Rapid Construction of Bridges with Concrete Filled Tubes

Dawn Lehman, Charles Roeder, and Max Stephens

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  - Transportation Northwest (now PacTrans)
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  - Washington Department of Transportation
  - PacTrans

Overview of Presentation

- Introduction and overview of research
- Component tests and member behavior
- Column-to-foundation connection
  - Fully restrained connection
  - Design requirements
- Current Research

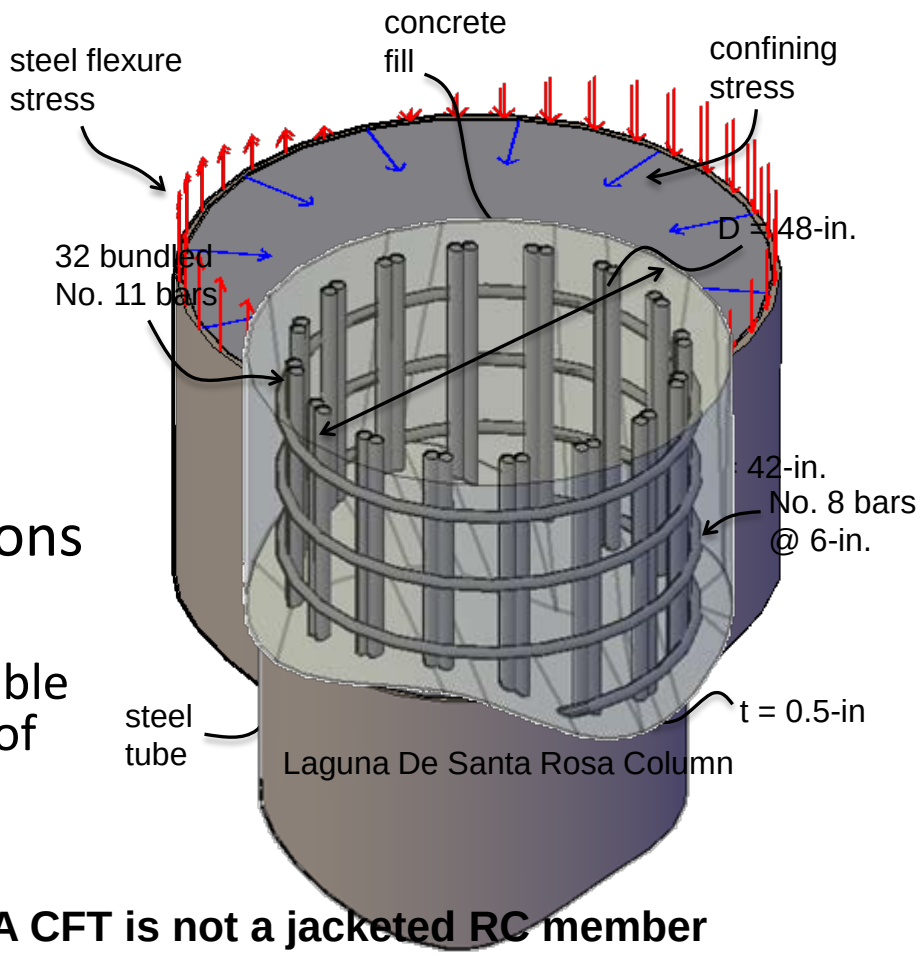
CFT is a Composite Solution

Advantages

- Reduced labor
- Large strength
- Large stiffness
- Inherent stability

Disadvantages

- Unknown deformation capacity
- Unverified design expressions
- No standard connections
  - Connections should be capable of transferring full strength of CFT

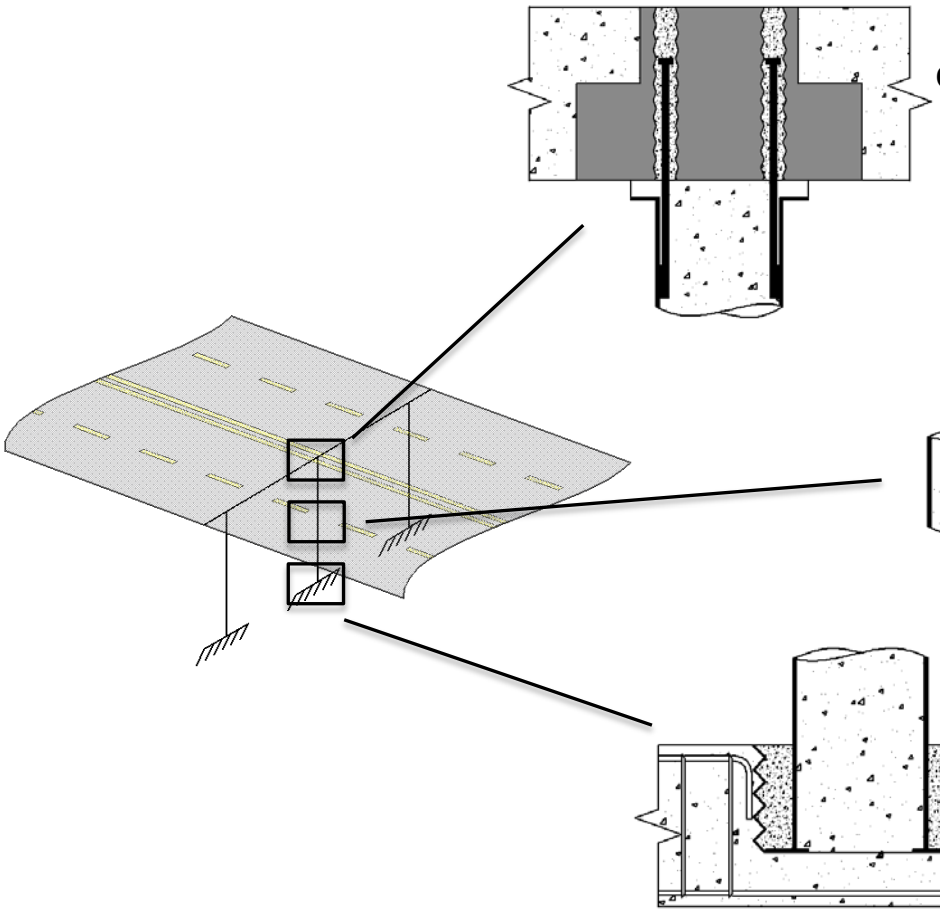


*** A CFT is not a jacketed RC member**

Laguna De Santa Rosa Column Re-designed using CFT

Objective

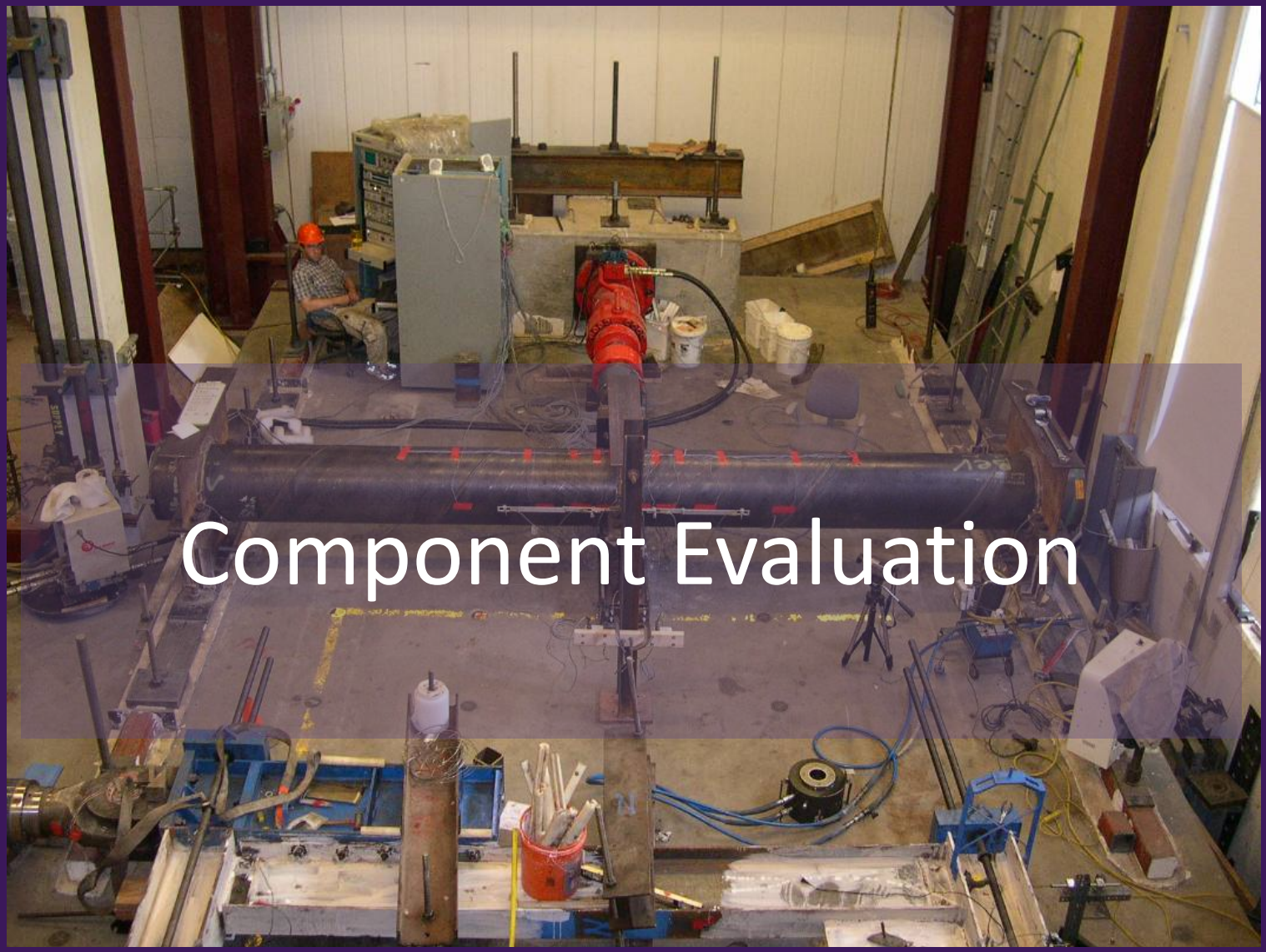
Develop design expressions such that CFT's can be widely implemented in bridge construction



