Precast Bent System for Rapid Construction in Seismic Regions

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Rapid Construction

- Reduce Traffic Congestion:
  - Time = $$ wasted
  - Fuel consumed
  - Air and noise pollution

- Minimize Environmental Impact
- Improve Public and Worker Safety

Solutions

- Organizational
  - Involve contractor early
  - Partner with owner
  - Encourage contractor to innovate
- Financial
  - Incentives (A and B contracting)
  - Capital investment by contractors
- Physical
  - Prefabricate to reduce on-site time

Solutions

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  - Involve contractor early
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  - Incentives (A and B contracting)
  - Capital investment by contractors
- Physical
  - Prefabricate to reduce on-site time

Prefabrication

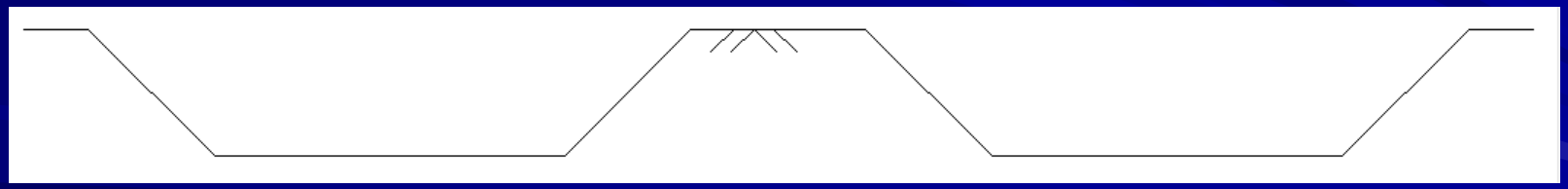
- Existing use of precasting
  - Deck units (some)
  - Girders (common)
  - Bents (some non-seismic)
  - Foundations and abutments (rare)

Courtesy of Concrete Technology Corp.

Goals of Present Research

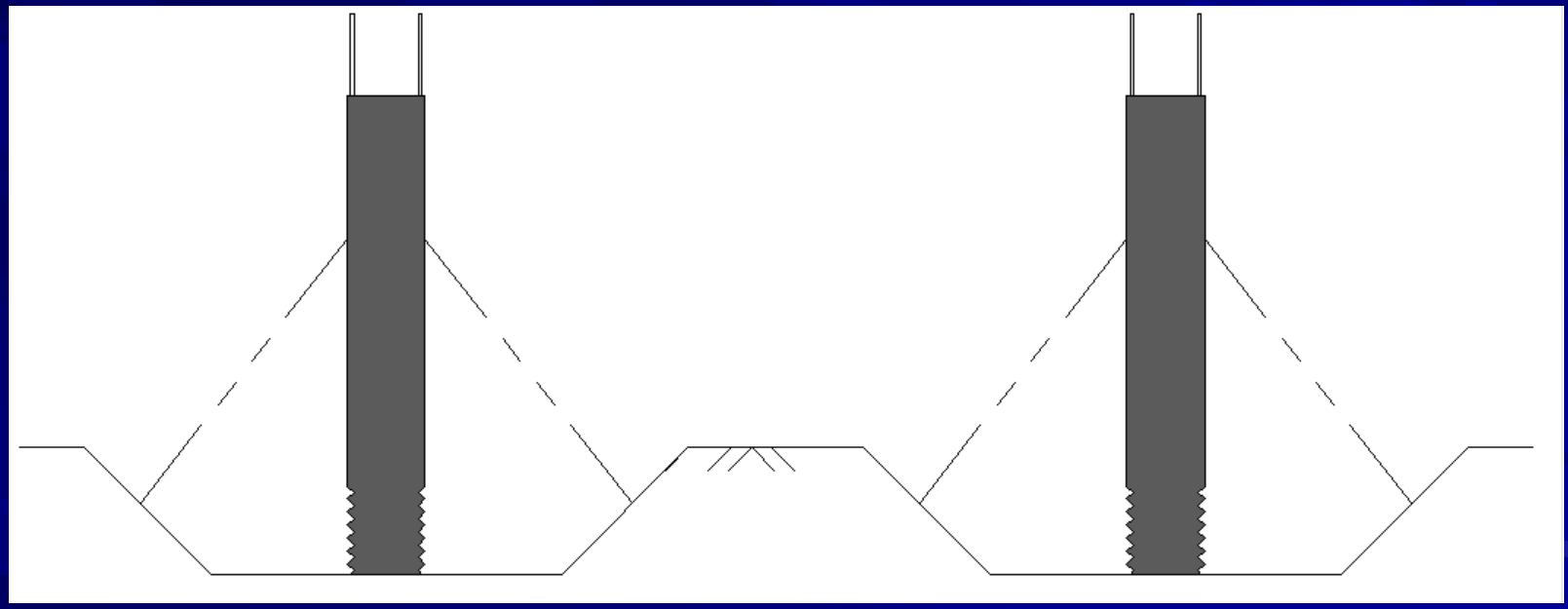
- Develop a precast bent system that:
  - Accelerates construction
  - Is easy to construct
  - Is seismically resistant
  - Avoids untried technologies
  - Is economical

Construction Procedure



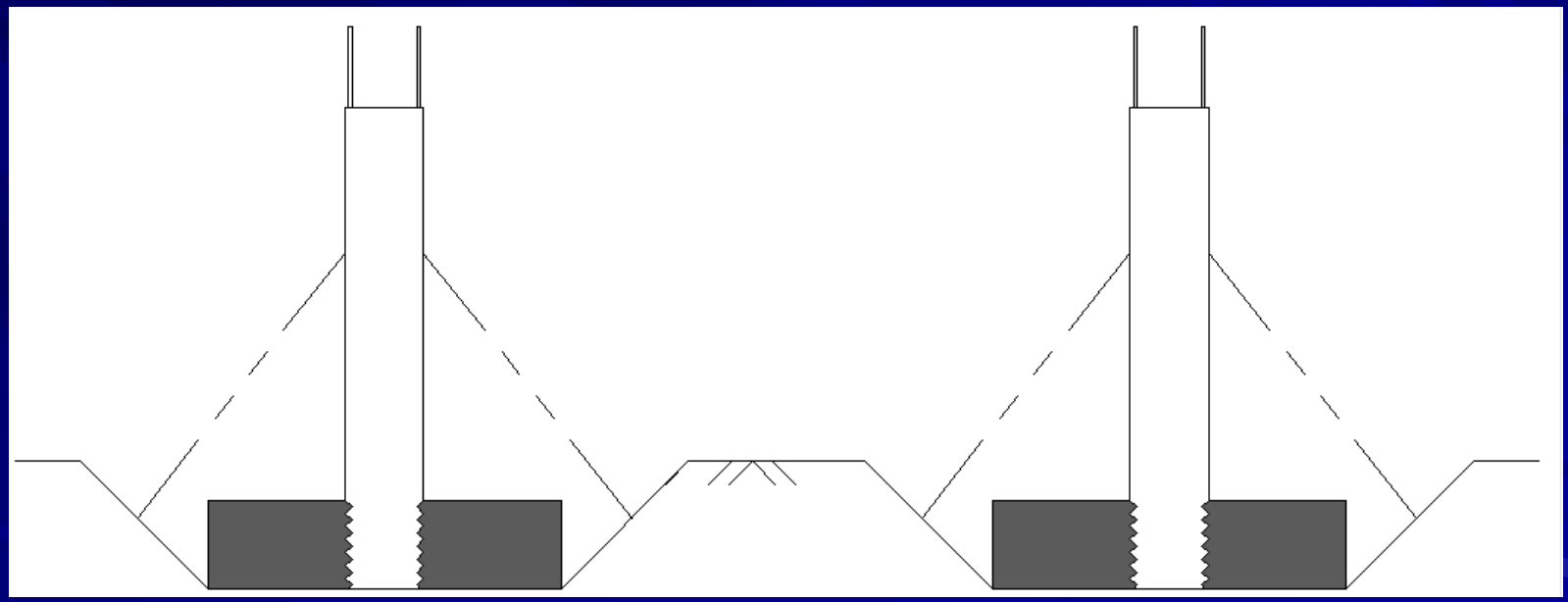
1) Excavate footing.

Construction Procedure



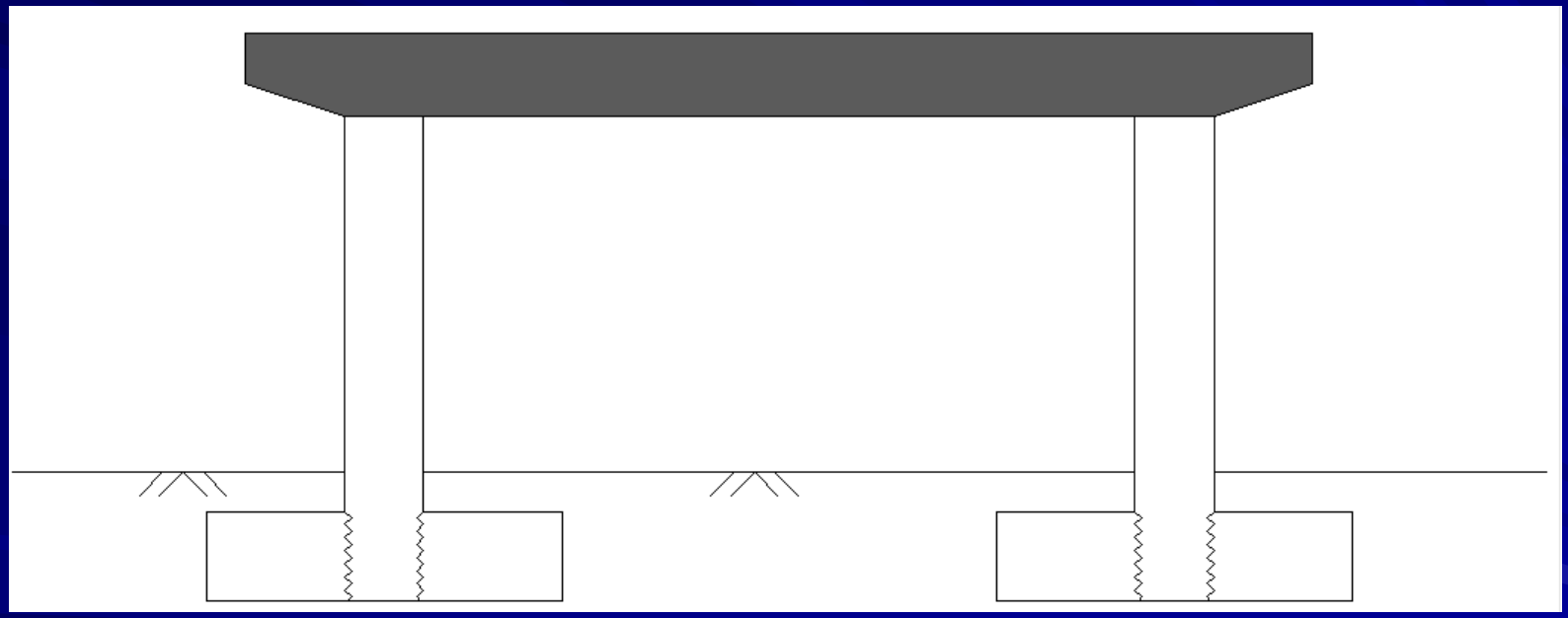
2) Position and brace precast column.

Construction Procedure



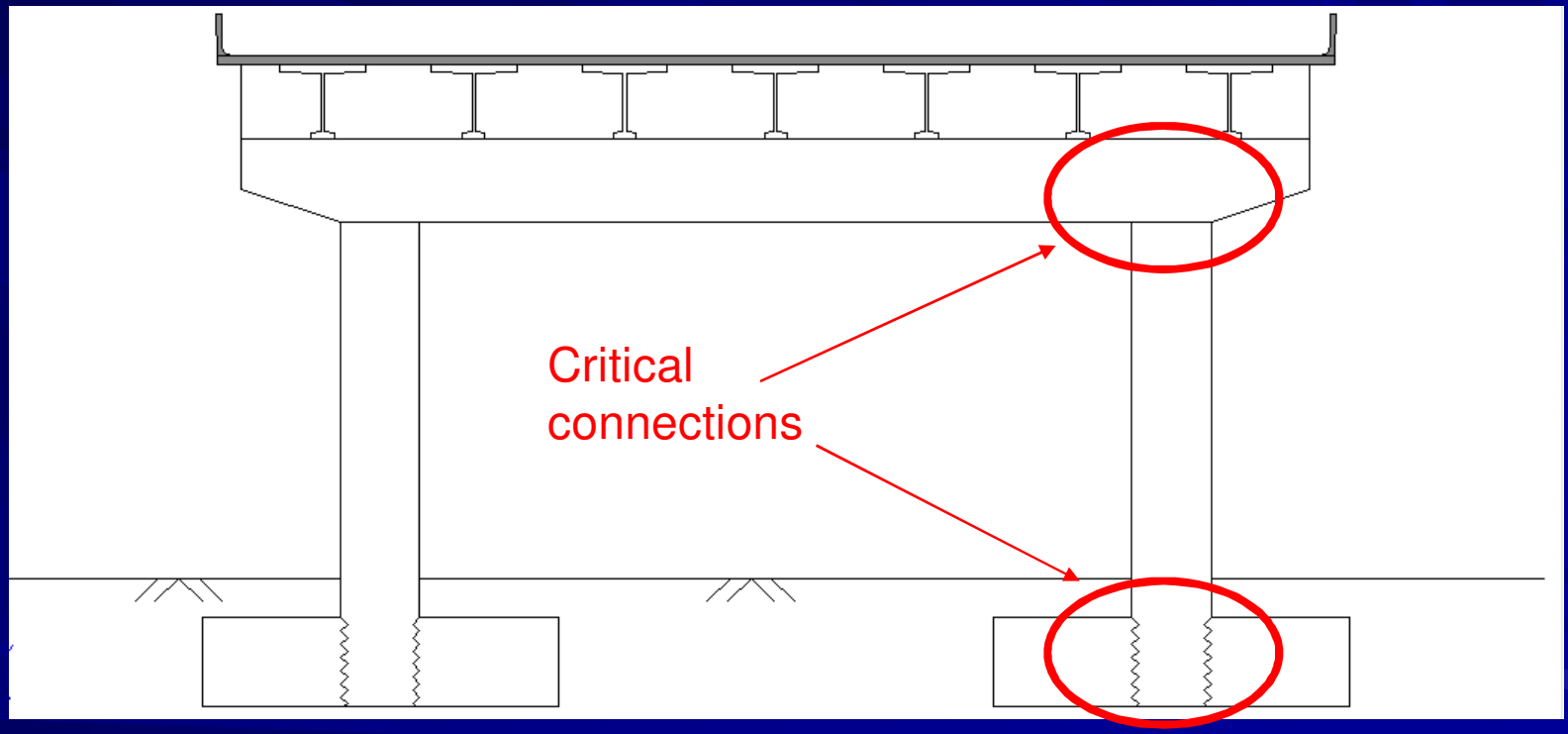
3) Place reinforcement and cast footing.

