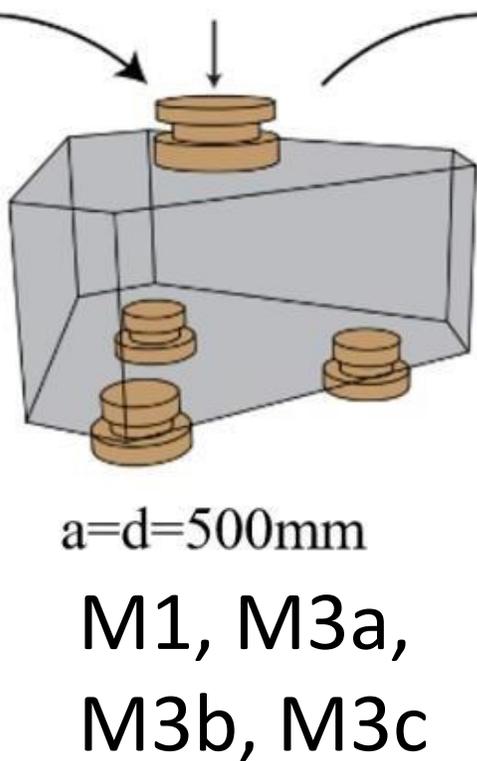
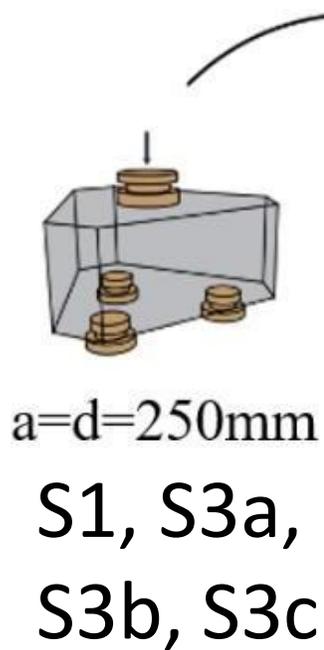
$d_{\text{agg}}=10\text{mm} (0.39\text{in.})$