Cap Beam Connection: standard cap detail capable of achieving strength and ductility requirements

CFT Component: expressions for stiffness and strength

Foundation Connection: standard foundation detail capable of achieving strength and ductility requirements



Component Evaluation

Component Evaluation Summary

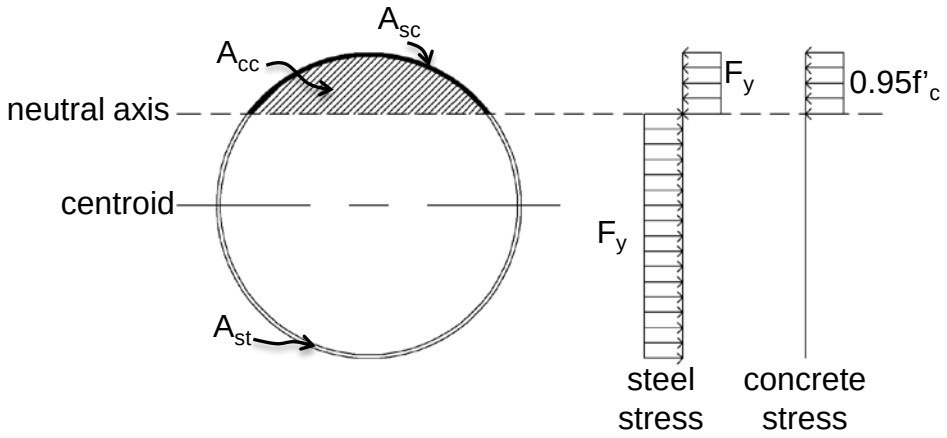
- 13 circular CFT tests conducted
- 122 circular CFT tests surveyed
- Strength and stiffness recommendations provided

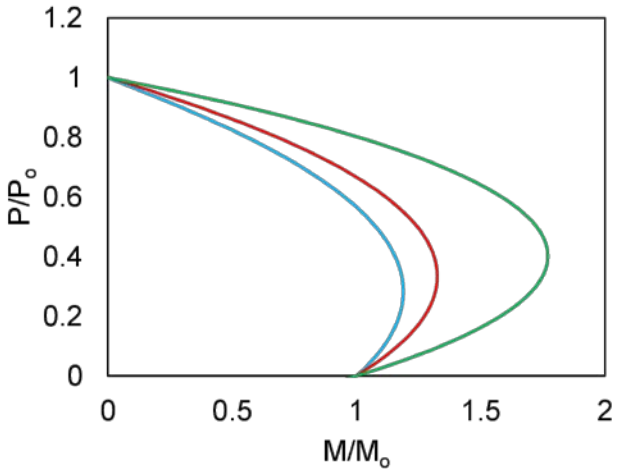
Design Expressions

- Design expressions verified and developed using experimental survey
  - Geometric limits
  - Column buckling
  - Moment strength
  - Effective stiffness
- Expressions currently being considered by AASHTO T-14

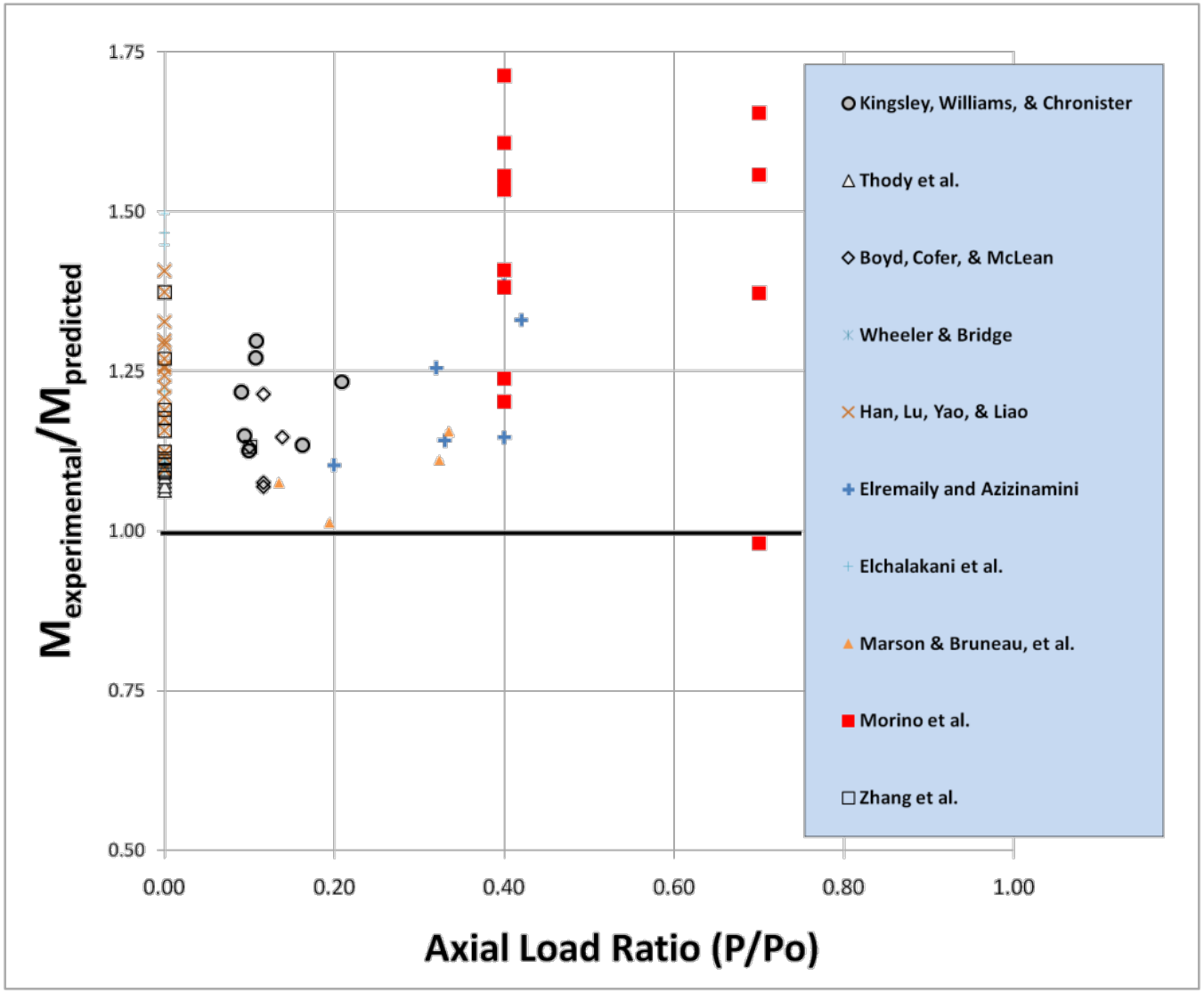
Plastic Stress Distribution Method

- Method of choice for flexural strength calculation
- Equilibrium based approach
- Assumptions
  - Steel is at yield in tension and compression
  - Concrete stress block at $0.95f'_c$
  - External axial load is applied at centroid