Construction Procedure



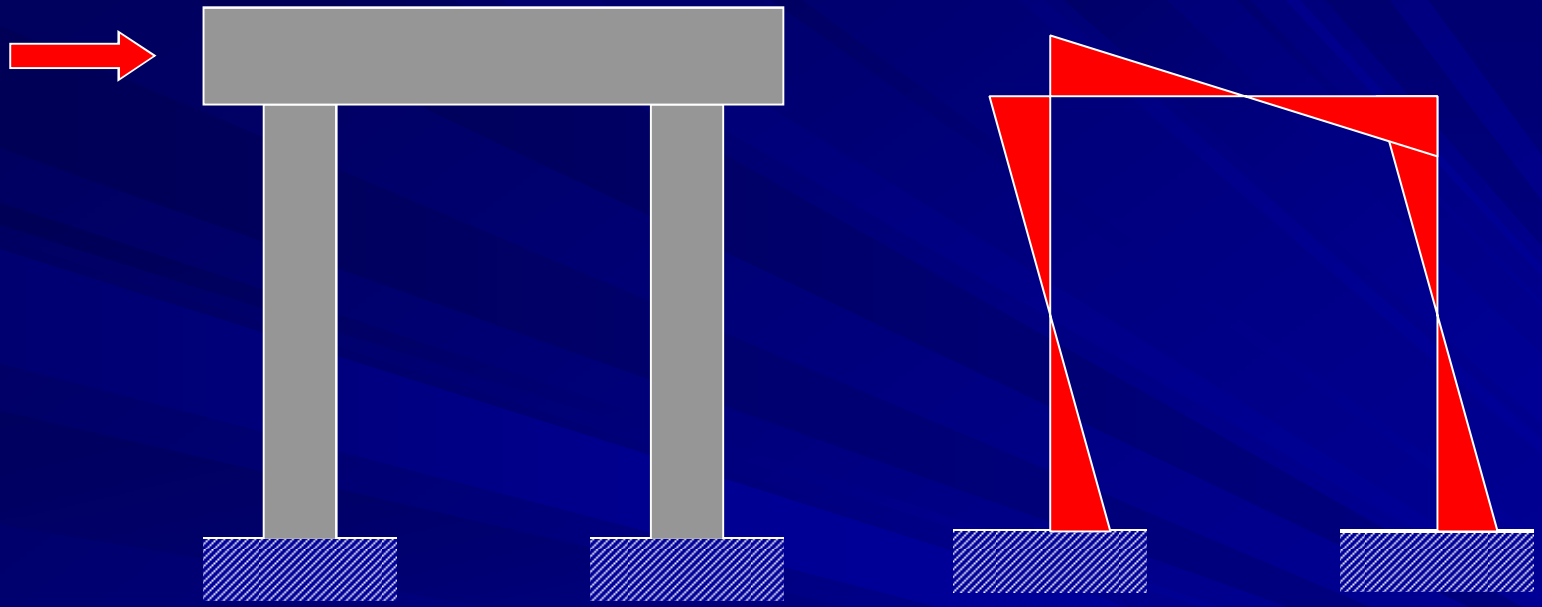
4) Set cap-beam, grout bars into ducts.

Construction Procedure



5) Place girders, diaphragms and deck.

Application in Seismic Zones



Fabrication/Transportation: make straight elements.

Site connections: then occur at member intersections.

But: that is where potential plastic hinges occur.

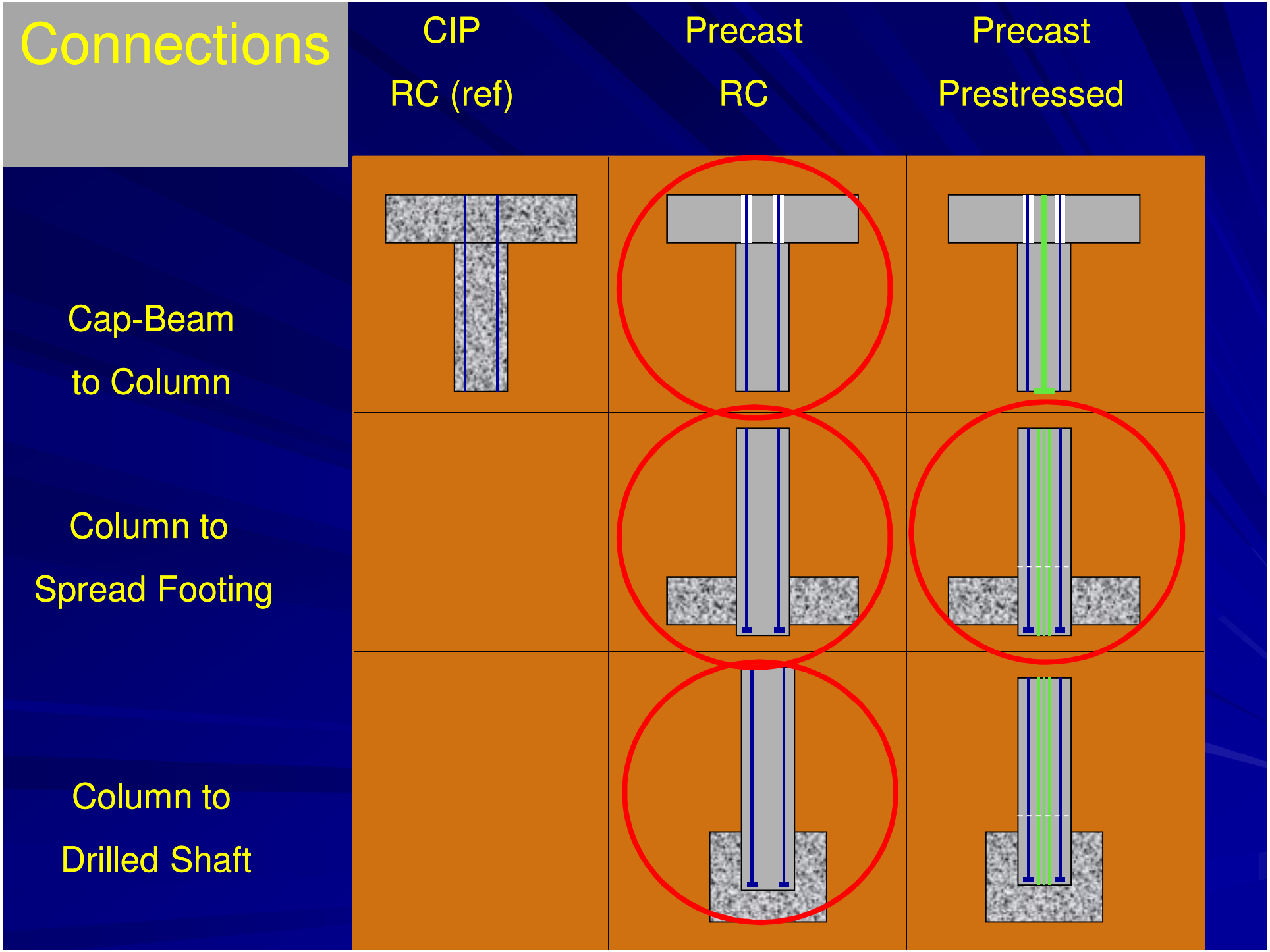
Family of modular connections

Mix and match connections to make a complete system.

Choice depends on:

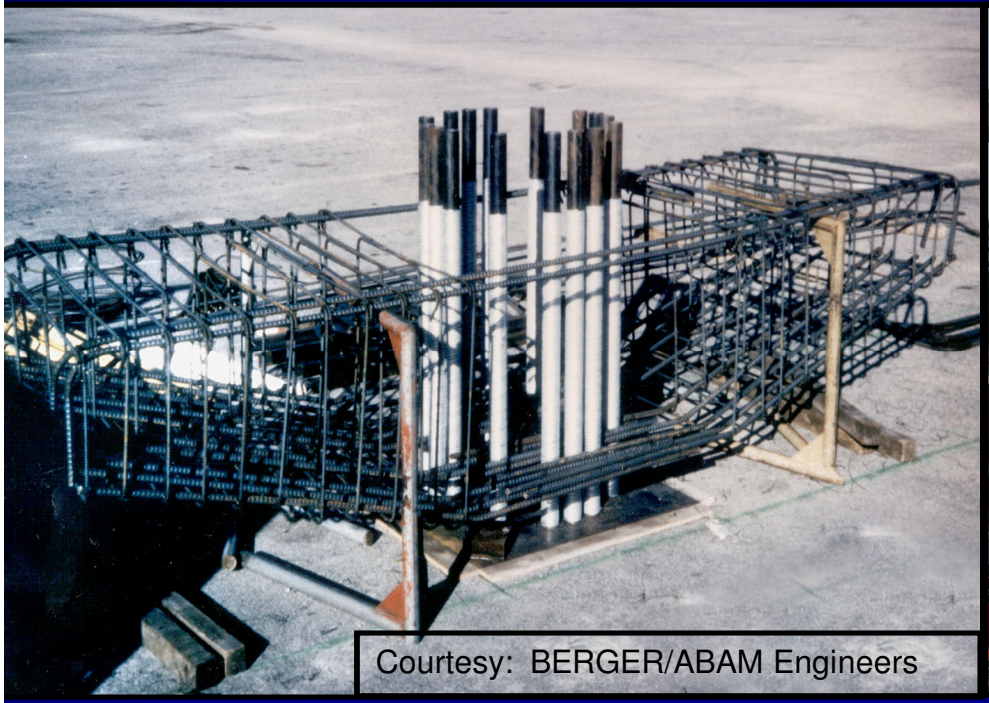
- Different conditions at top and bottom of column.
- Footing type: Spread footing vs. drilled shaft.
- Need for elastic re-centering after an earthquake.

Connections



Column-to-Cap-Beam Connection

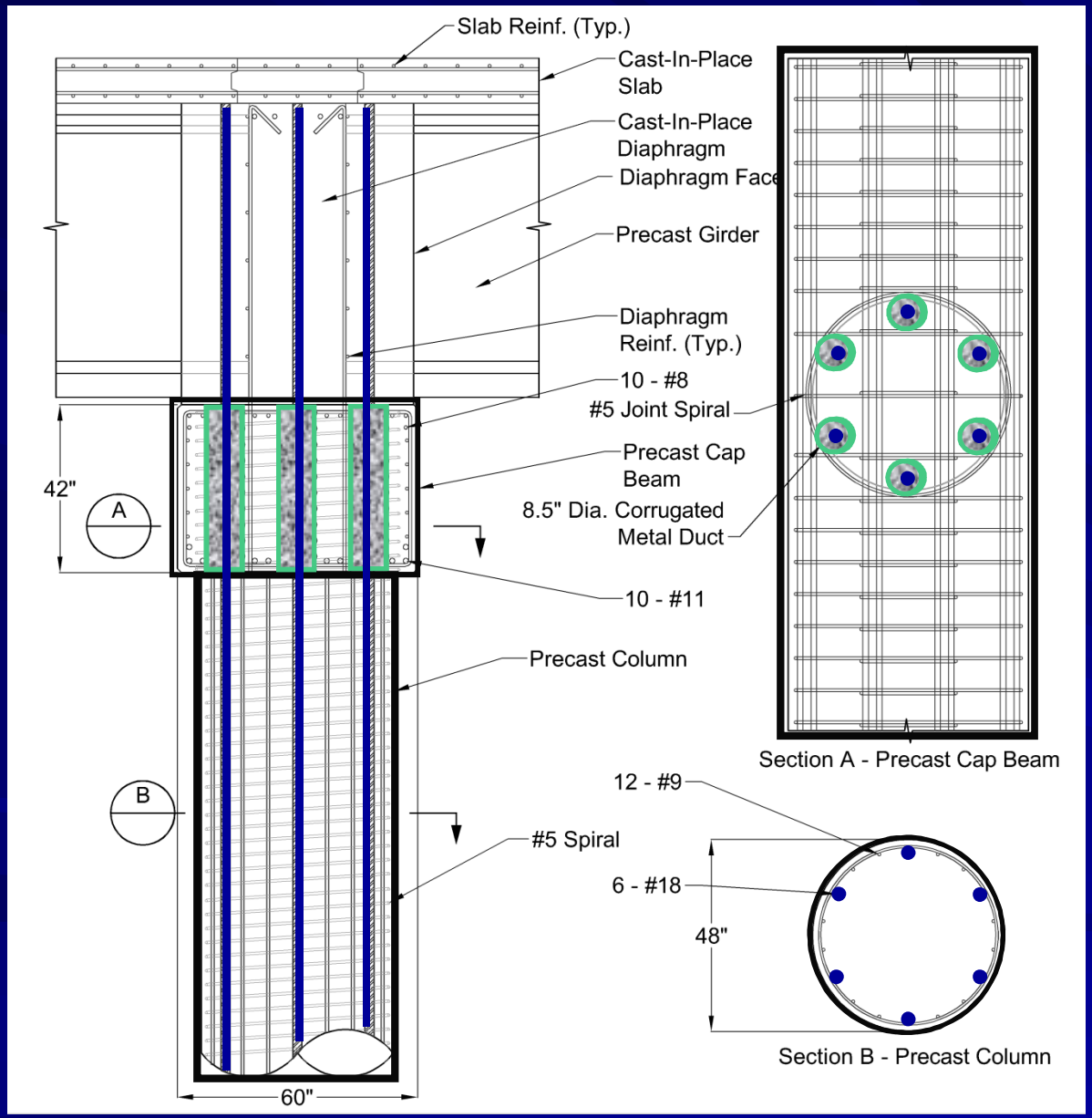
Cap Beam Connection:
Many small bars and ducts



Courtesy: BERGER/ABAM Engineers

Tight tolerances.