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

S

M

L



S



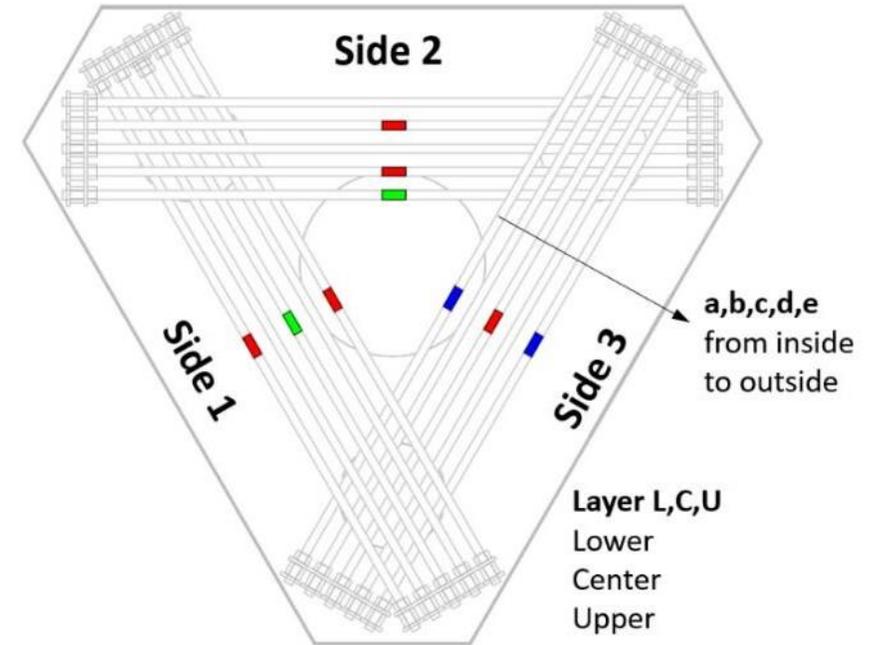


S

L

# Instrumentation & Setup

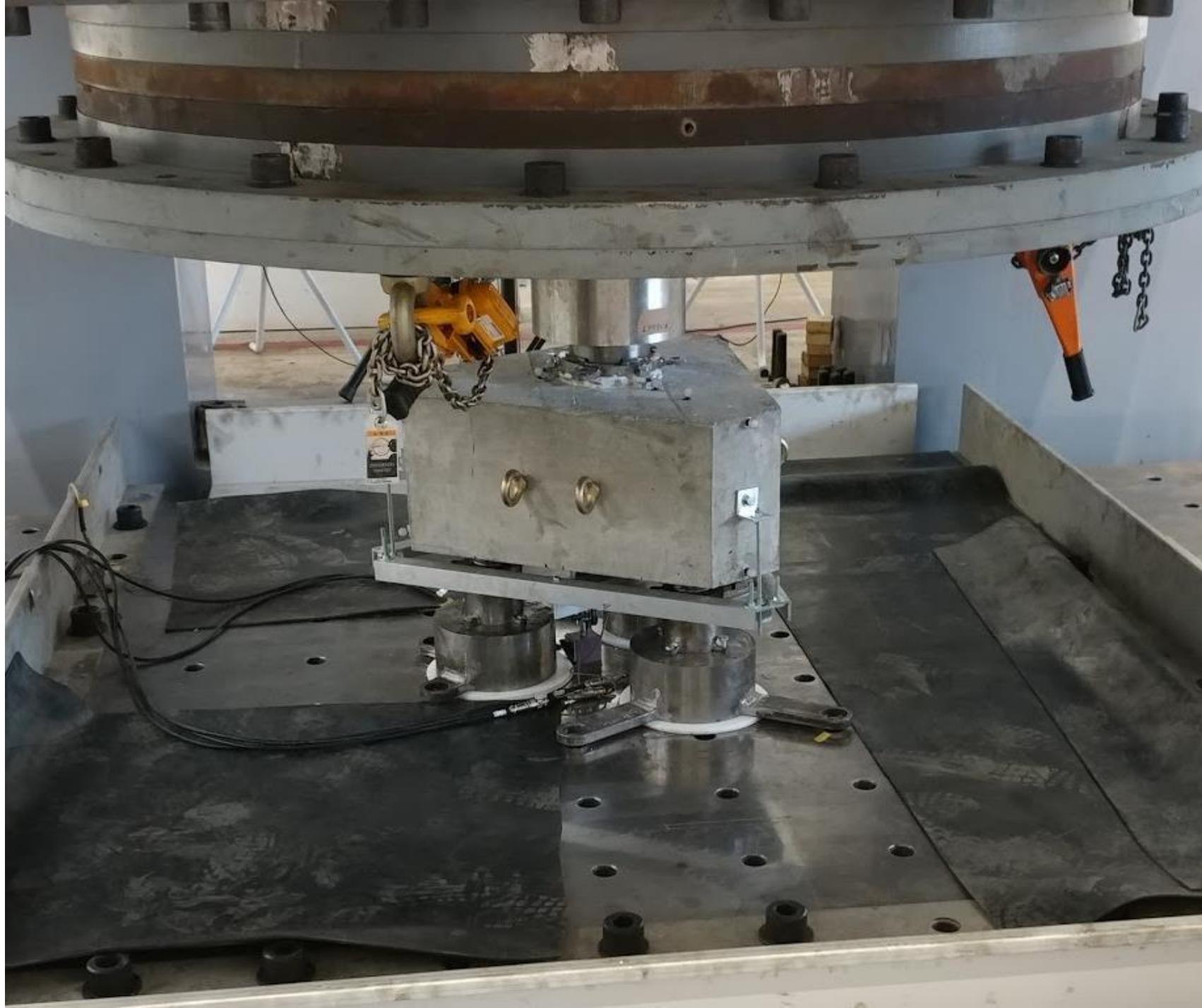
- **Sensors**
  - Displacement gauges
  - Strain gauges
  - Cameras
- **Loading**
  - Upper loading platen
  - Three lower platens each with 1/3 area
  - Monotonic to failure
- **Post-Testing Destructive Examination**
  - Saw cut to examine crack patterns