Comparison with Test Data



Effective Stiffness of Circular CFT

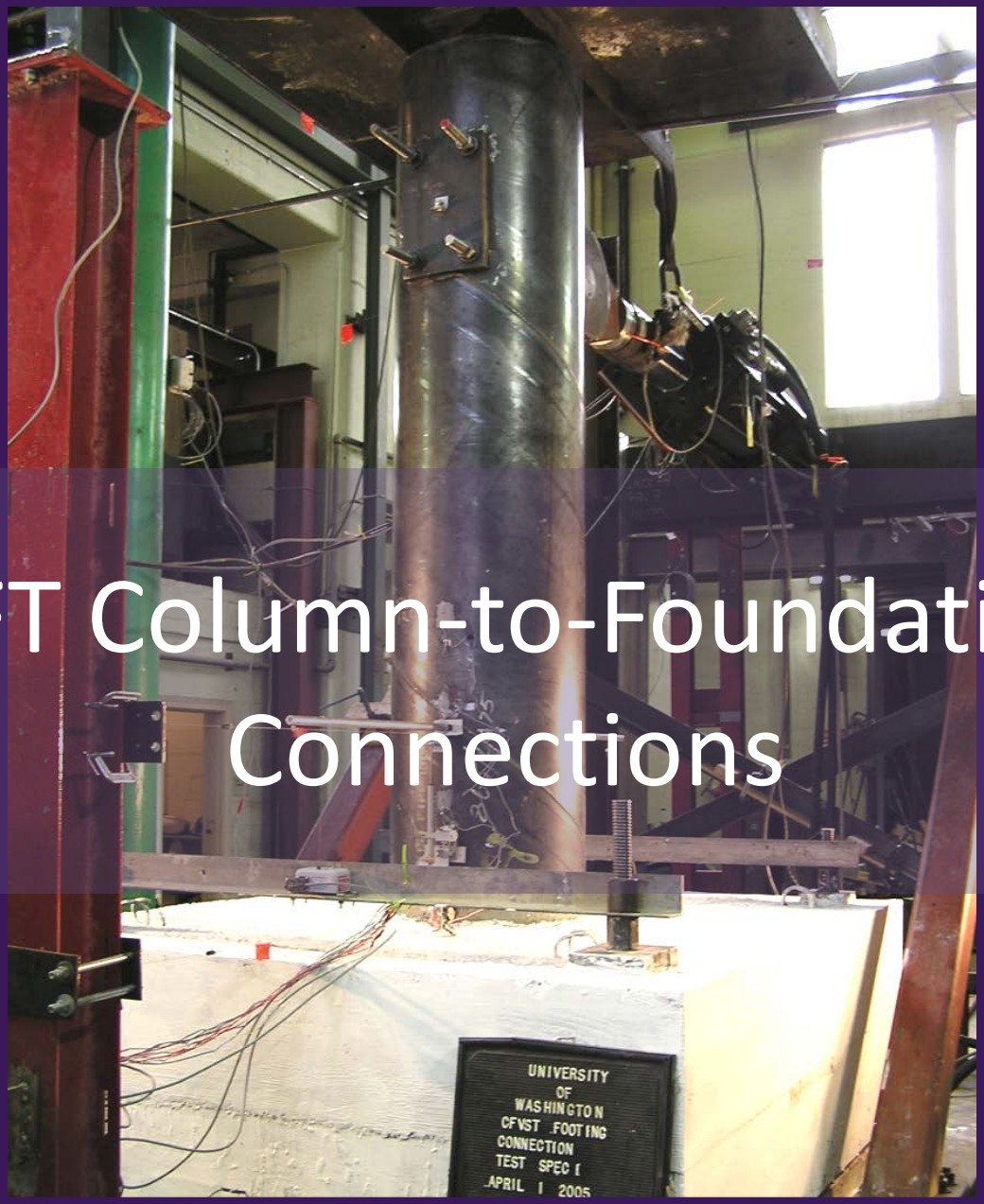
$$\longrightarrow EI_{effPROPOSED} = E_s I_s + C_3 E_c I_c$$

$$\longrightarrow C_3 = 0.15 + \frac{P}{P_o} + \frac{A_s}{A_s + A_c} < 0.9$$

Experimental Stiffness Comparison of All Specimens

$EI_{experimental} / EI_{eff\_predicted}$				
Research Data Set	**Mean**	**Min.**	**Max.**	**Std. Dev.**
AISC	0.81	0.50	1.23	0.20
ACI	1.27	0.76	2.00	0.33
Combined AISC-ACI	1.14	0.71	1.81	0.27
Proposed Expression	1.00	0.70	1.57	0.22

Measured-to-Predicted Average is 1.0



CFT Column-to-Foundation Connections

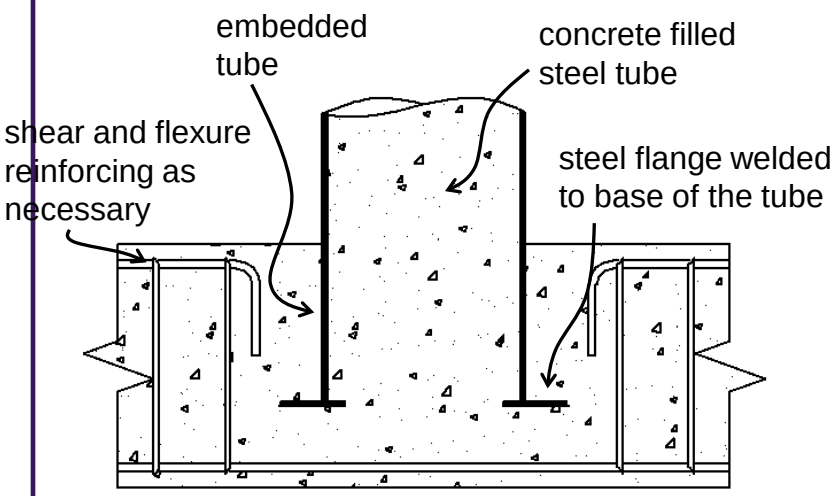
Foundation Connection Types

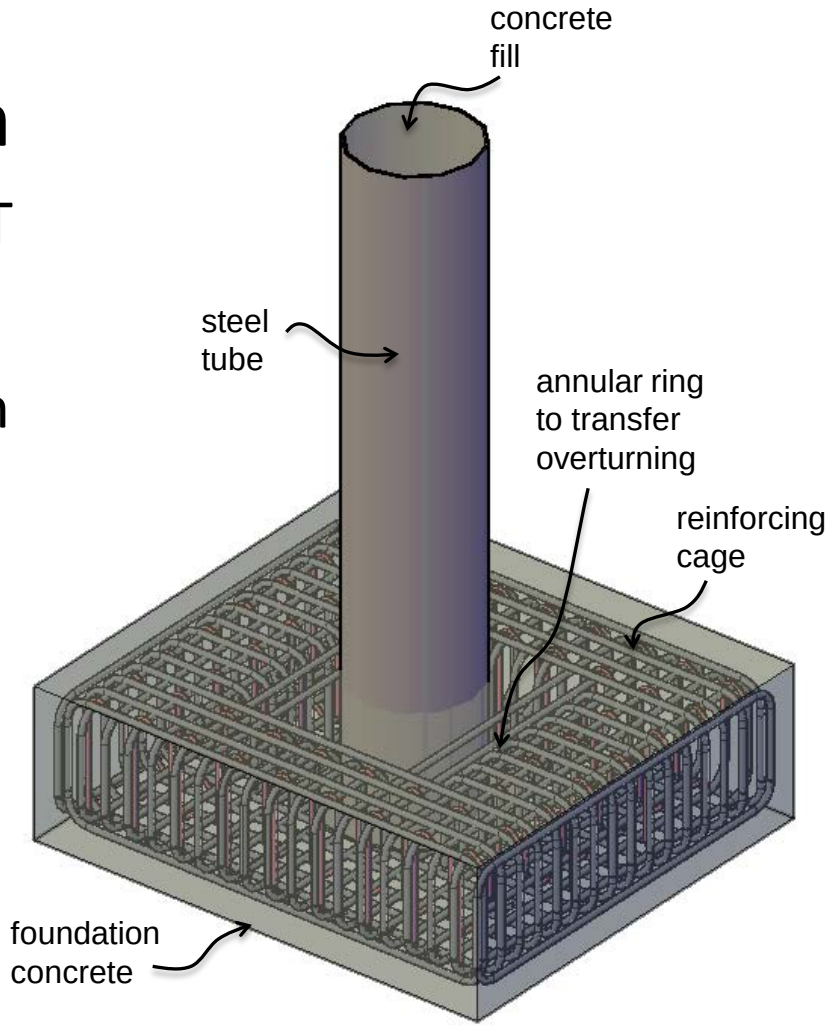
- Fully restrained moment connection
- Tube embedded in foundation concrete
- Annular ring used to transfer overturning forces
- Two connections evaluated
  - Monolithic connection
  - Isolated connection