Cap-Beam Connection: Large bars



- Precast column
- Precast cap beam
- 6 # 18 rebar
- 8.5” corrugated steel ducts
- High strength grout

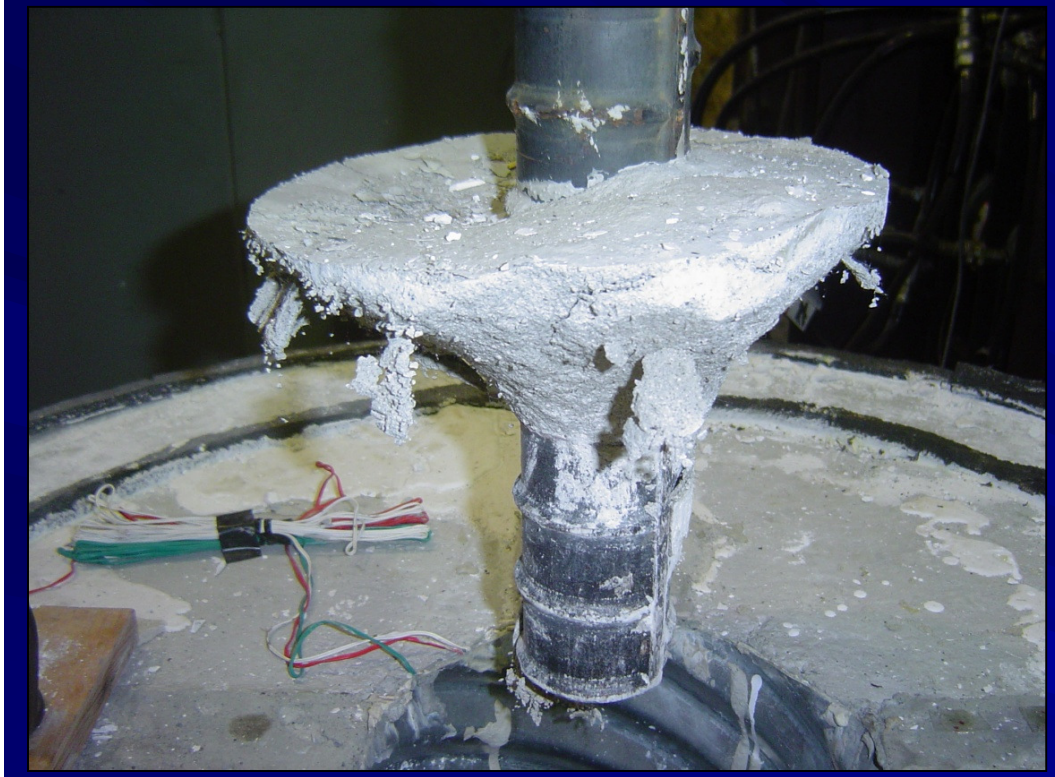
Key Research Questions

- Can #18 bars be anchored in the cap-beam for construction and seismic loads?
- How will the system perform seismically?

Question 1 – Anchorage ?

Full-Scale Anchorage Tests

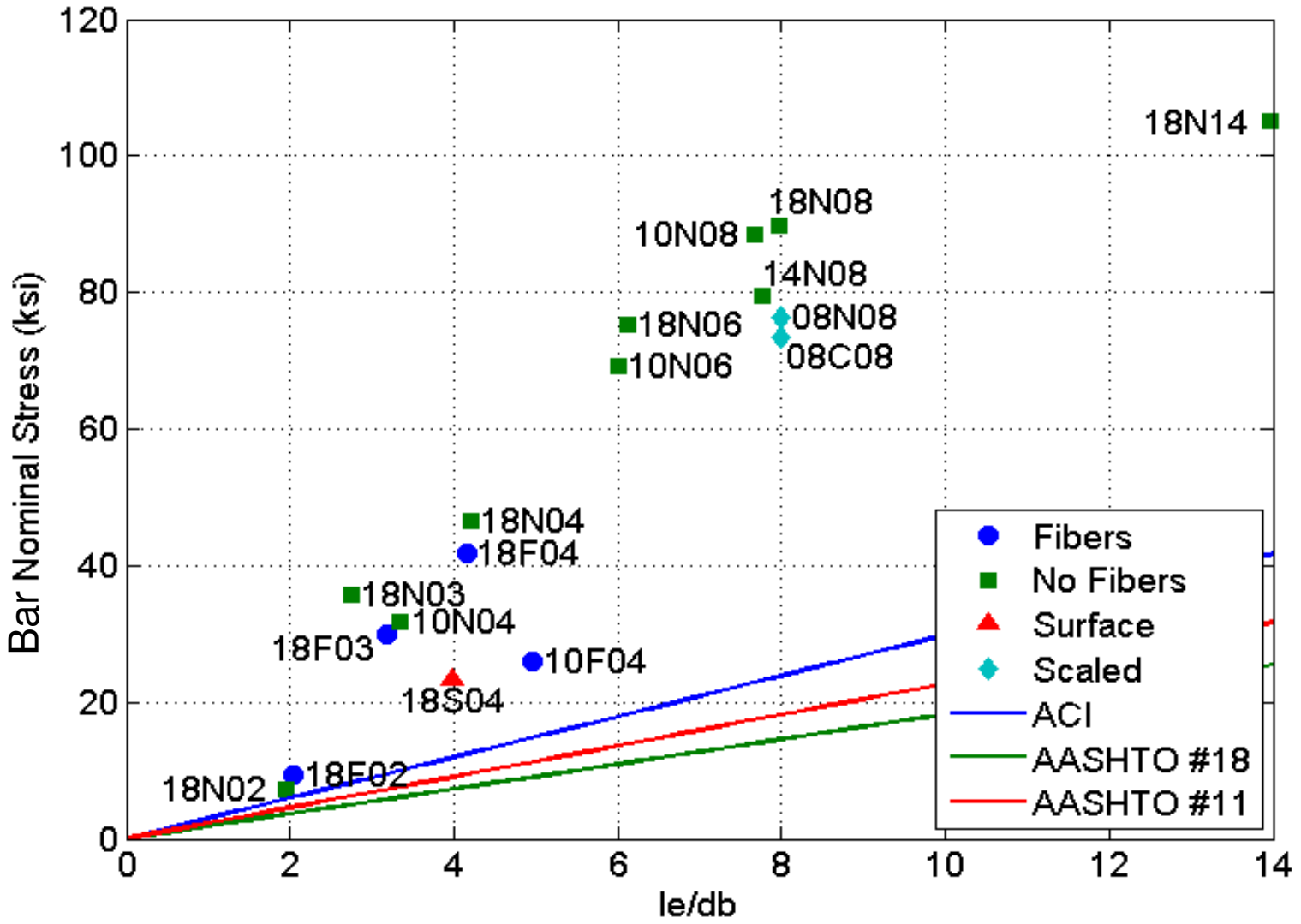
Long embedment – bar yields and fractures