# BATS

雙軸向動態試驗系統



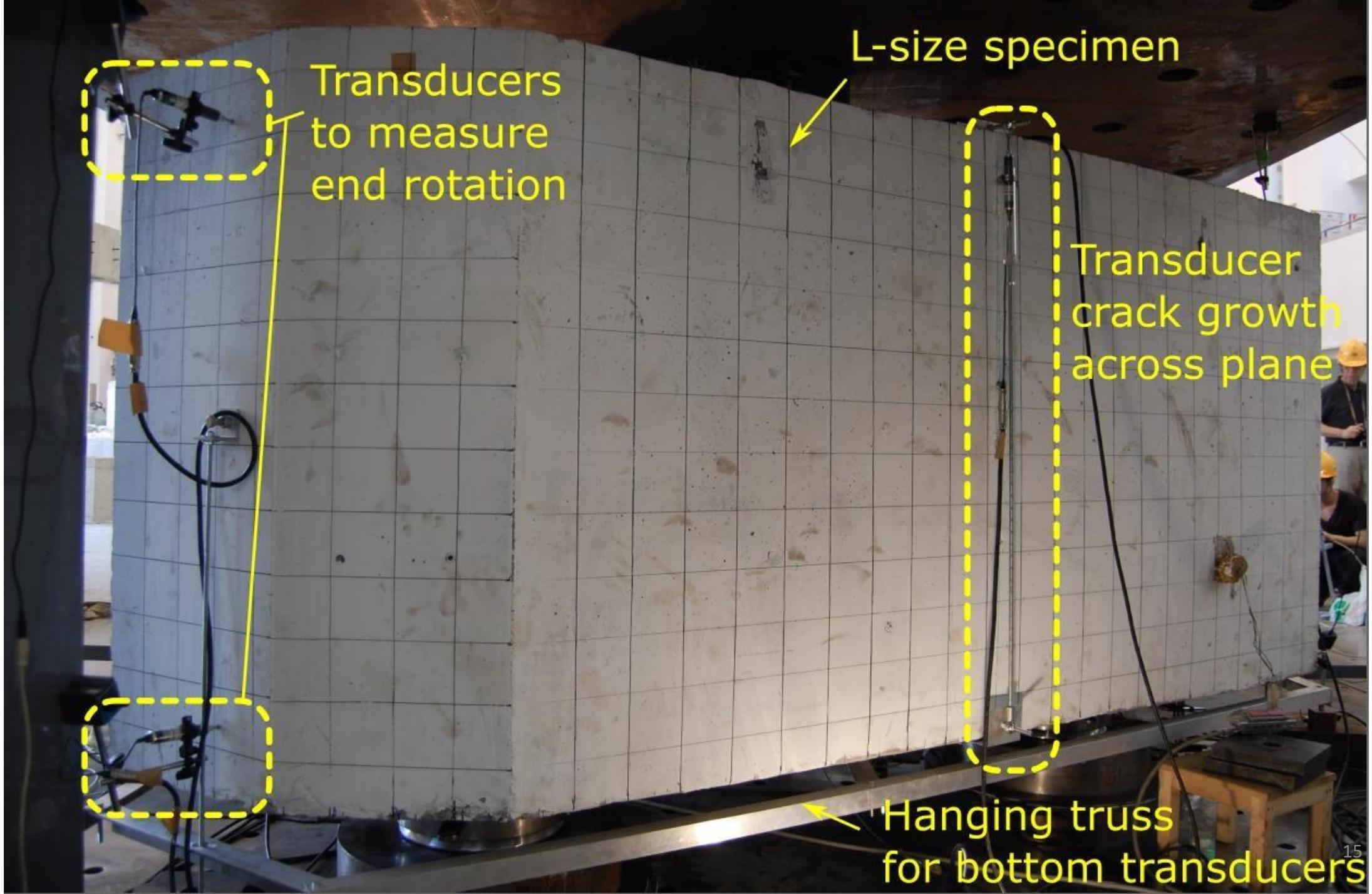


L-size specimen

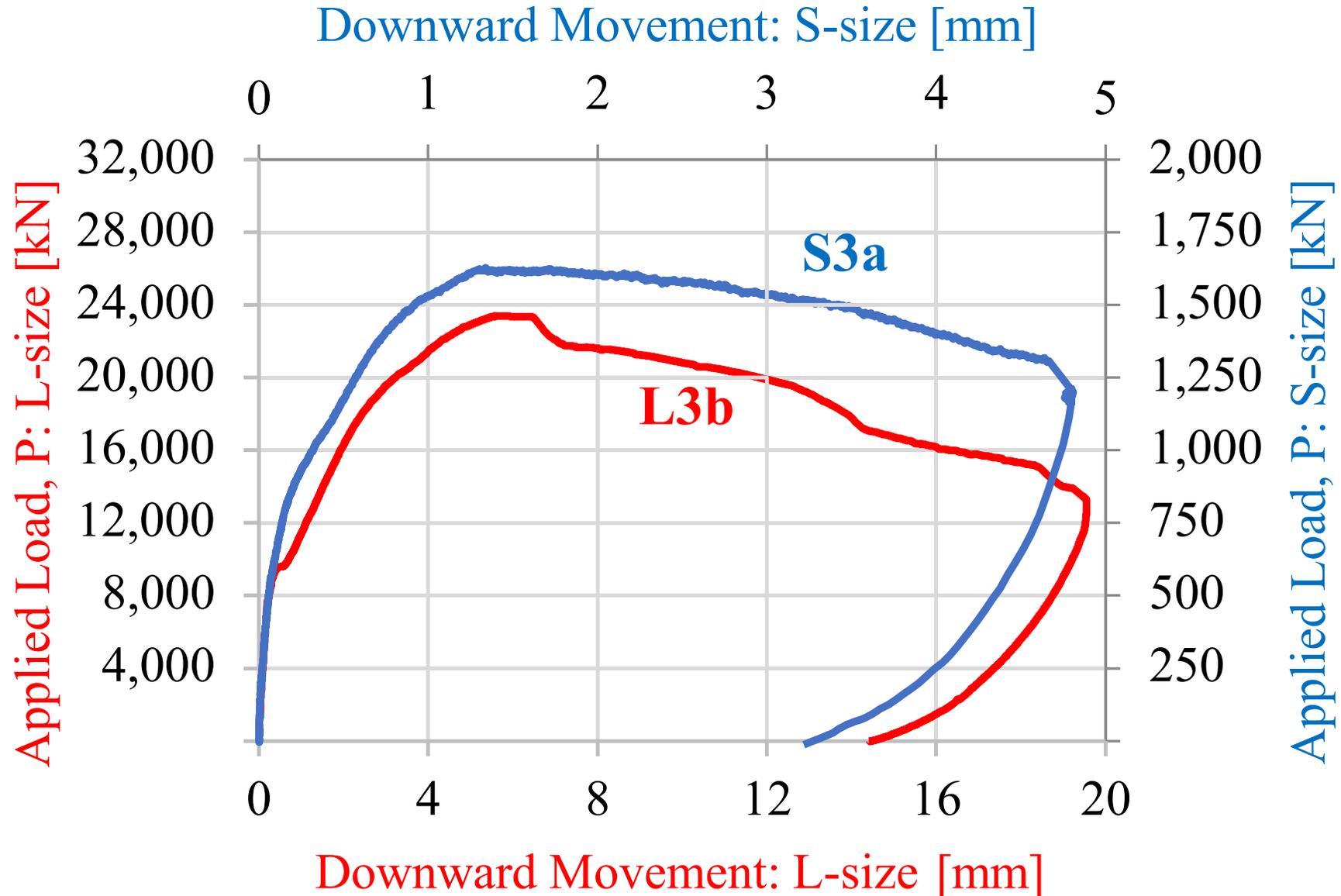
Transducers to measure end rotation

Transducer crack growth across plane

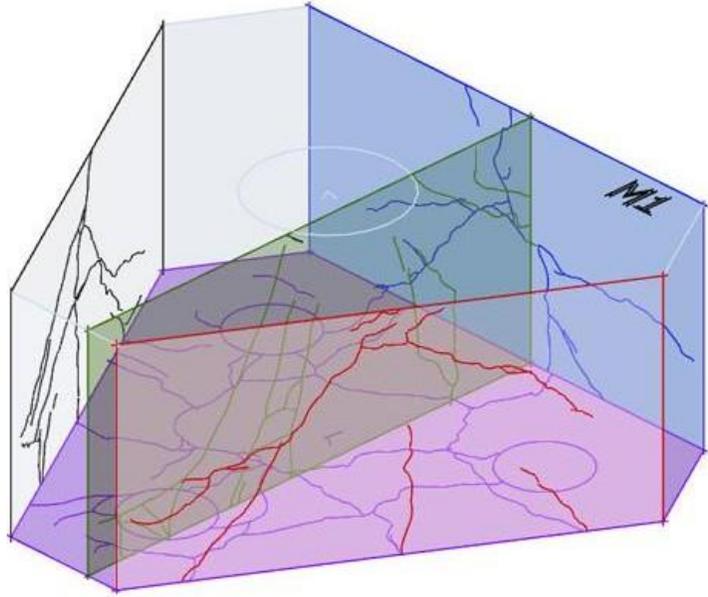