Monolithic Connection

Monolithic Connection

1. Temporarily support CFT
2. Build foundation cage
3. Cast CFT and foundation

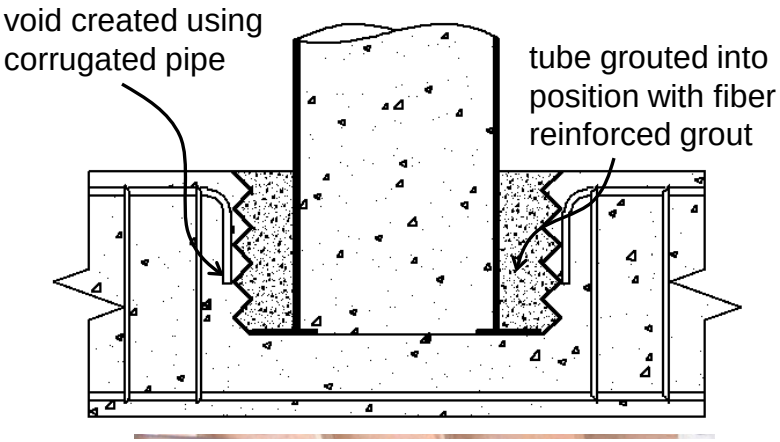


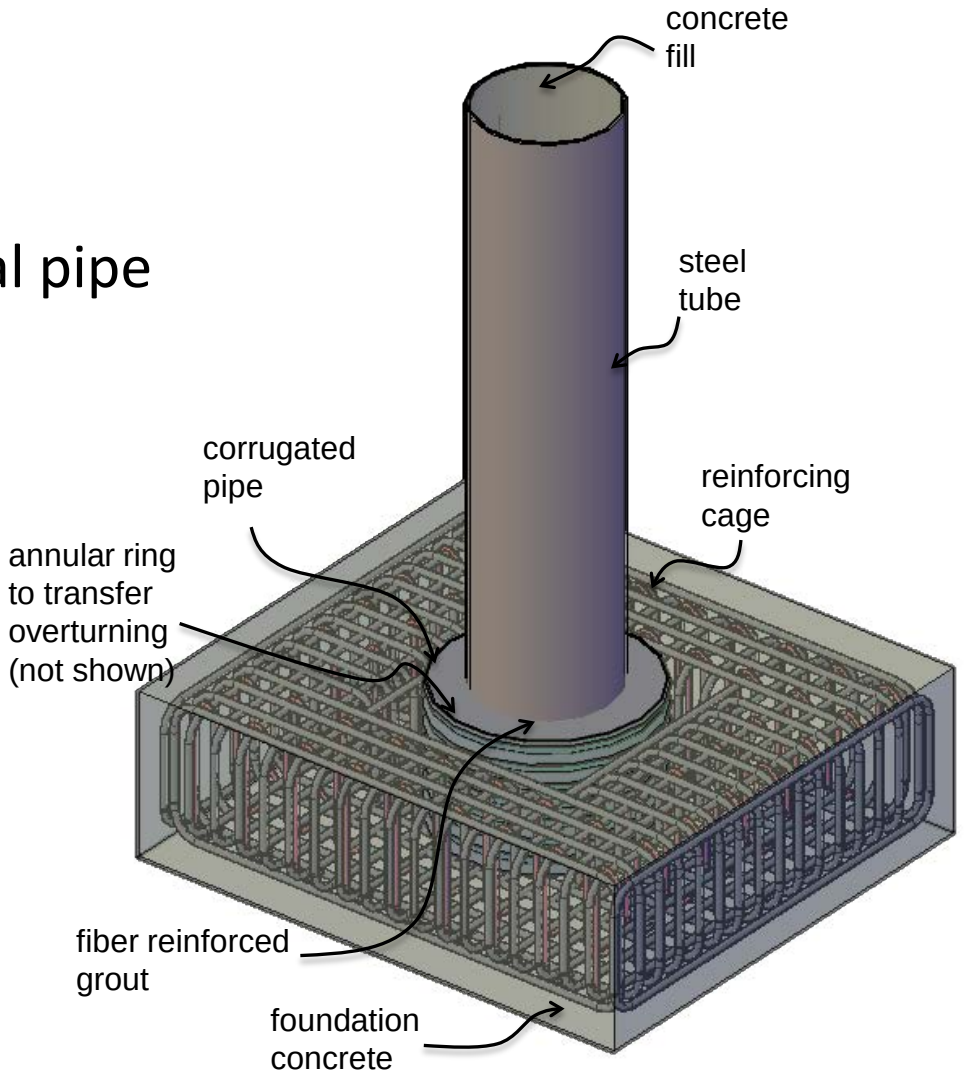


Connection Types

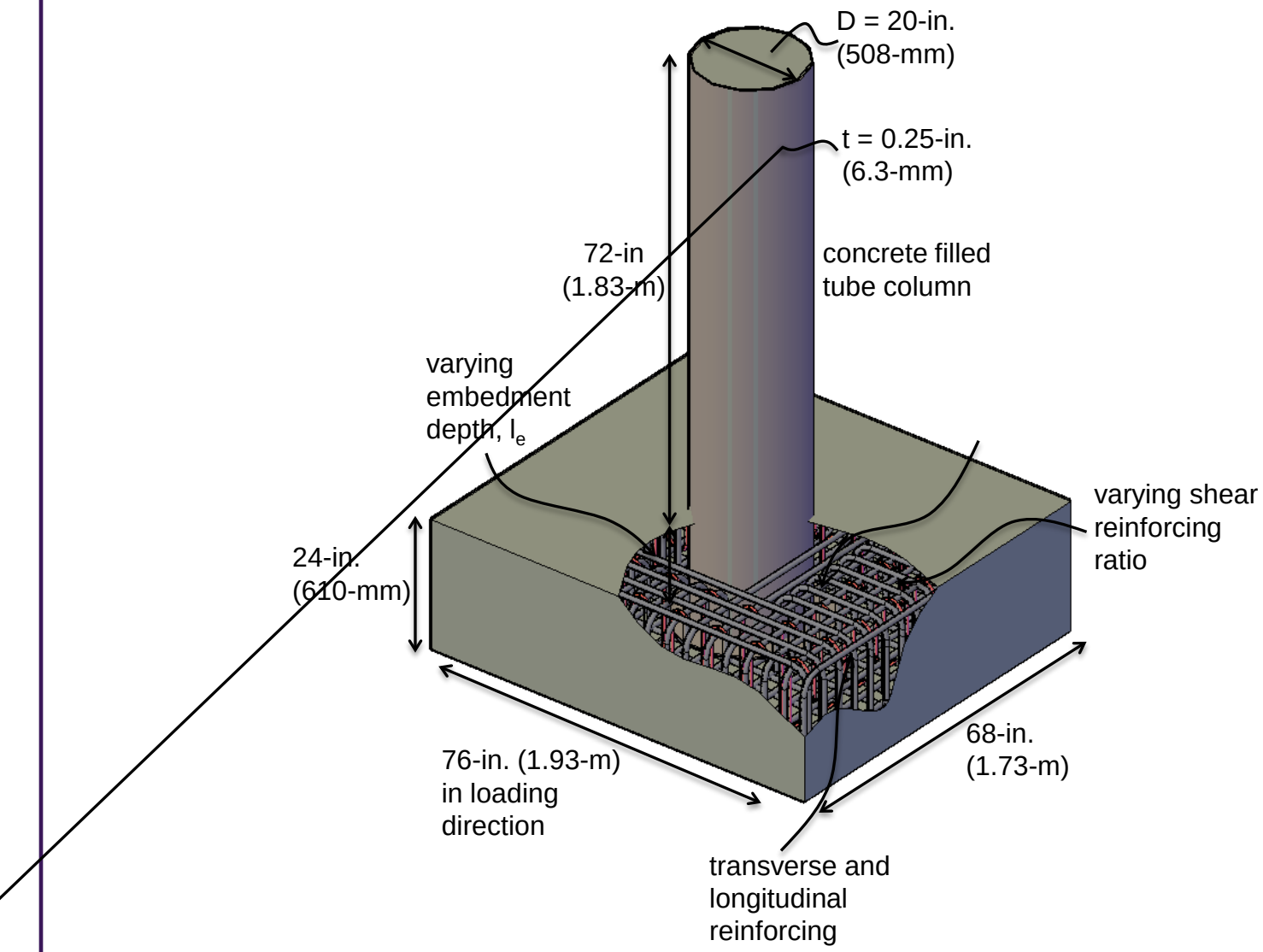
Isolated Connection

1. Built foundation cage
2. Insert corrugated metal pipe
3. Cast foundation
4. Install and grout tube
5. Cast column





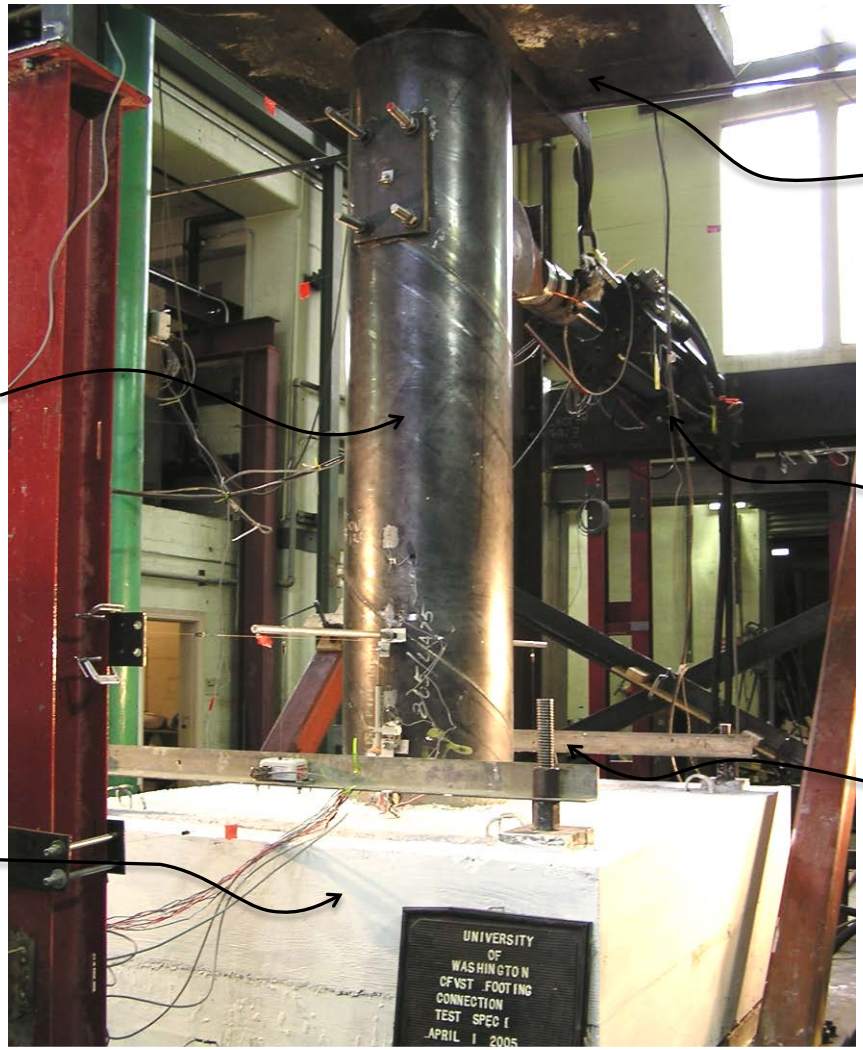
Specimen Overview



Study Parameters

- Type of connection: monolithic and isolated
- Type of tube: spiral welded and straight seam weld
- Tube strength
- Tube geometry (D/t ratio)
- Foundation boundary conditions
- Shear reinforcing ratio
- Axial load ratio
- Embedment depth