Short embedment – bond fails

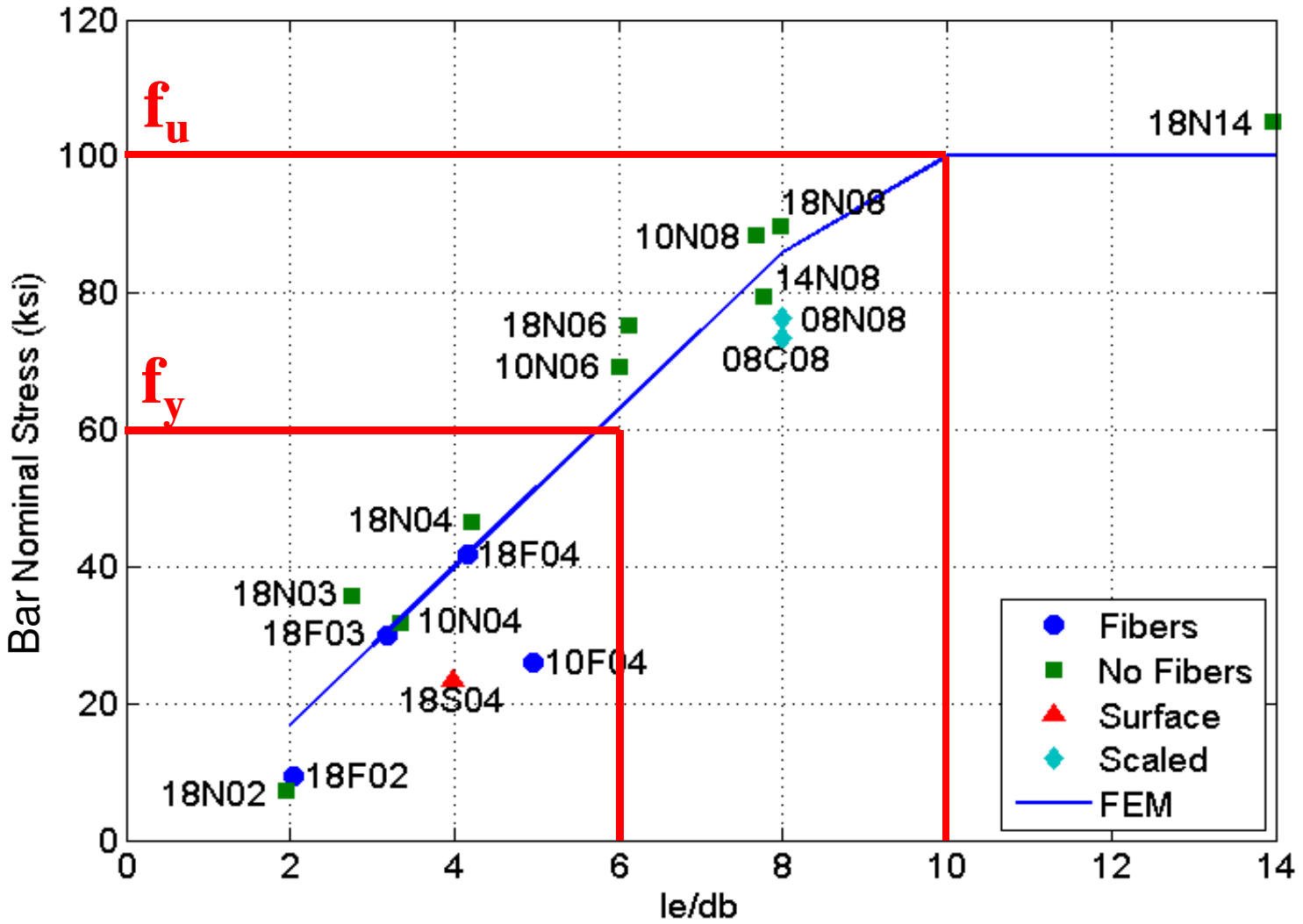
Full-Scale Anchorage Tests

Tests results vs. ACI/AASHTO requirements



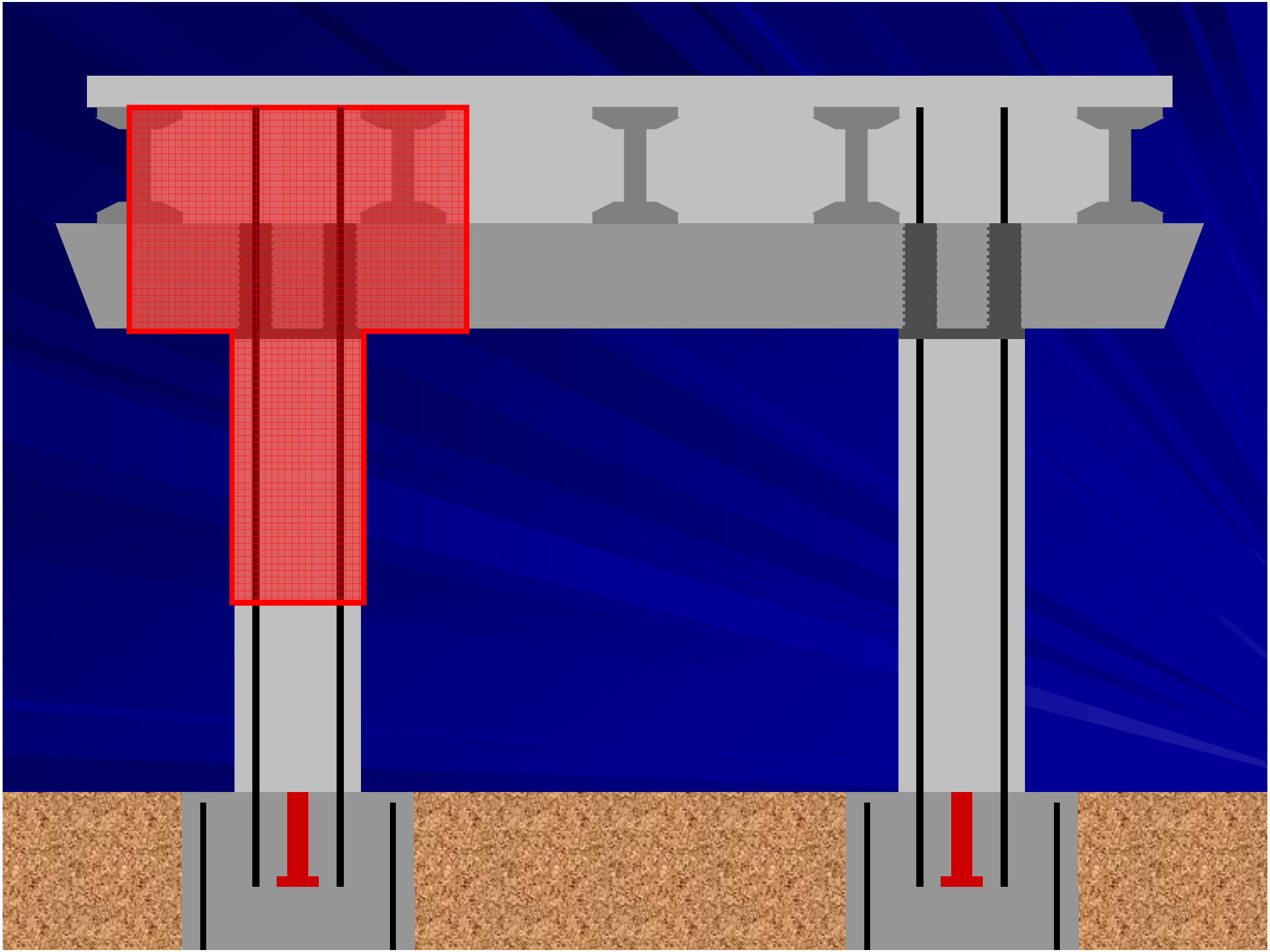
Full-Scale Anchorage Tests

Tests results vs. FE model

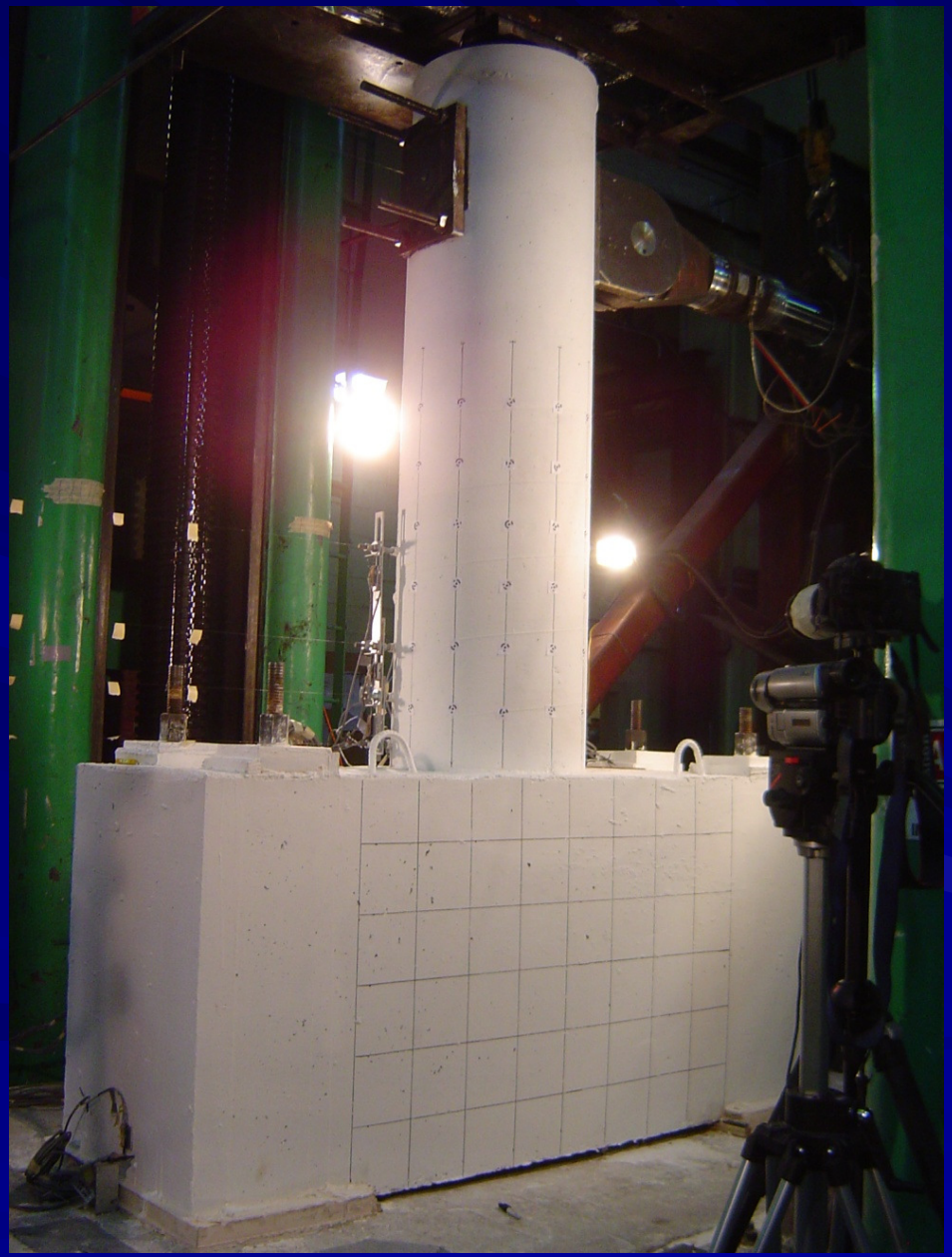


Question 2

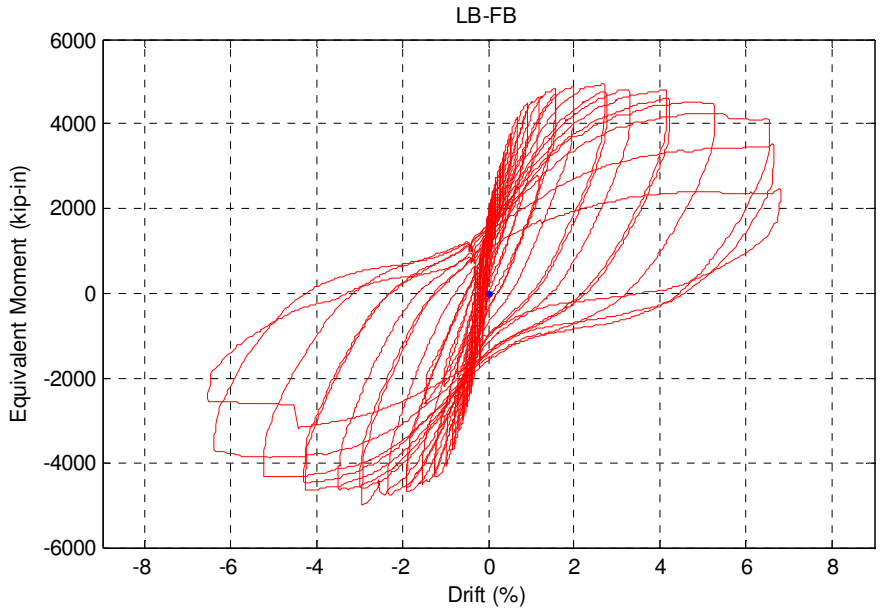
Seismic Performance?