Hanging truss for bottom transducers



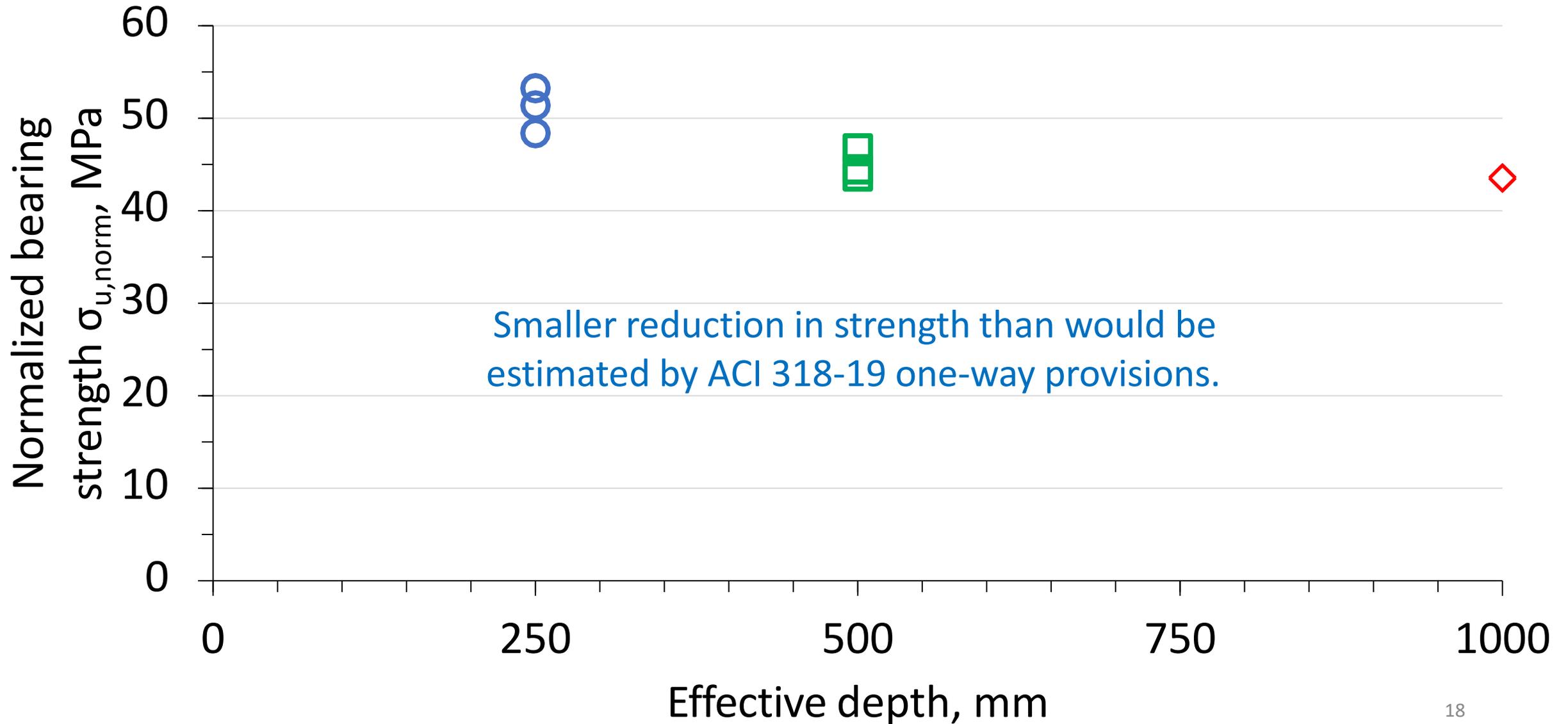
# Behavior – S3 vs. L3



# Cross-Sections



# Strength



# Summary

- Tests of pile caps 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%

# Conclusions

- Controlling key geometric ratios like aggregate diameter to effective depth reduced the effect
- Generally, the size effect does not appear to be as severe as employed in ACI Code provisions – there seems to be a floor as previously proposed by Kim et al. (1999)

**Thank You!**