Test Configuration



constant axial load applied via Baldwin test machine ($P = 10\%P_o$)

CFT-column

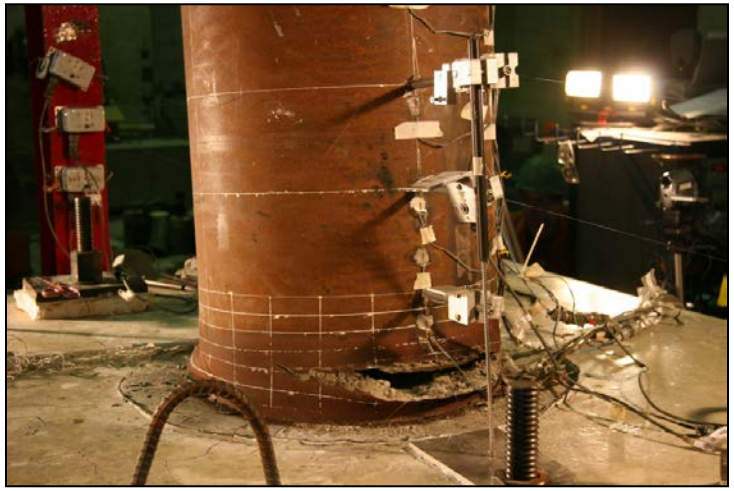
cyclic load applied via horizontal actuator

anchor rods

foundation

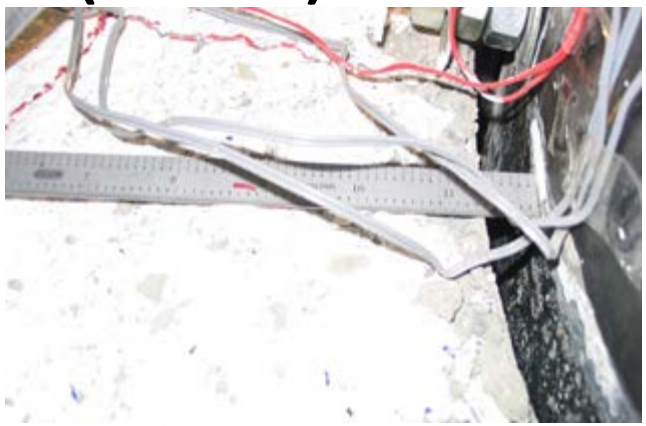
Experimental Summary

- Total of 19 tests conducted
- Embedment depth very important
  - Drifts of 7-10% for adequate embedment
- Failure mechanism is tearing
- Initial buckling does not reduce capacity
- Lower strength steel tubes achieved higher drifts

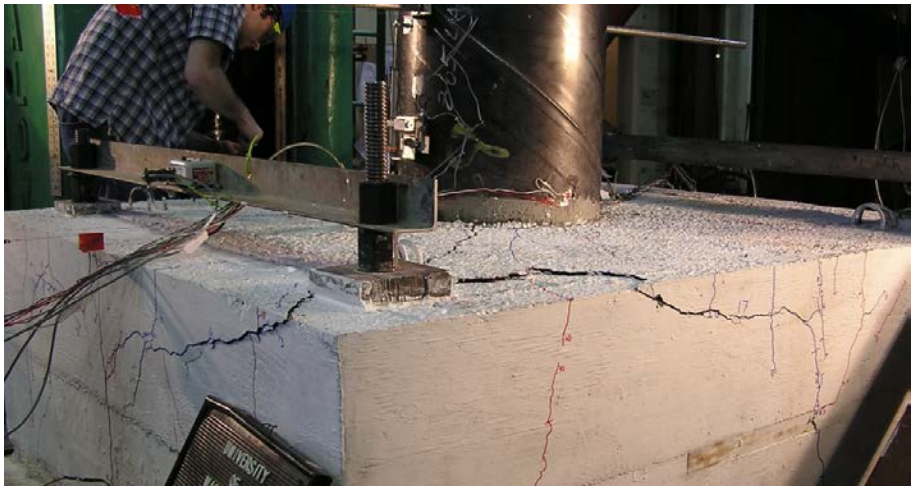


Observed Behavior with Inadequate Embedment (0.6D)

bisecting cracks: 0.75% drift



interface gap: 2.5% drift



footing uplift: 4% drift

final state: 8% drift

Observed Behavior with Adequate Embedment (0.9D)