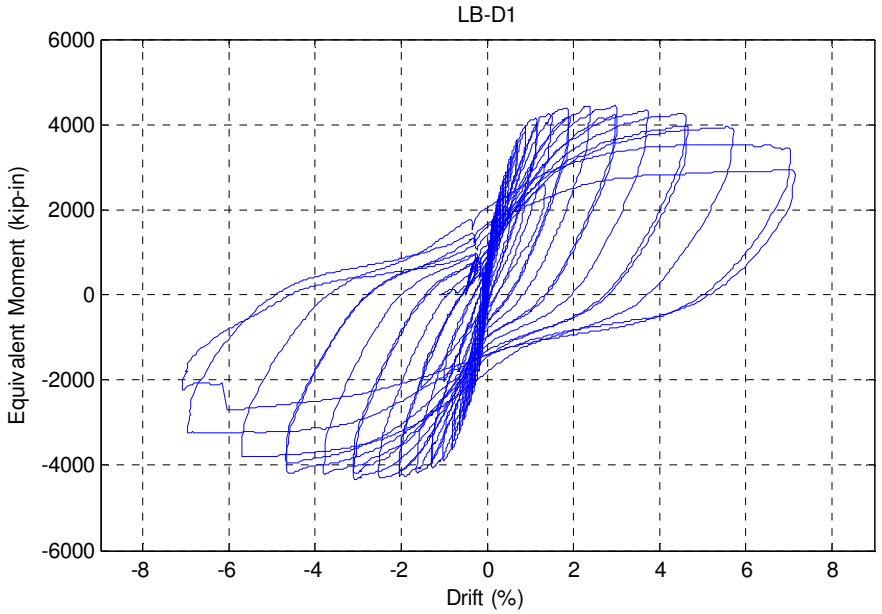


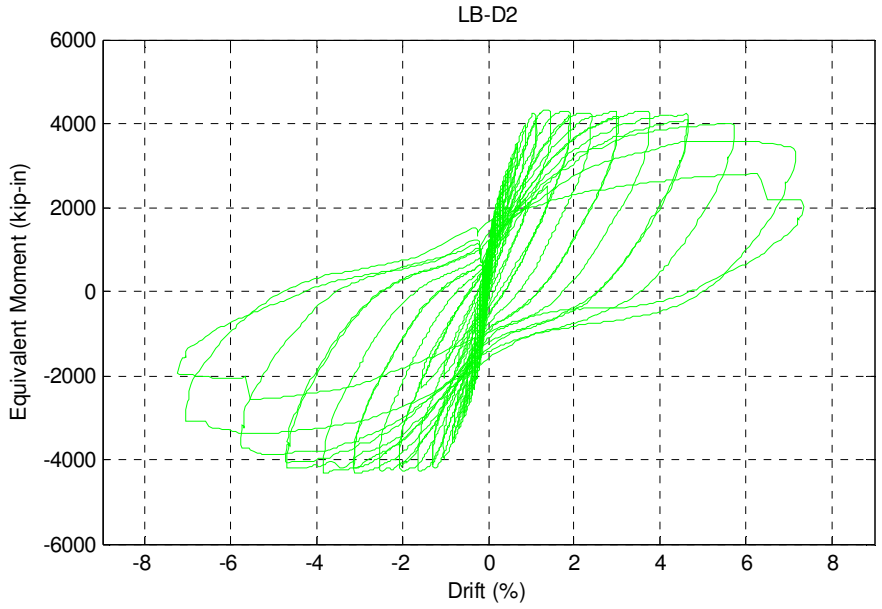
Seismic Performance

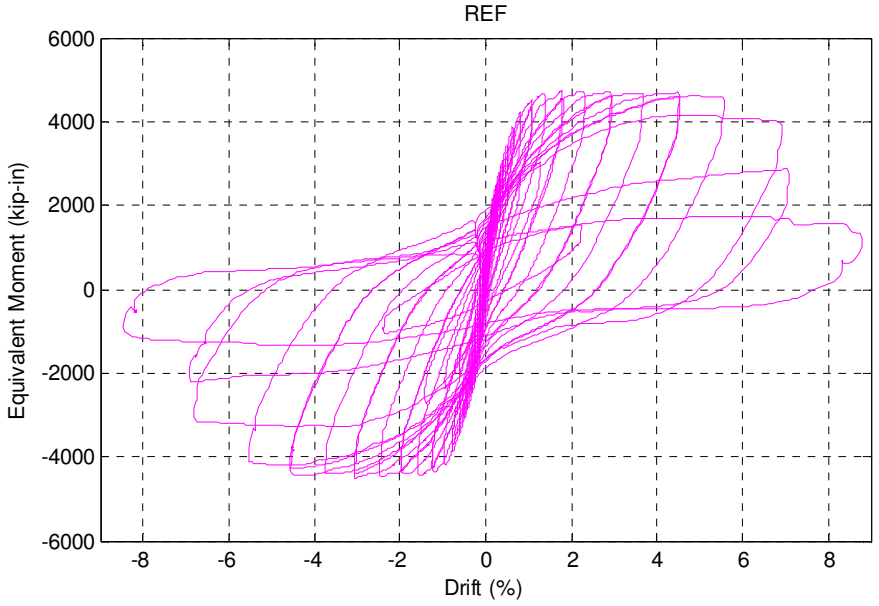


Equivalent Moment vs. Drift

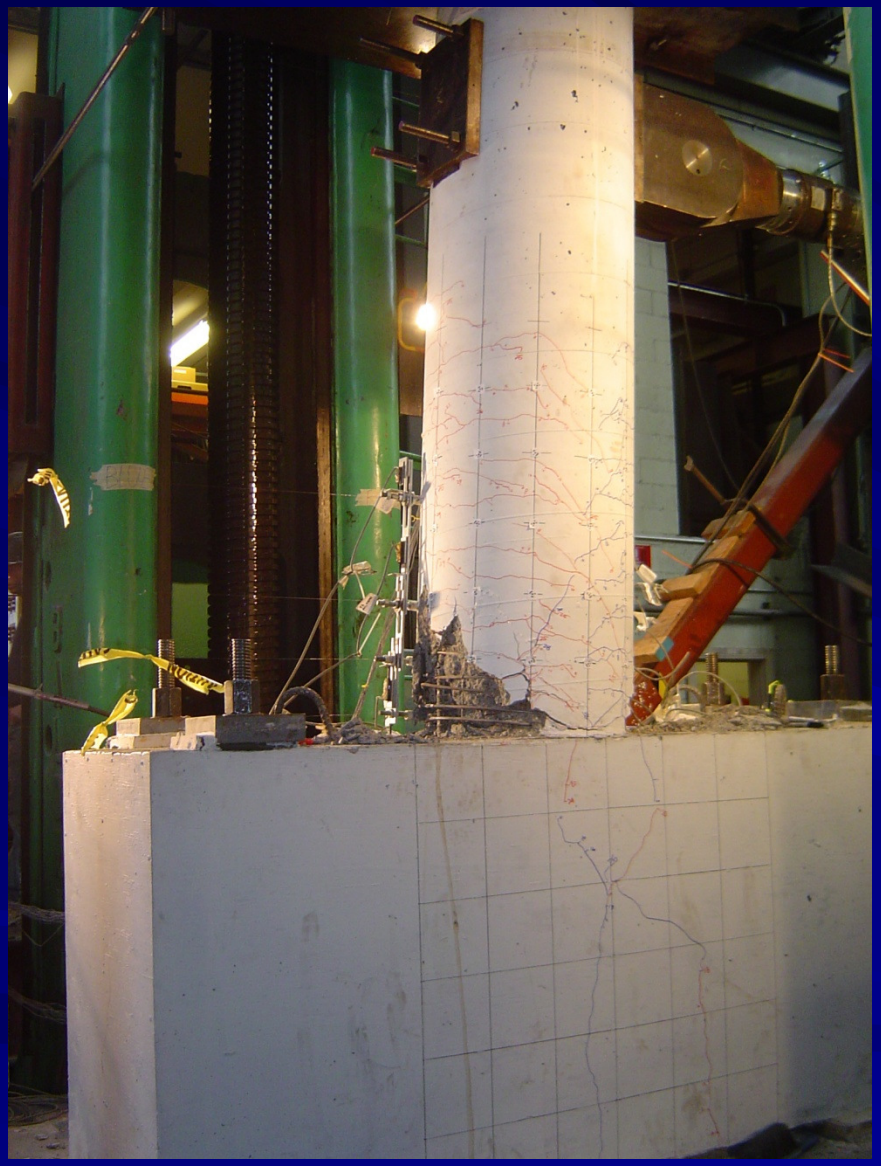






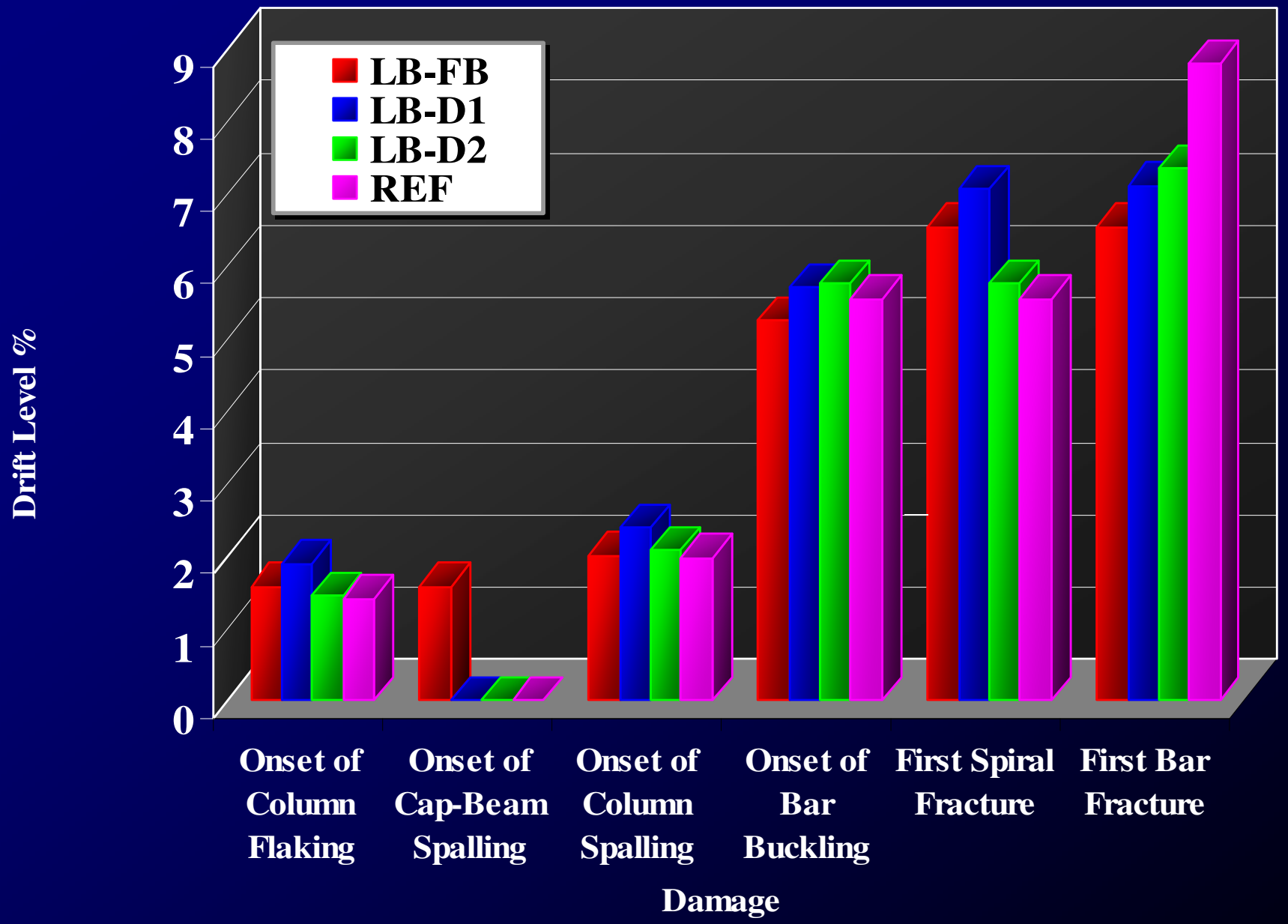


Failure Mechanisms



LB-FB: Bar buckling and spiral fracture at 6.5% drift

Observed Damage



Conclusions: Cap-Beam Connection

Constructability:

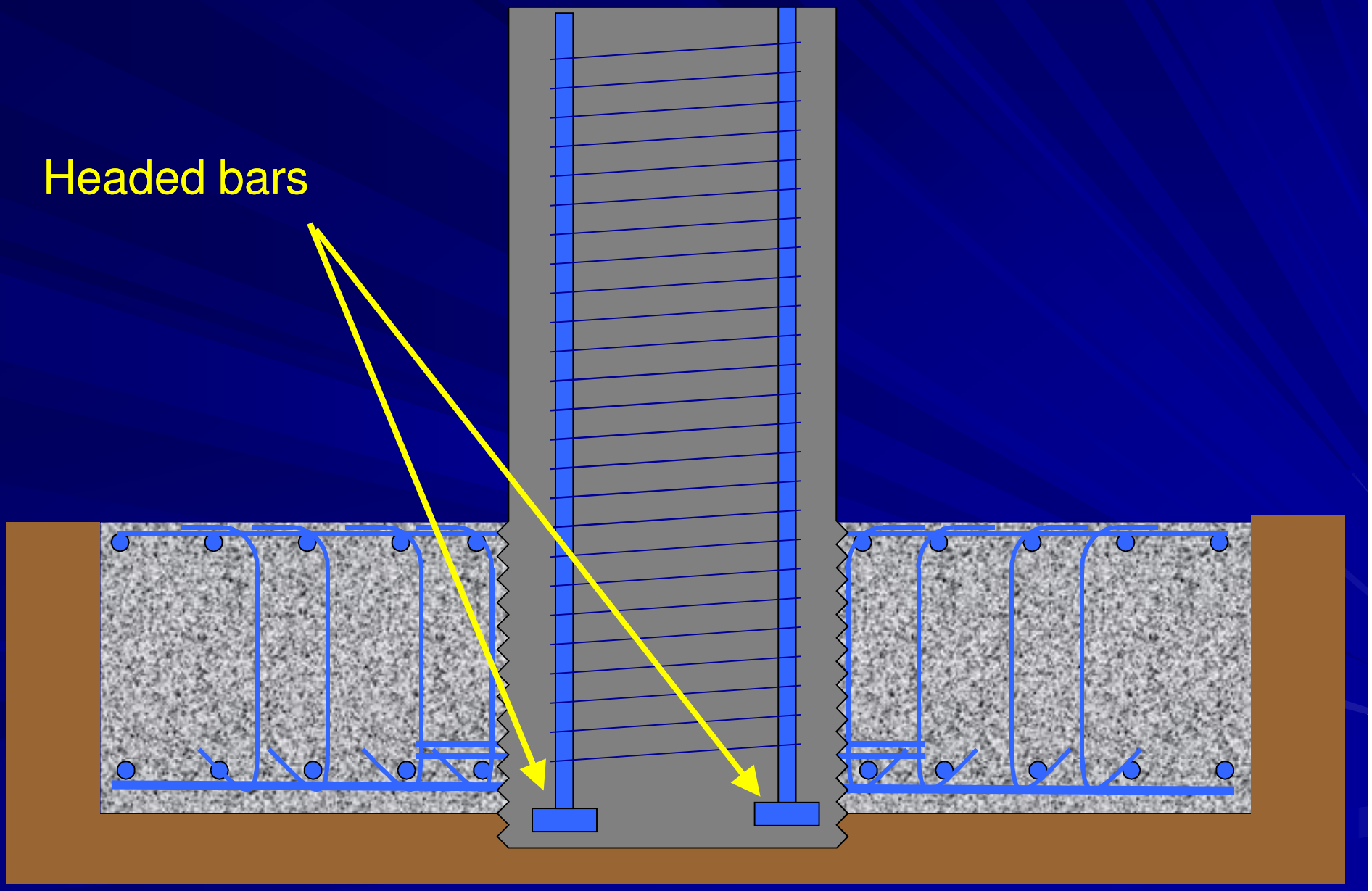
- Construction is fast and easy.
- Potential time savings from avoiding:
  - Cap beam formwork, steel, concrete curing.

Seismic Performance:

- Failure occurs in column, not connection.
- Seismic response is same as c.i.p.

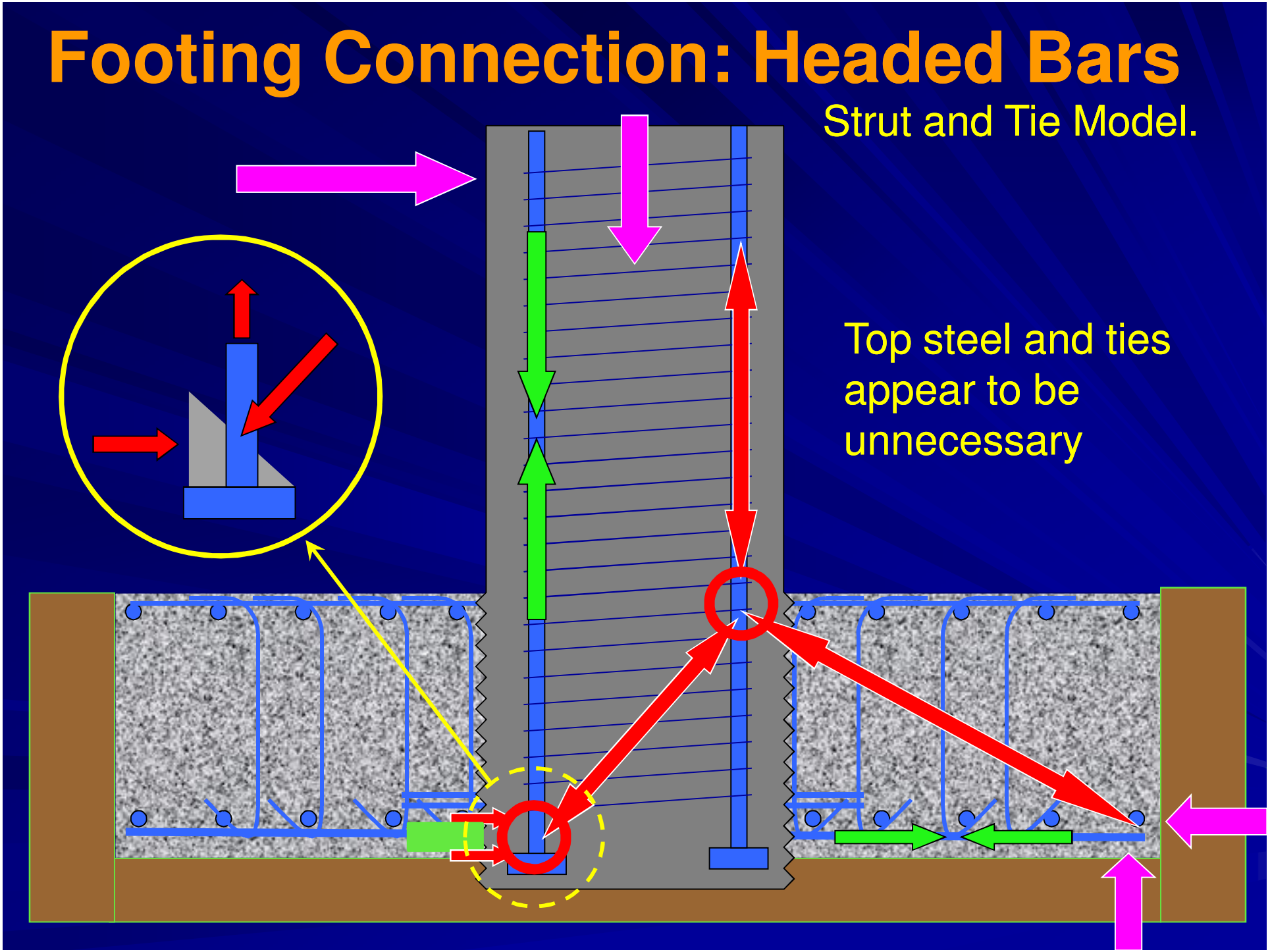
Column-to-Footing Connection

Footing Connection: Construction



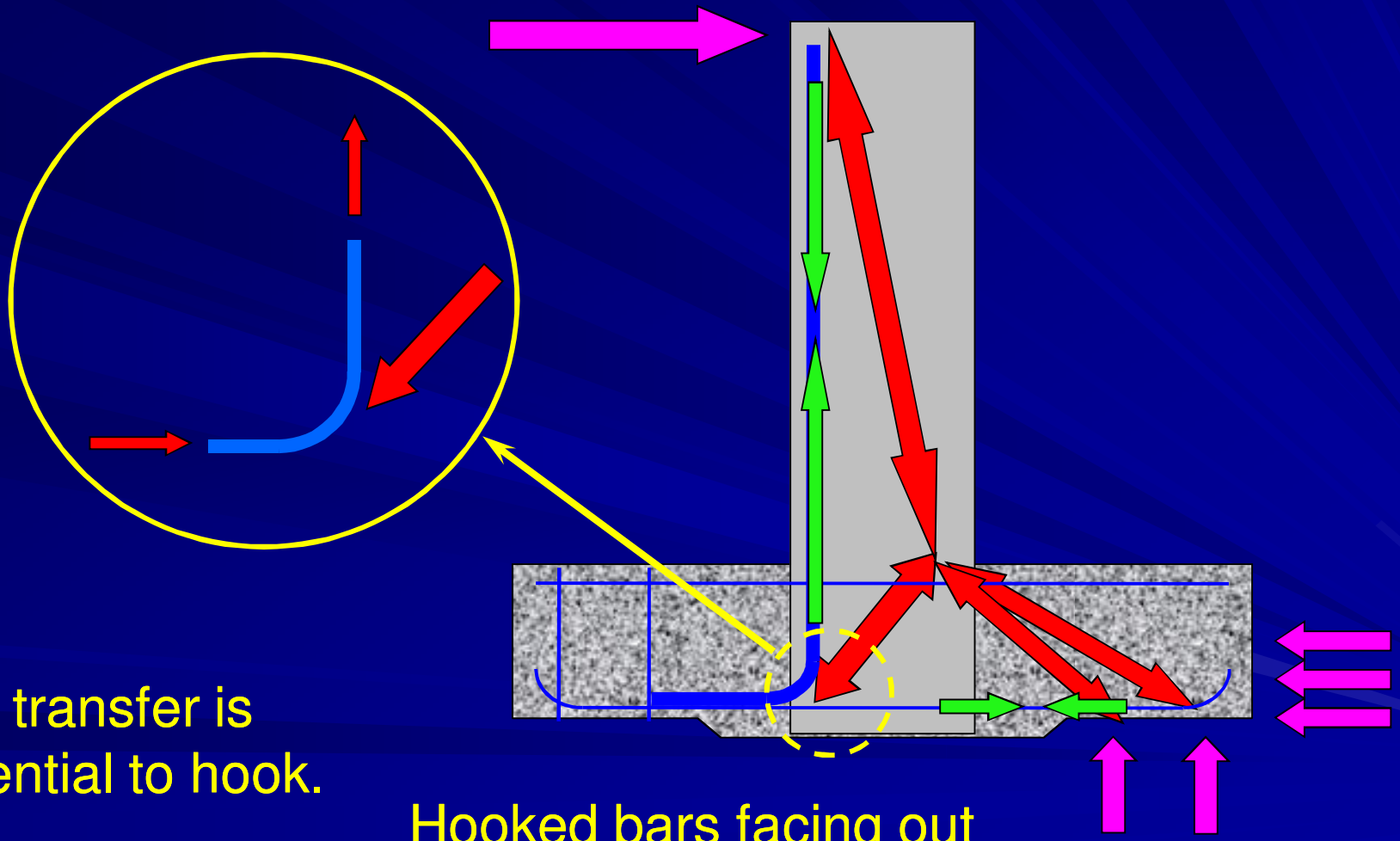
Footing Connection: Headed Bars

Strut and Tie Model.