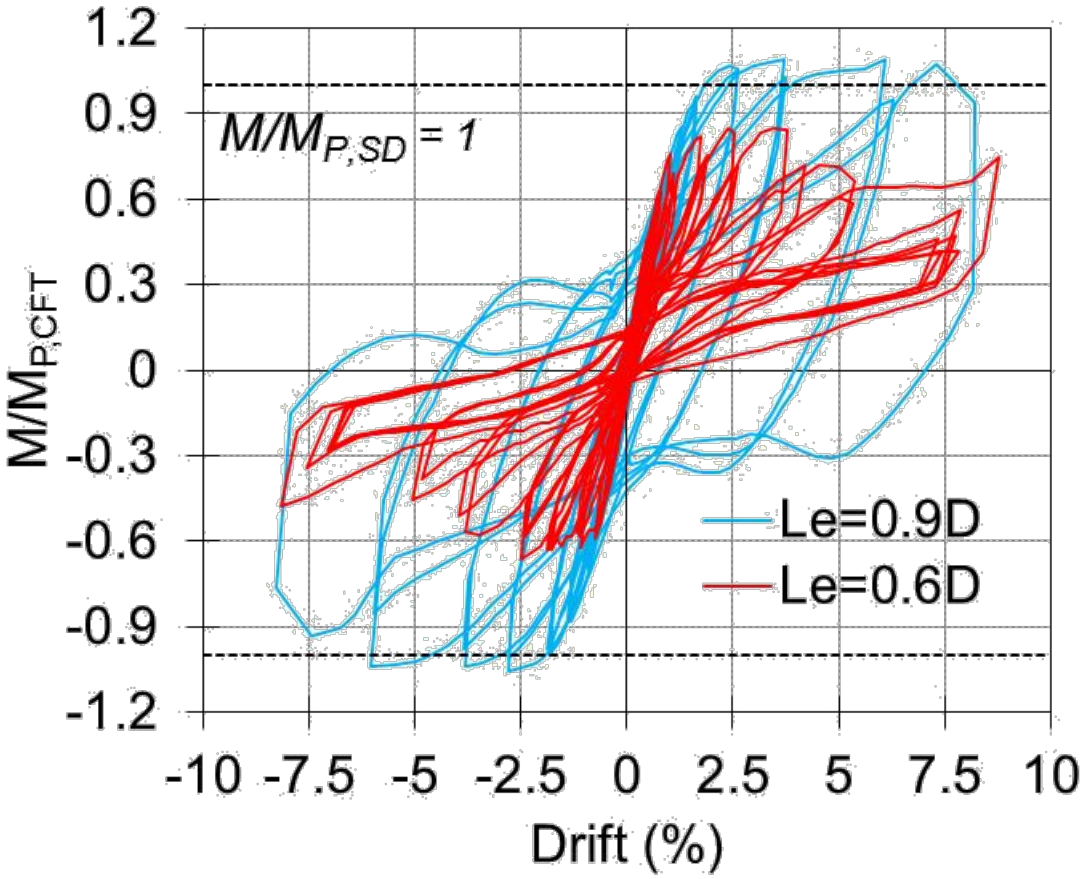
limited footing damage: 2.5% drift

tube buckles: 4% drift

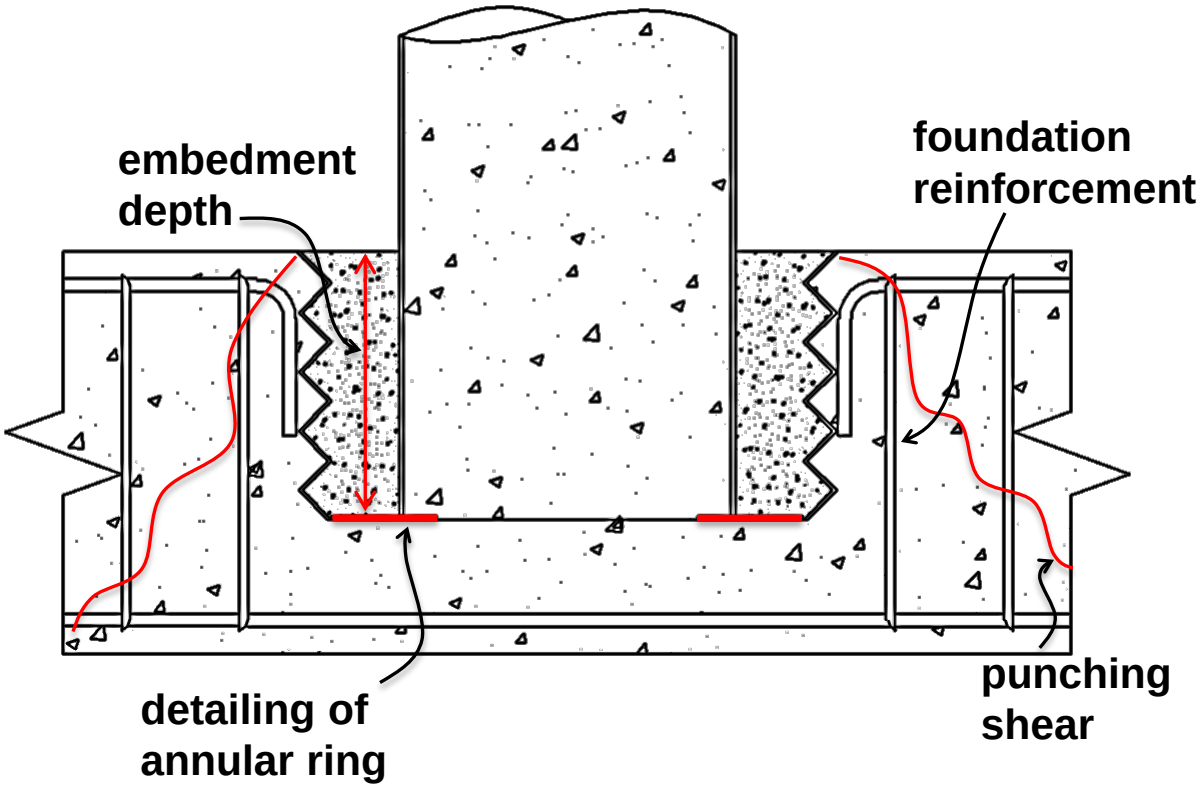
initiation of tearing: 6% drift

final state: 7.2% drift

Hysteretic Response



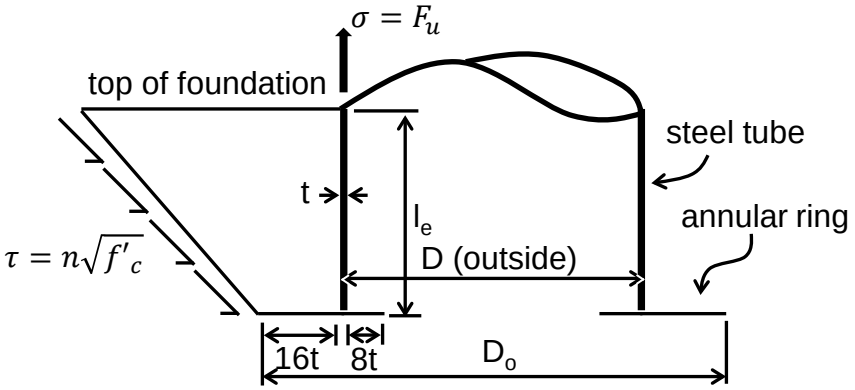
Requirements for Fully Restrained Connection to a Cap Beam or Foundation

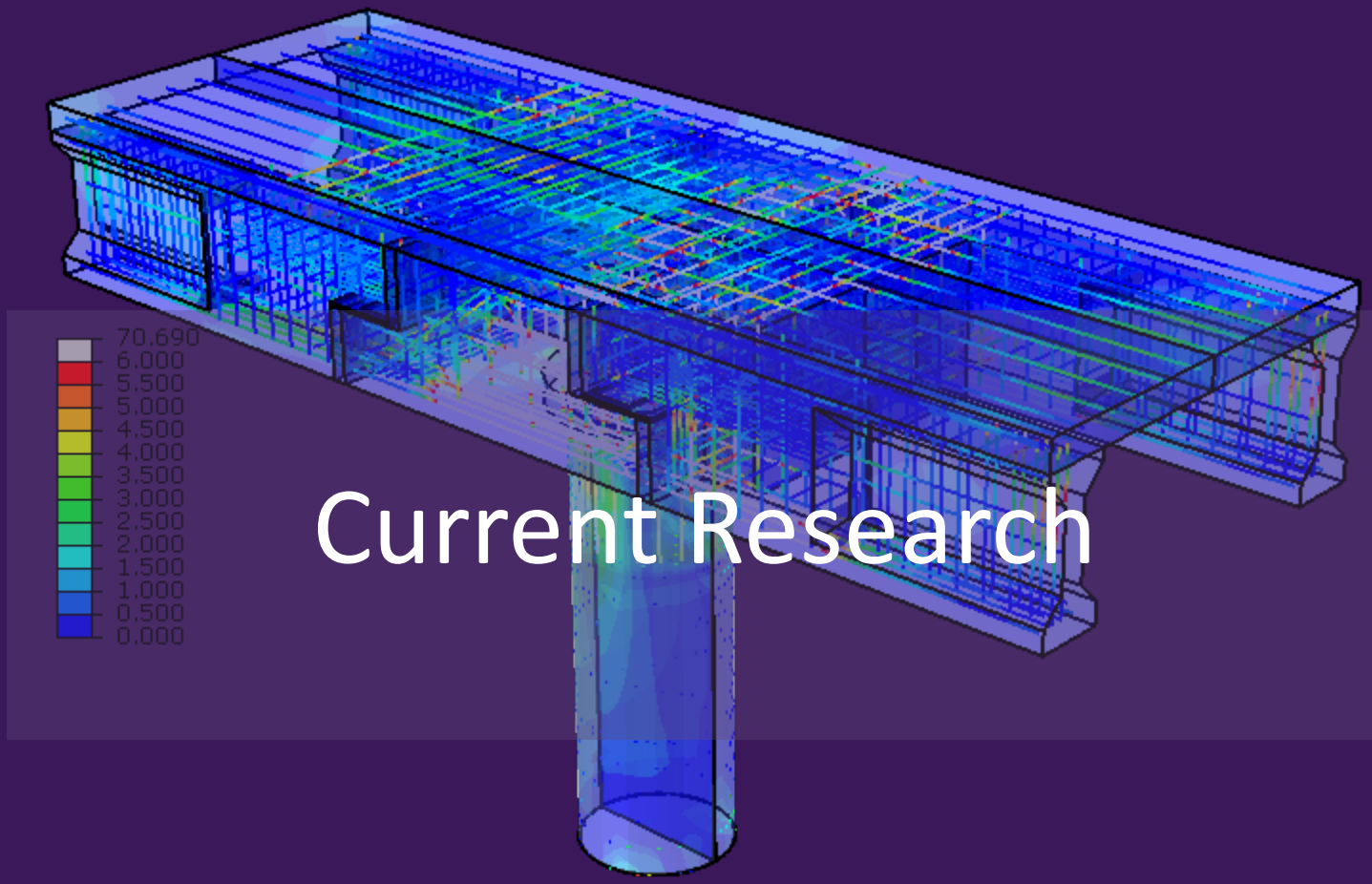


Embedment Depth

- Required embedment to prevent cone pullout
- Expression derived using single strut model and experimental results
- Shear strength coefficient, n, of 6. (f'_{cf} in psi)

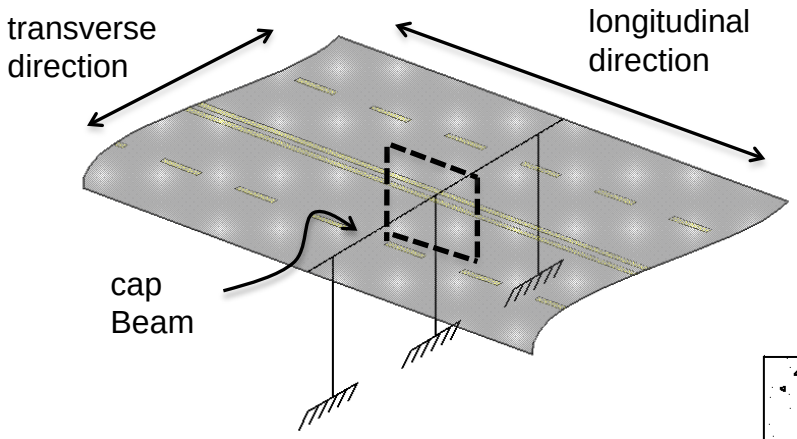
$$\longrightarrow L_e \geq \sqrt{\frac{{D_o}^2}{4} + \frac{DtF_u}{6\sqrt{f'_{cf}}}} - \frac{D_o}{2} (psi)$$

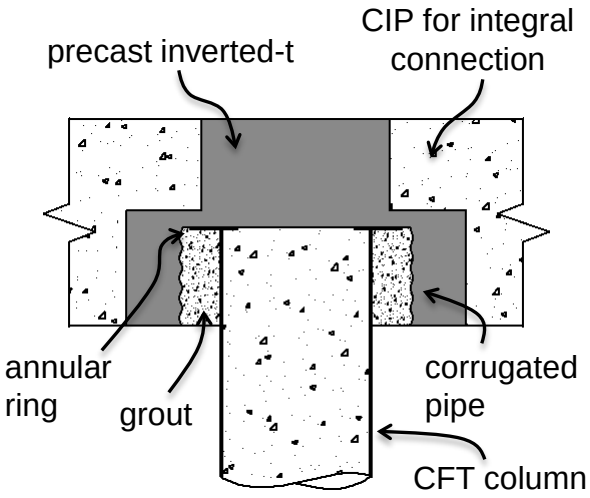




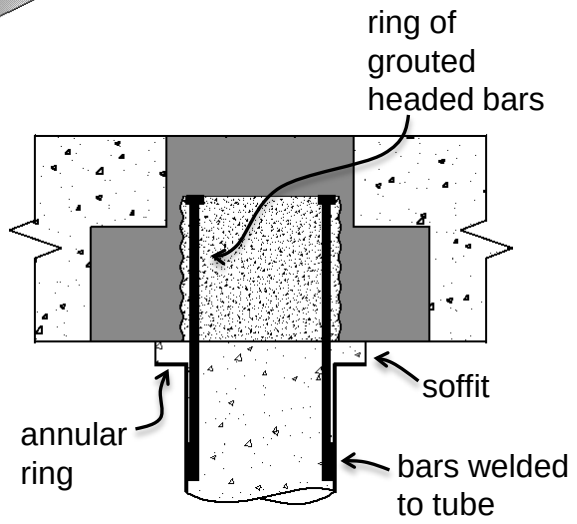
Current Research

Connection Alternatives



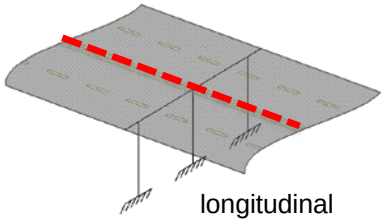


CFT Connection

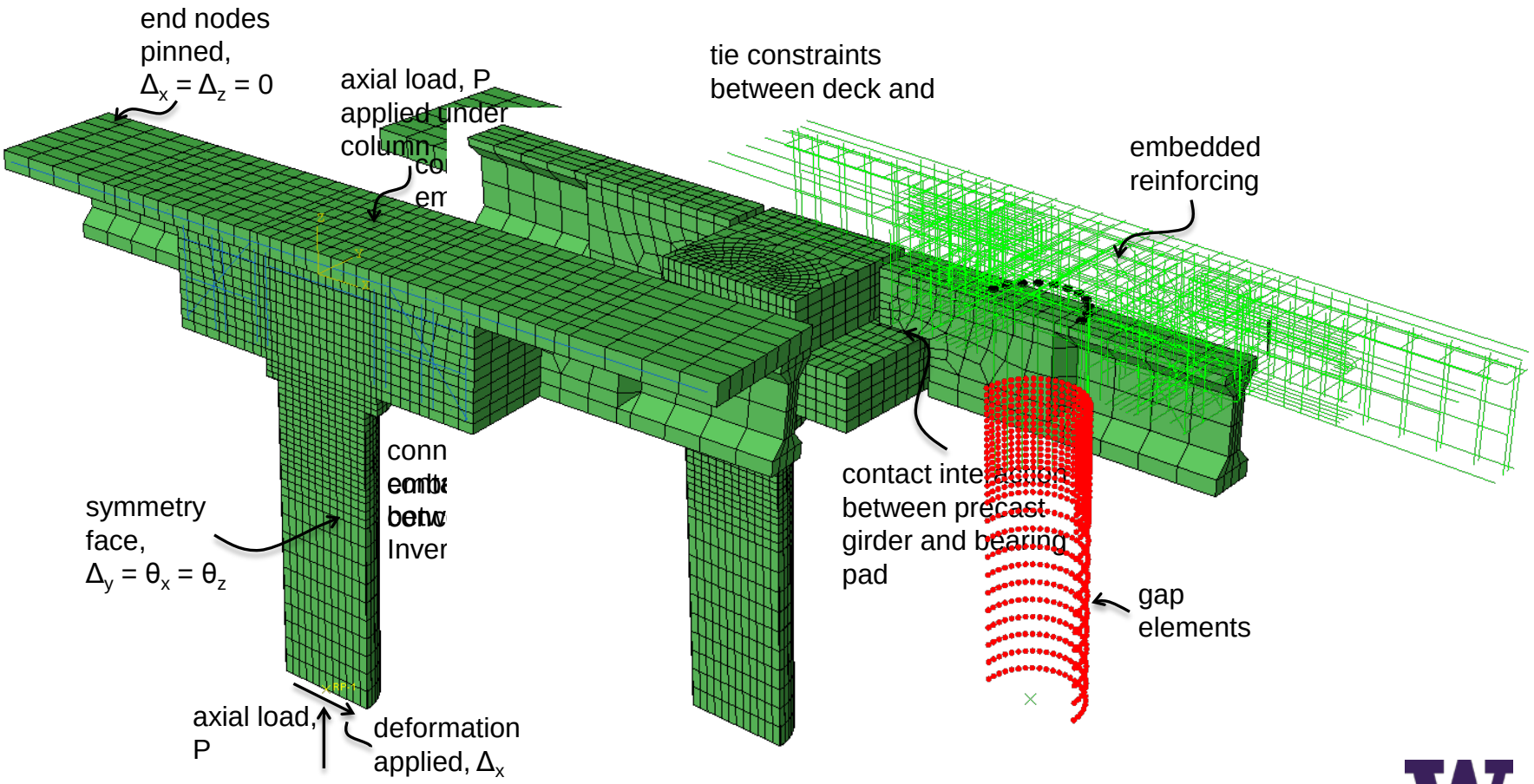


Reinforced Concrete Connection

Numerical Analysis

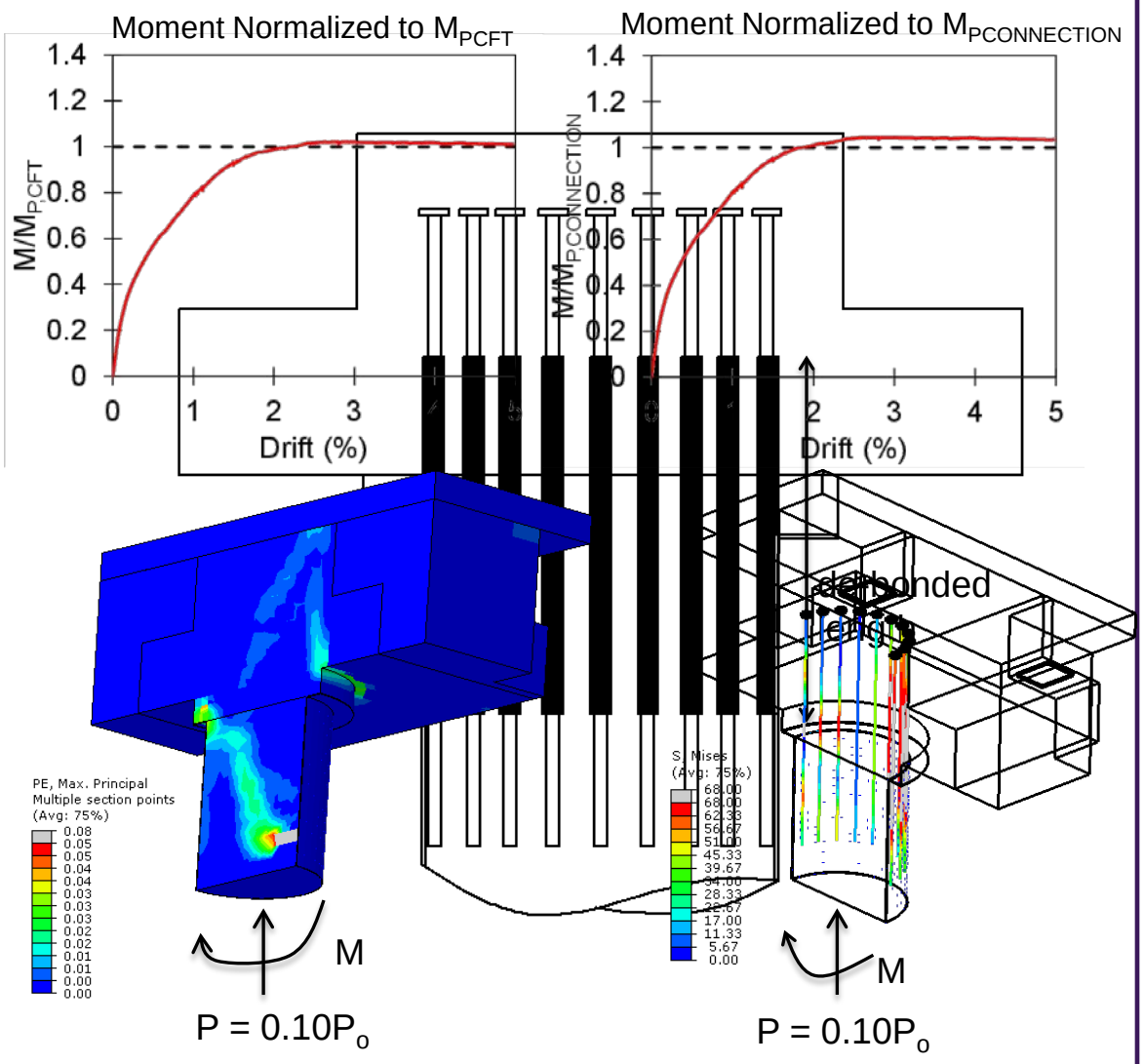


FE model in ABAQUS



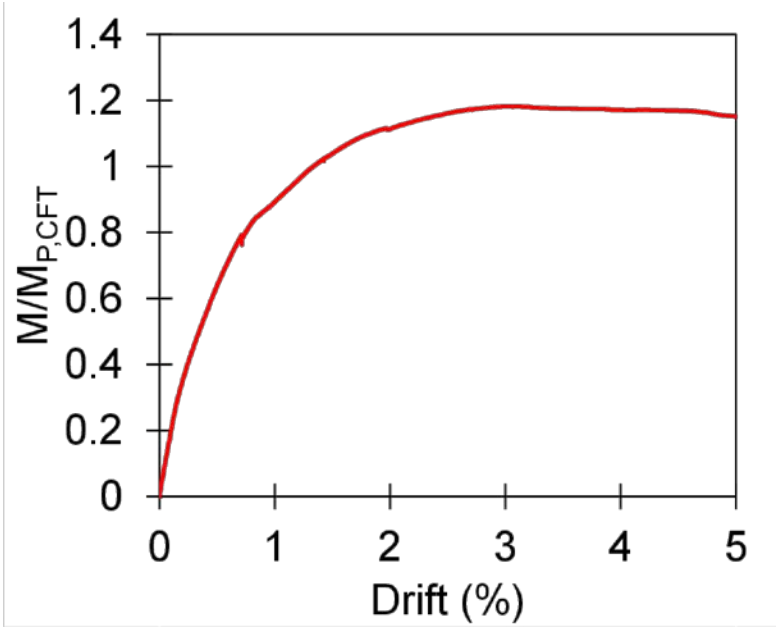
Reinforced Concrete Connection

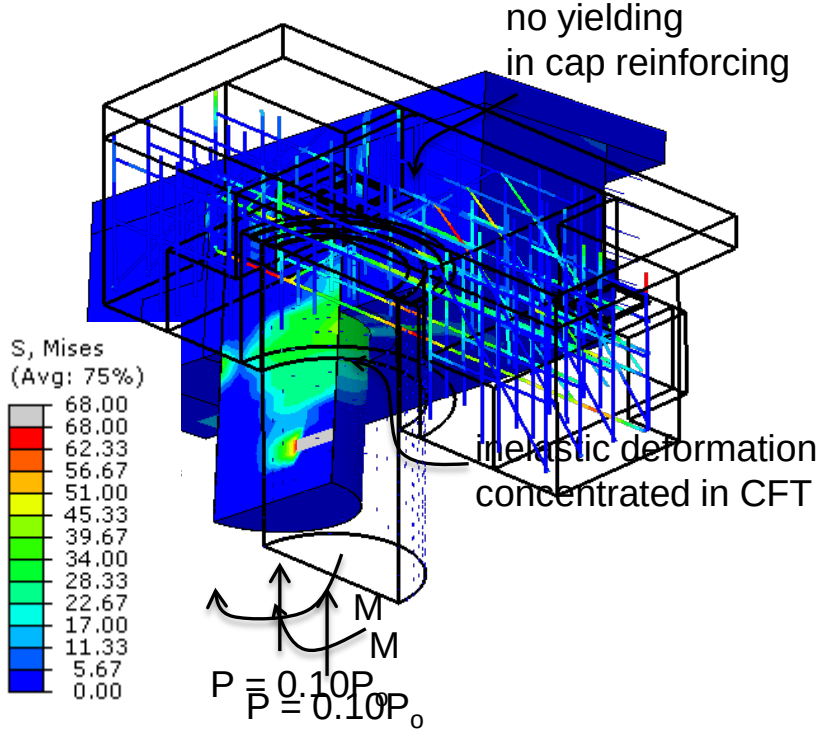
- Maximum reinforcing ratio, ρ = 3%
- Reinforcing de-bonded in connection region
- Inelastic deformation isolated to connection reinforcing



CFT Connection

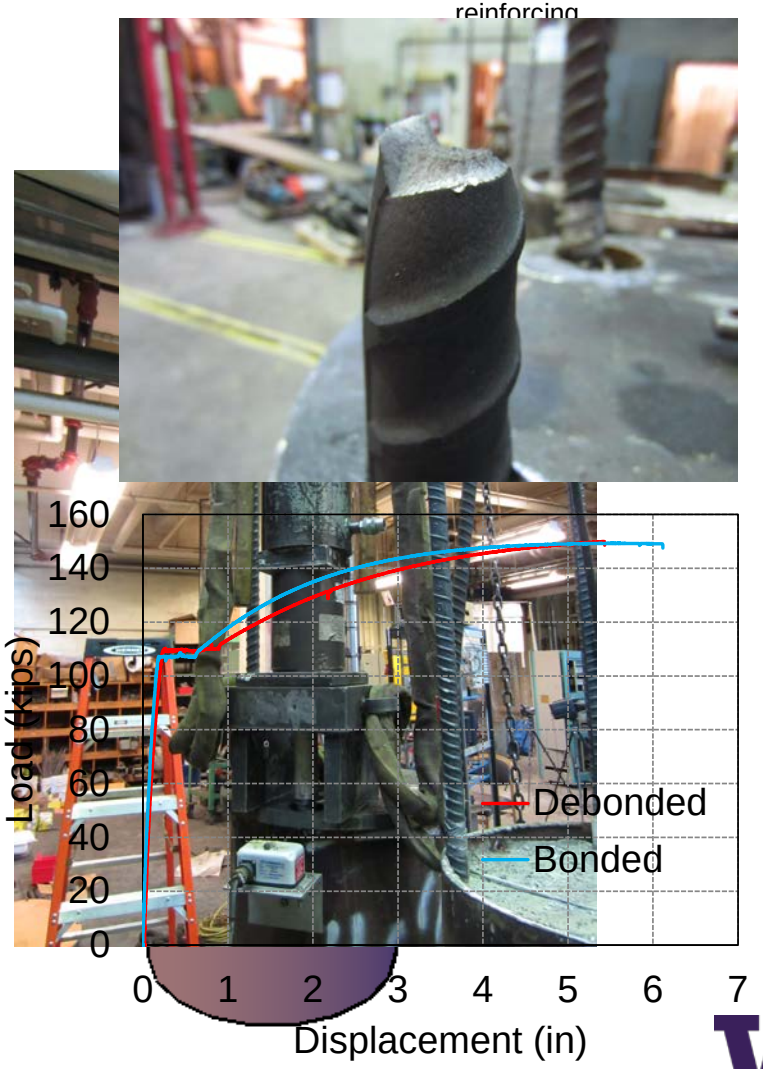
- Inelastic behavior concentrated in CFT
- No yielding in cap beam reinforcing



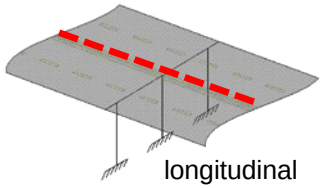