Footing Connection - Conventional

Strut and Tie Model.



Load transfer is tangential to hook.

Ineffective!

Hooked bars facing out (Conventional cip)

Spread Footing Connection - Tests:

Specimen #1

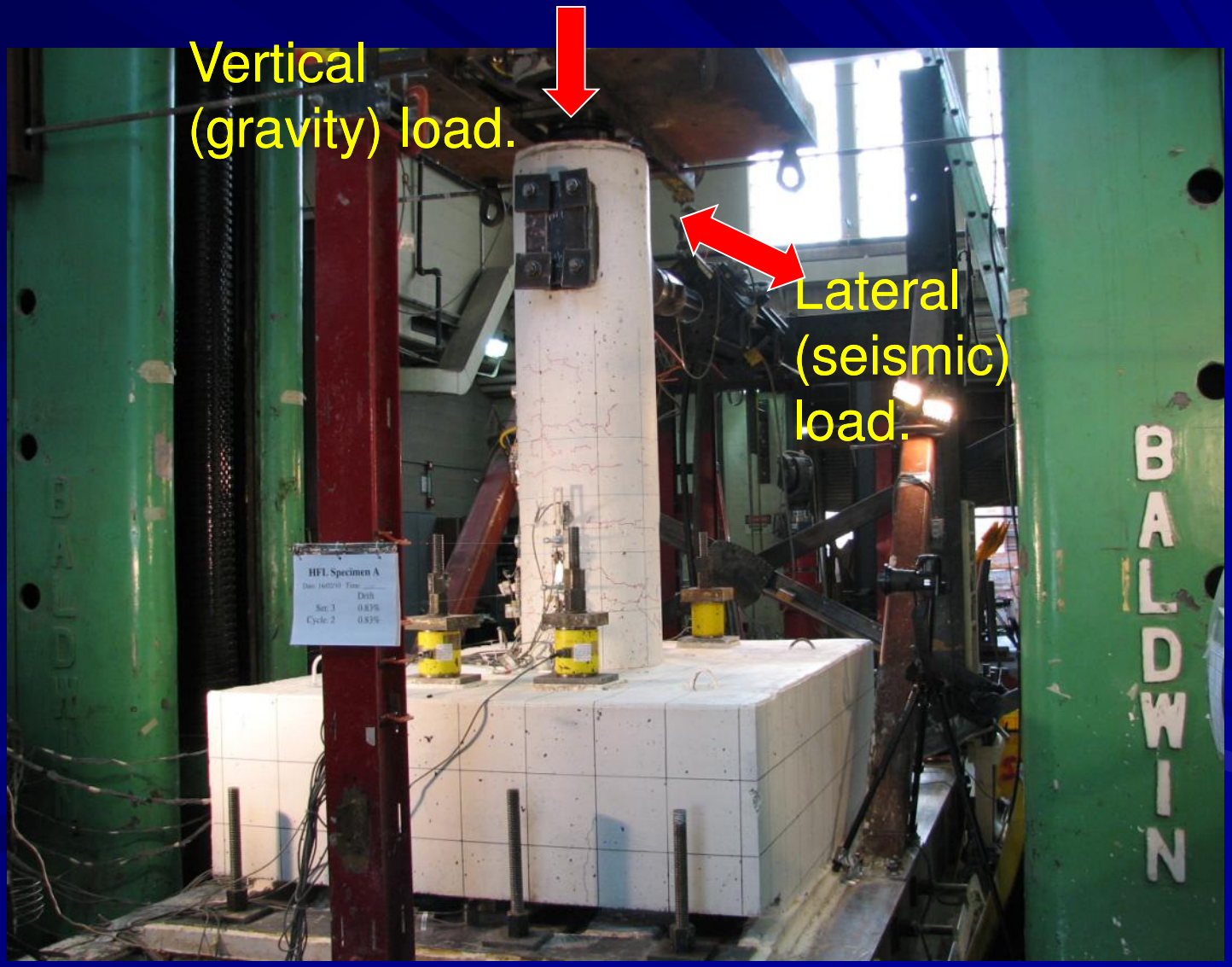
- Use footing steel identical to that required for cast-in-place.
- Verify vertical punching shear
- Verify cyclic lateral load resistance.

Specimen #2

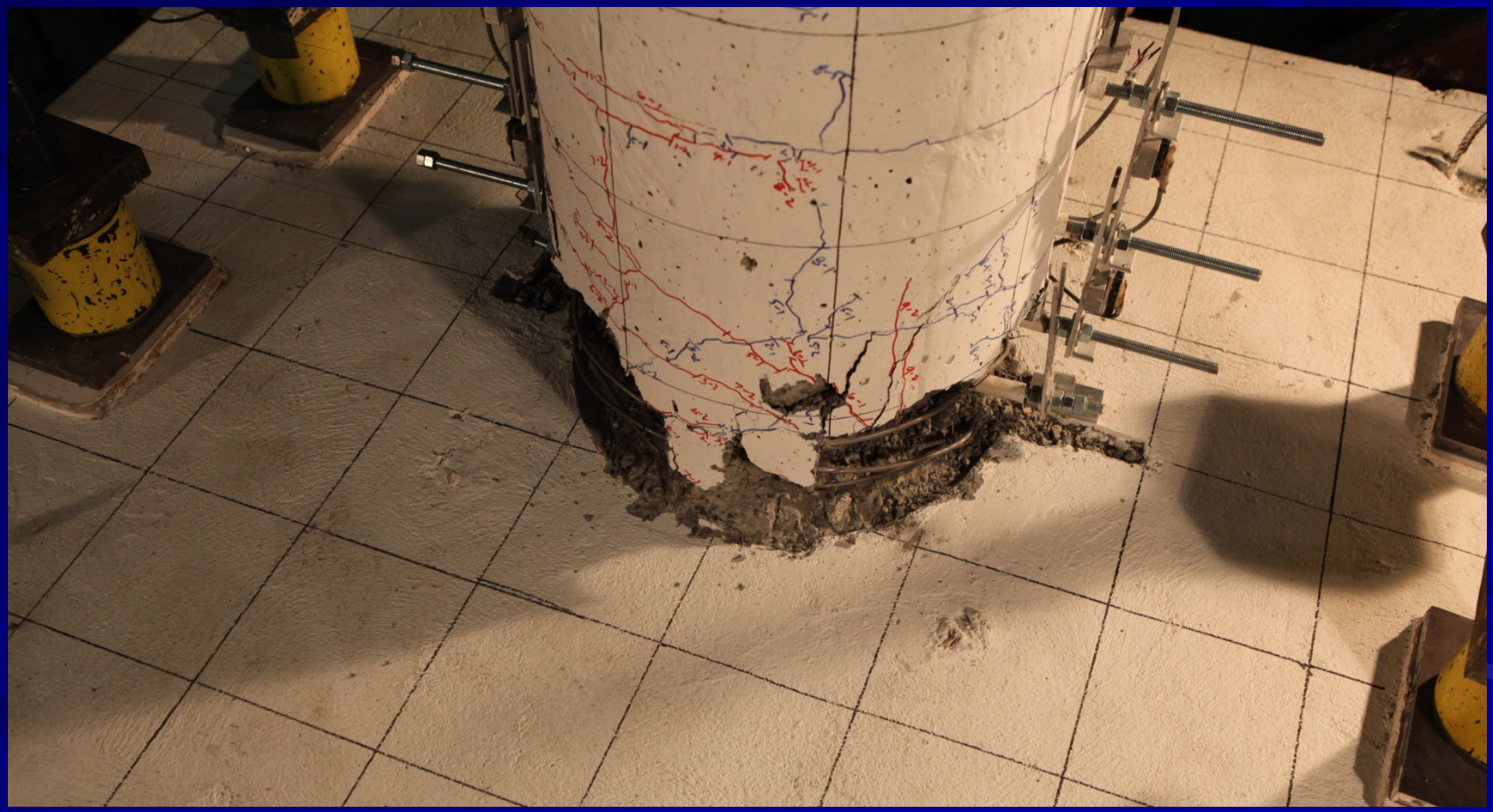
- Reduce tie steel and “shear friction” steel in footing.

Spread Footing Connection: Construction

Spread Footing Connection - Test

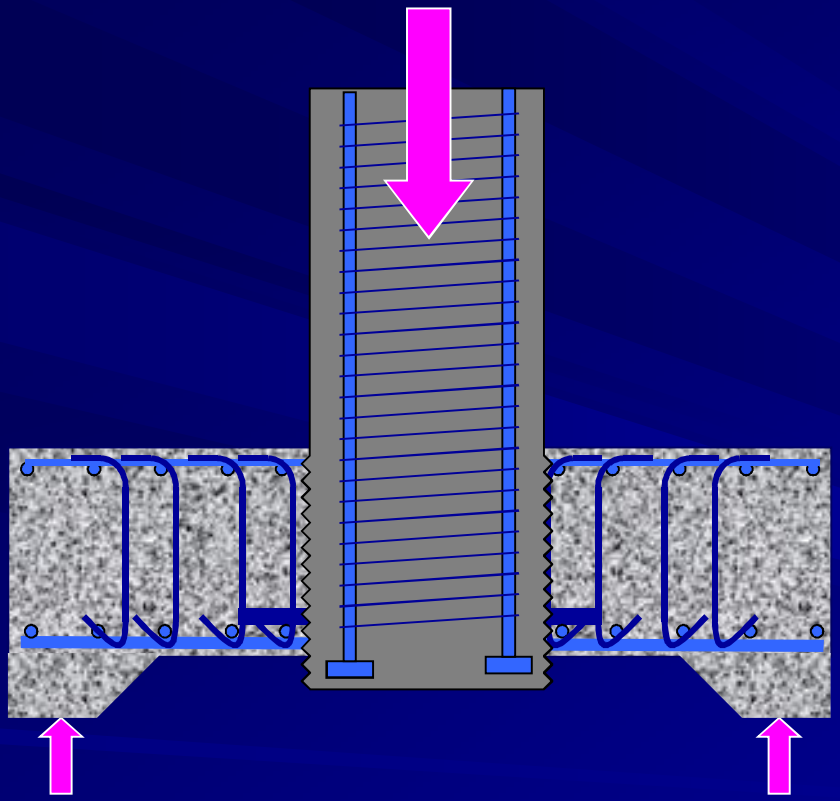


Spread Footing Connection - Test



After seismic testing. Foundation undamaged.

Spread Footing Connection: Gravity Load Test



Column crushed at load = 3.5 * (1.25DL + 1.75LL).

No damage to footing. No sign of punching failure.

Spread Footing Connection: Specimen 2 (reduced steel)

Results essentially identical

to those for Specimen #1.

Spread Footing Connection

Constructability: Easy to fabricate, transport and erect

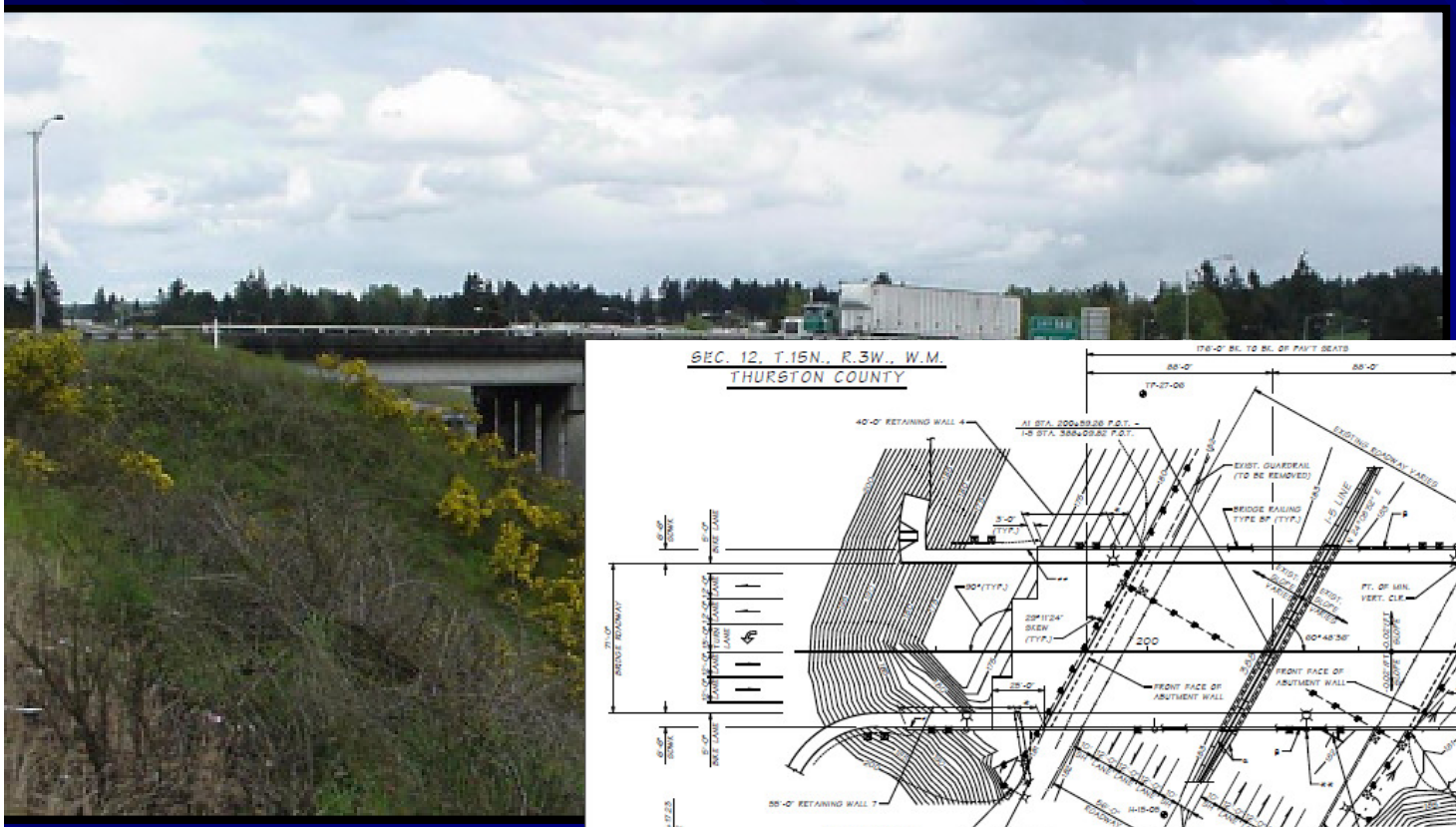
- Column has no projecting bars.
- No “form-saver” bars.
- No connection alignment.
- Reduce or eliminate footing ties & top steel.