Welded Reinforcing Experiments

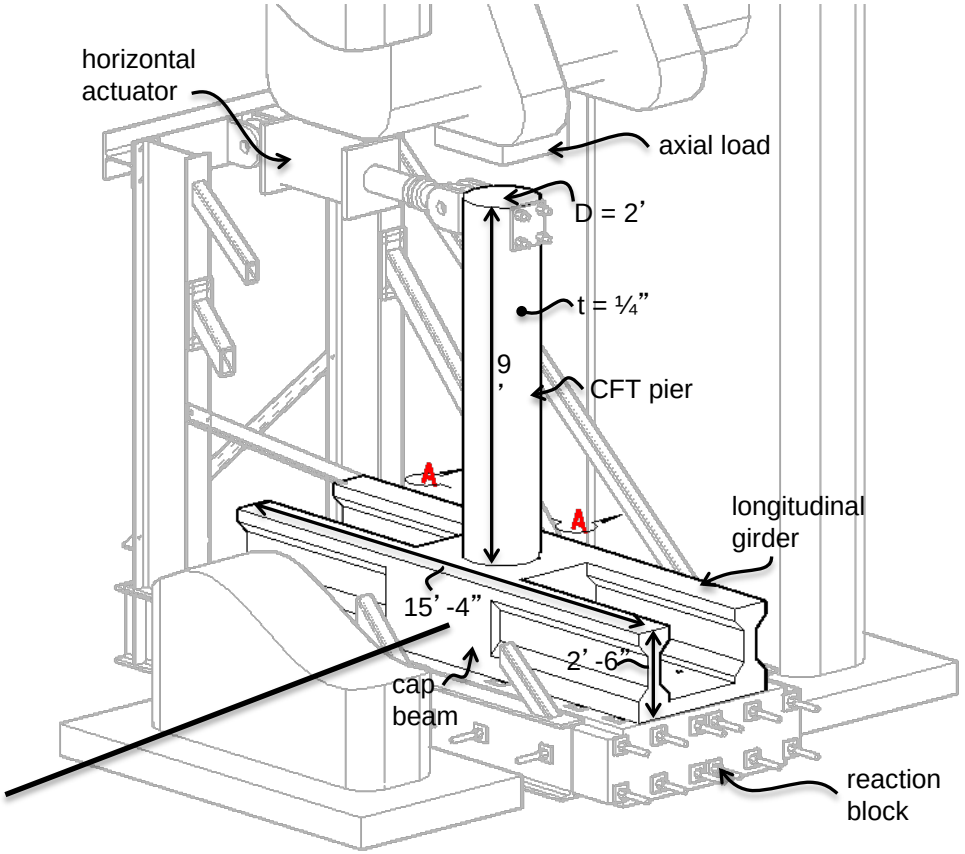
- Welded connection detail evaluated using pullout tests
- Primary variables
  - Weld strength
  - Effects of debonding
- Failure mode of all bars characterized by bar yield and fracture

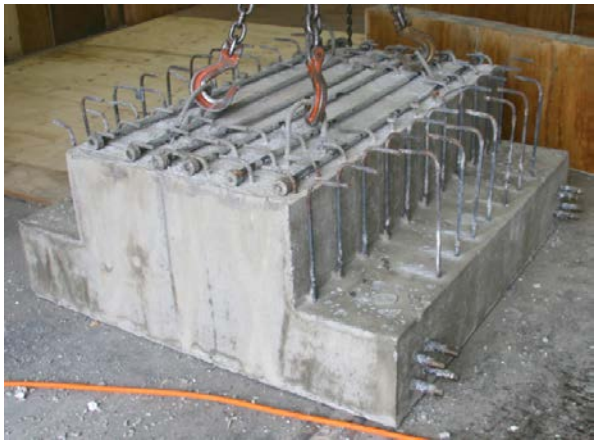


Ongoing Research



- Large scale experiments
  - Range of Connections
  - Target Design Parameters





Final Points

- CFT design expressions validated using a large database (122 specimens). Specification language developed
- CFT foundation connection expressions validated using experimental and analytical results
- CFT cap beam connections analytically evaluated
- Large scale cap beam tests planned to validate numerical results and develop design expressions

Thank You