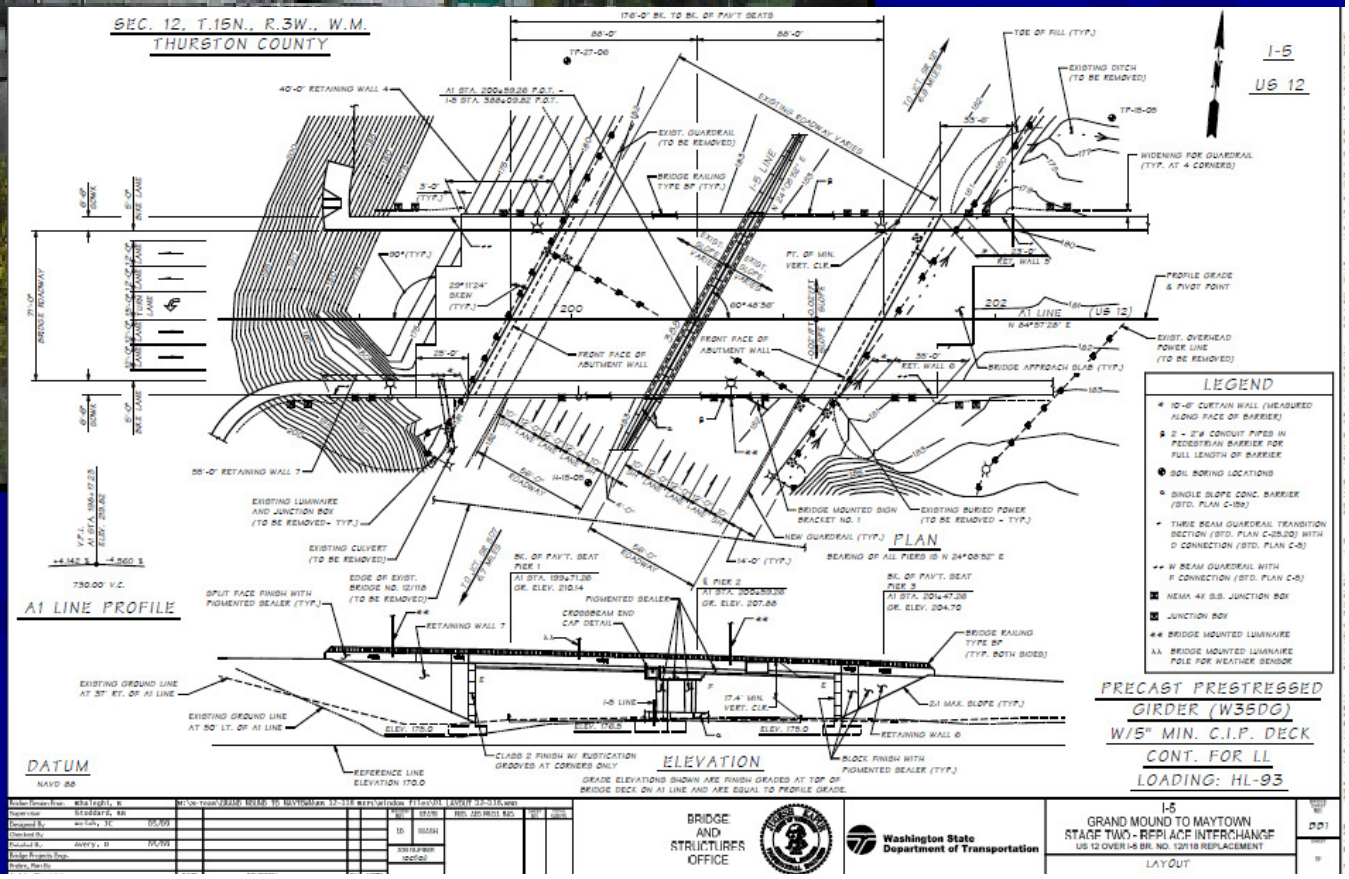
Spread Footing Connection

Structural Performance:

- Headed bars provide better anchorage than hooked bars facing outwards.
- Failure in column. Footing undamaged in lateral load and vertical load tests.
- Seismic performance as good as, or better than, conventional c.i.p. construction.

Implementation

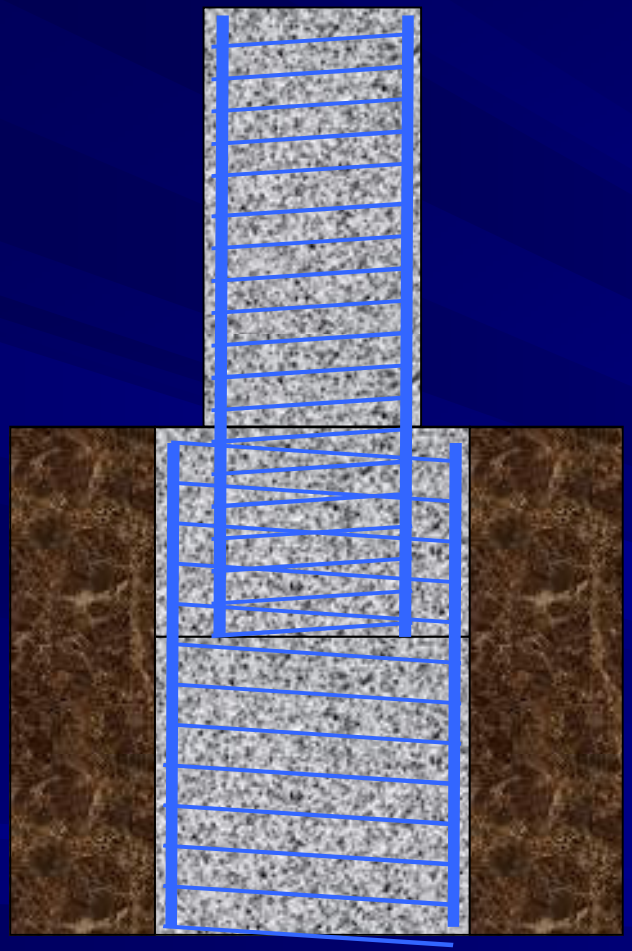




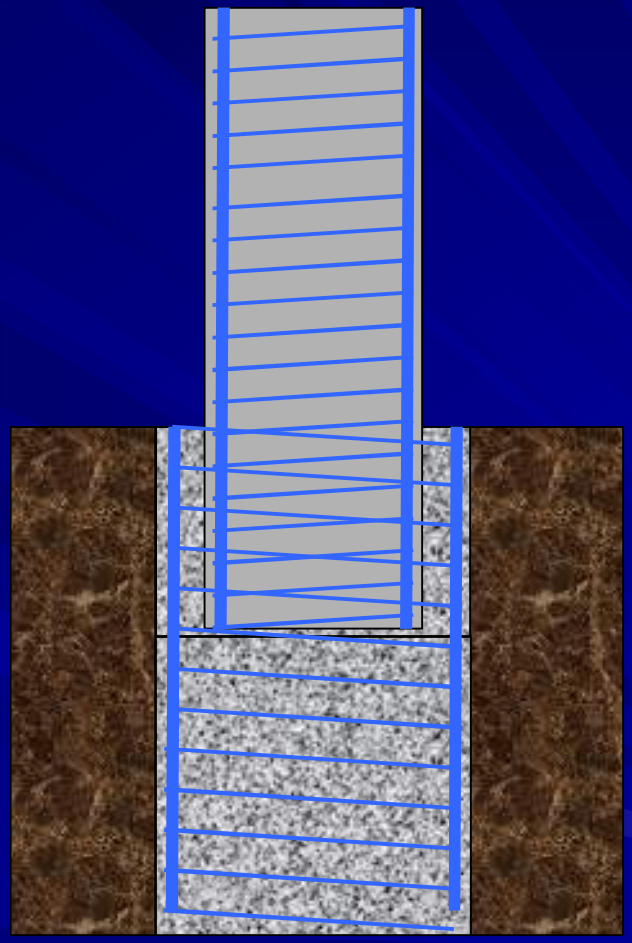
Bid Opening:

October 14th

Drilled shaft connection



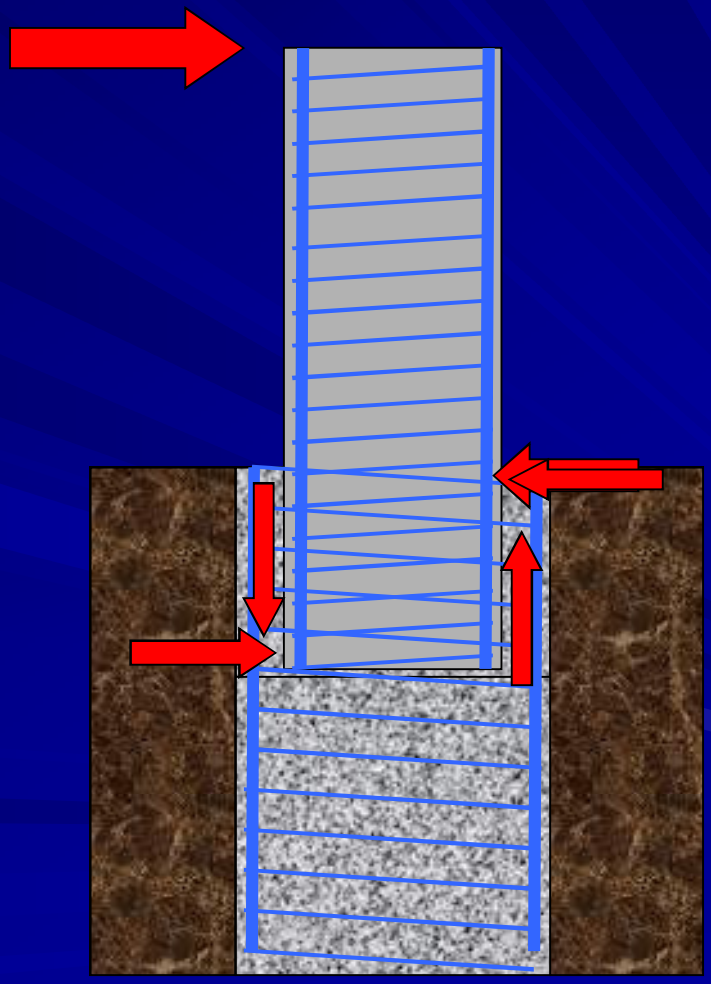
Cast-in-place



Precast

Drilled shaft connection

Moment transfer in transition region

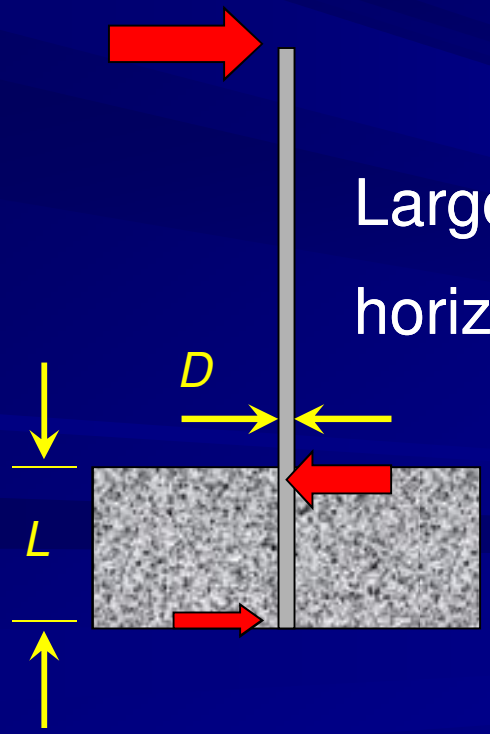


- Horizontal force couple
- Vertical force couple
- Big shear on annular region.
- Large forces in spiral
- Moment transfer by vertical bars.
- Low forces in spiral

Drilled shaft connection

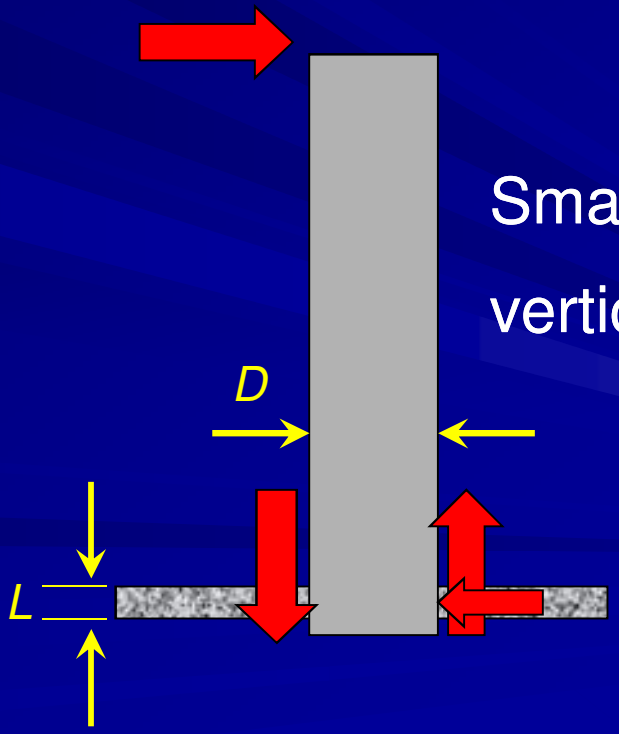
Horizontal or Vertical force couple?

- Probably depends on L/D ratio of transition region.



Large L/D –

horizontal forces



Small L/D –

vertical forces

Drilled shaft connection

Length of Transition region:

- Controlled by vertical bar development.

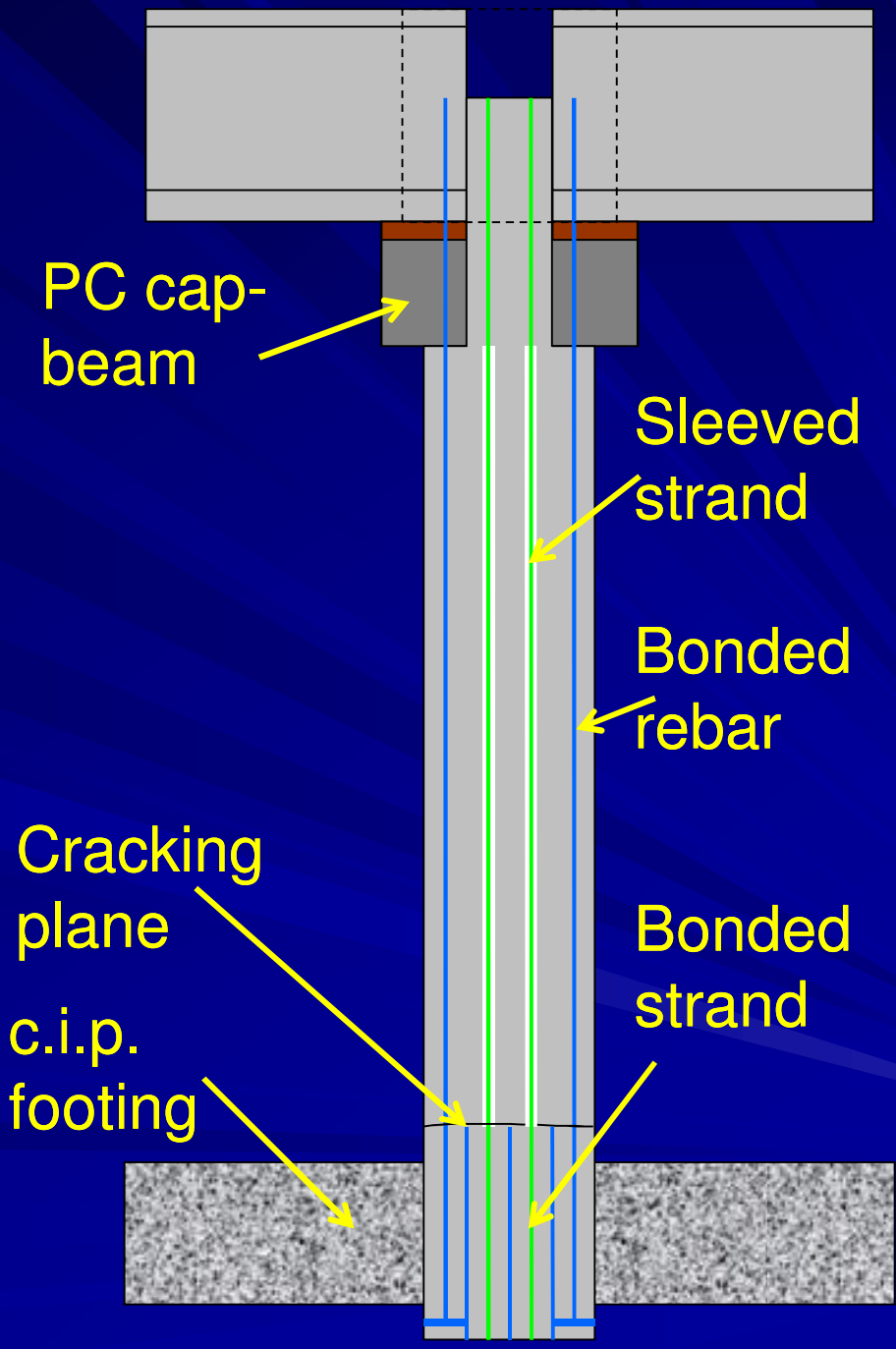
Study variable: Strength of spiral in shaft.

- Specimen #1: same as c.i.p. shaft.
- Specimen #2: reduced spiral.

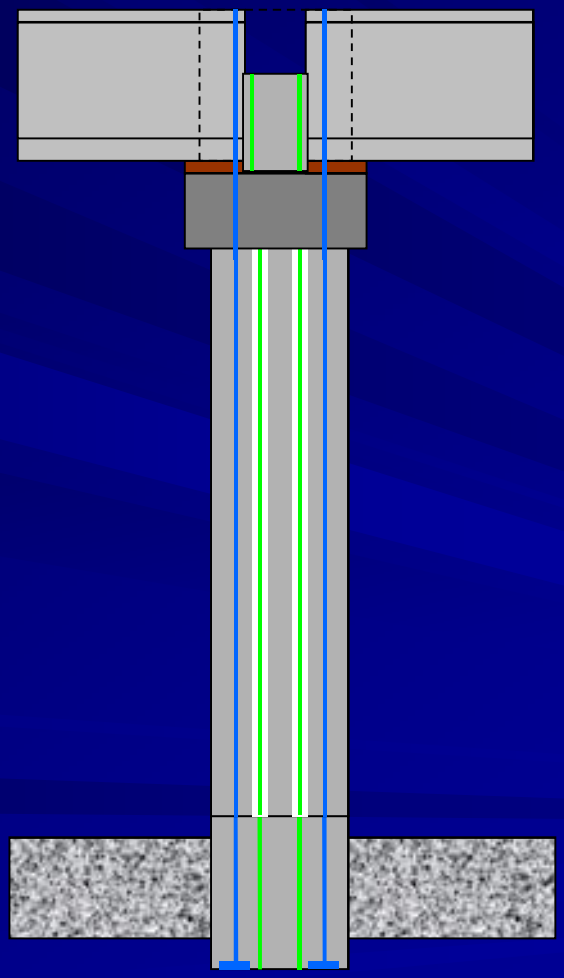
Specimens being built now

Pre-Tensioned System

Pre-Tensioned System - Components



Pre-Tensioned System



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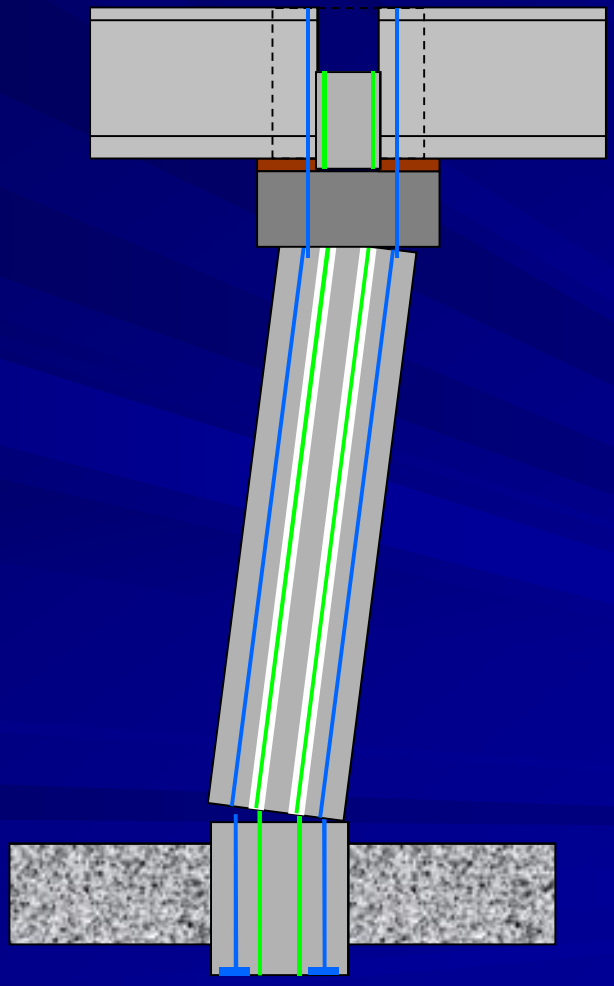

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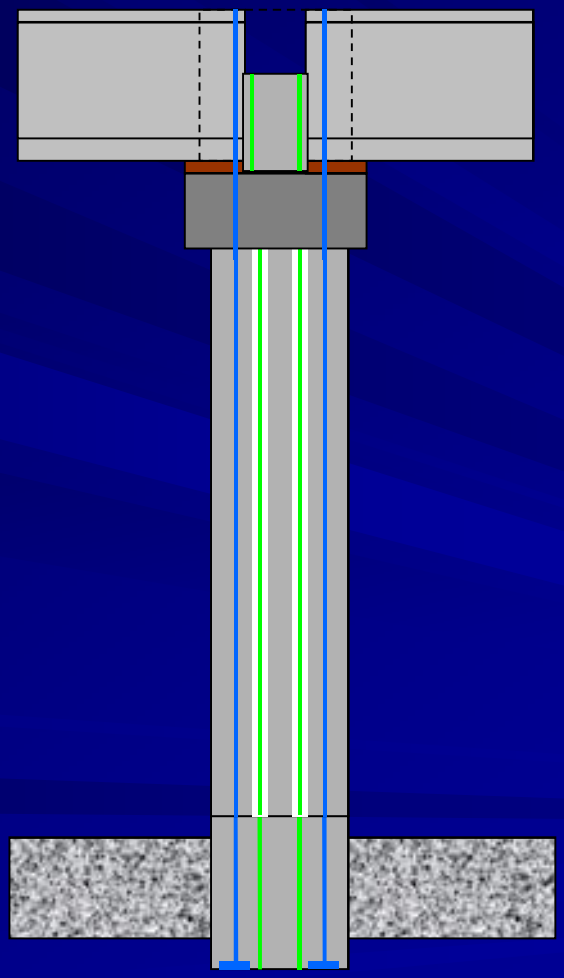

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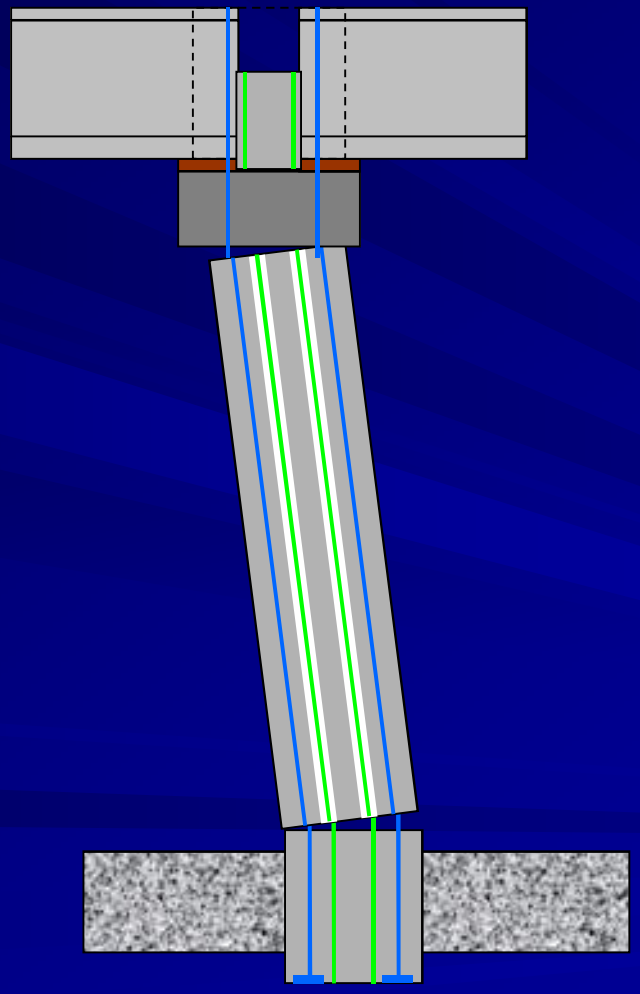

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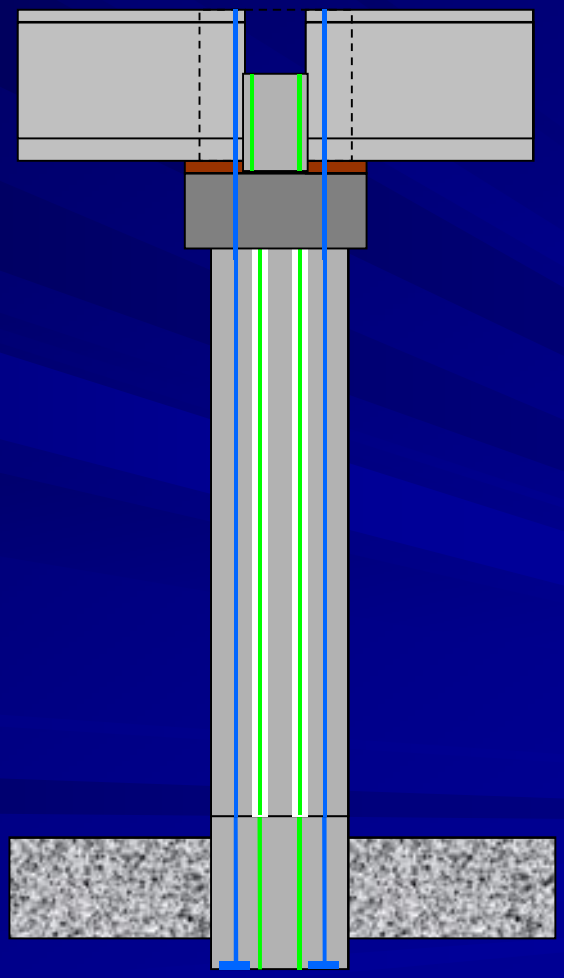

Pre-Tensioned System

1. Unbonded prestressing:
   - remains elastic,
   - re-centers column,
   - reduces residual displacements.
2. Pre-tensioning solves corrosion problems perceived to exist in post-tensioning.
3. Pre-tensioning in a plant:
   - Allows good QC
   - Eliminates need for special equipment on site (e.g. PT)
4. Rebars can be added for energy dissipation.

Acknowledgments

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- PEER

Ideas (and criticism) from

- Many, many people, but especially
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Thank You