Civil and Environmental Engineering Department

University of California, Berkeley, CA 94720

Self Compacted Hybrid Fiber Reinforced Concrete Composites for Bridge Columns

C.P. Ostertag and Marios Panagiotou
University of California, Berkeley
CEE Department

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Outline

I) Hybrid FRC (HyFRC) Concrete
(brief review)

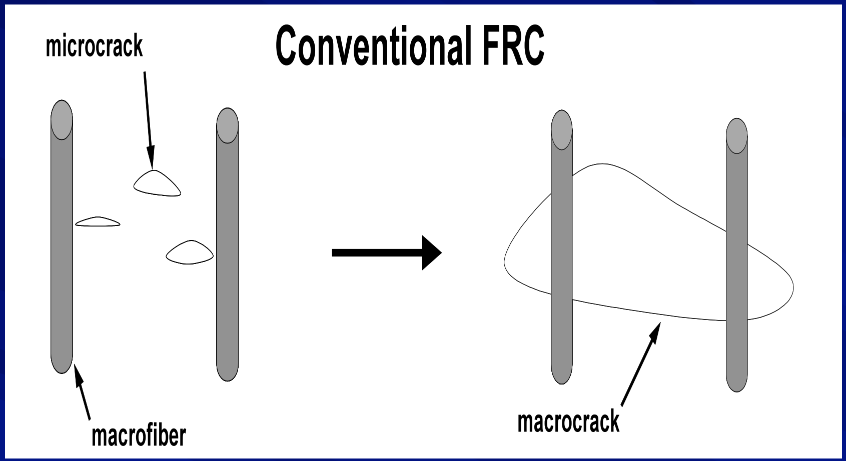
II) HyFRC vs Self-compacted (SCC) HyFRC Concrete

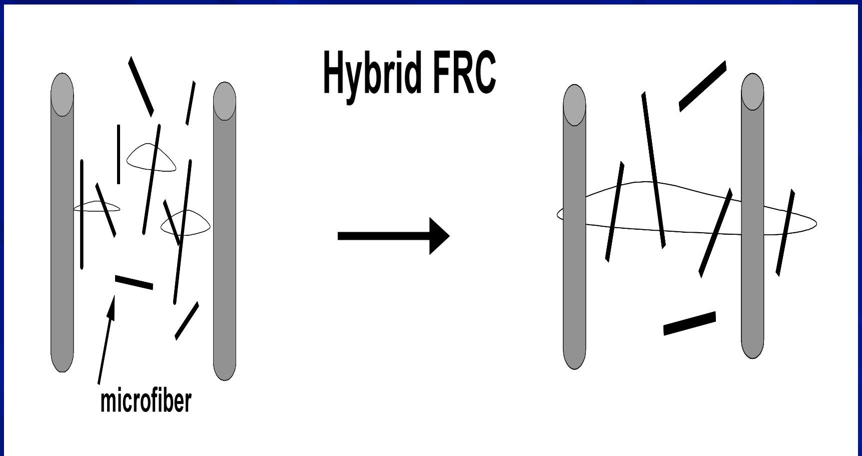
III) Optimization of SCC Hybrid FRC for bridge columns

IV) Design and Testing of SCC Hybrid FRC bridge columns

I) Hybrid (HyFRC) concrete

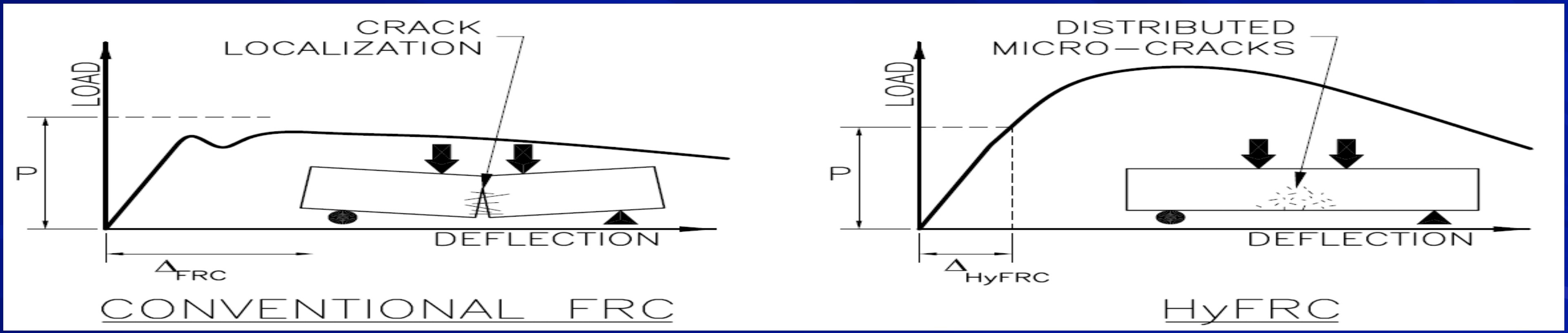
Crack Control through fiber hybridization





Crack Control in conv. FRC
on Macro-scale only

Crack Control in "HyFRC"
on Micro- + Macro-scale



Mechanical property enhancement through addition of microfibers which control microcracks at onset and delay formation of macrocracks

II) HYFRC VS SELF COMPACTED HYBRID (SCC HYFRC) CONCRETE

Difference in Flowability

Vf=1.5%; [0.8% (60mm)/0.5% (30mm)/0.2% PVA]

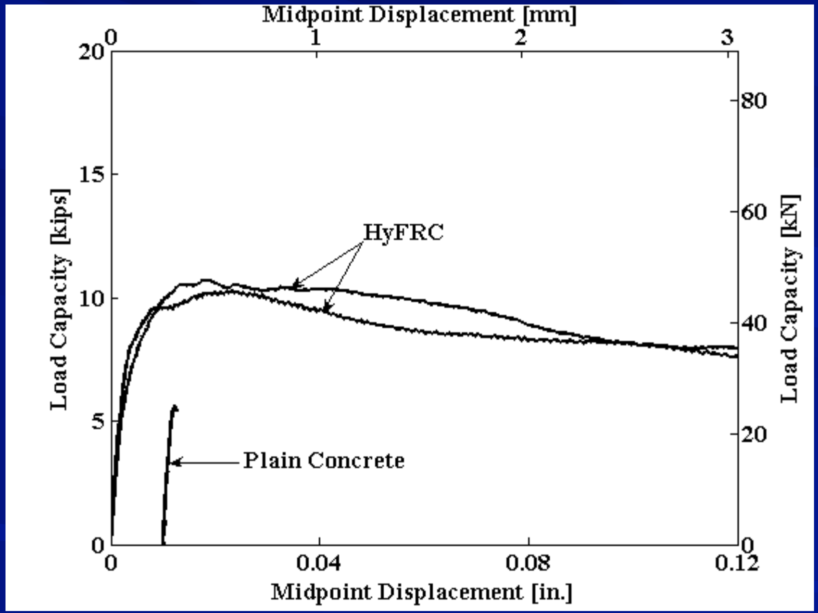
HyFRC

SCC HyFRC

Initial SCC HyFRC

	Cement (lb)	Fly Ash (lb)	Water (lb)	FA (lb)	CA (lb)	SP (wt. % binder)	VMA (wt. % binder)	60mm (V_f)	30mm (V_f)	8mm (V_f)
Mix (#1)	675	225	405	1670	835	0.46	0.84	0.8	0.5	0.2

Flexure Tests



- The mix did not exhibit sufficient fluidity or fiber dispersion to be suitable for highly reinforced bridge columns
  - $\phi_{slump\ flow\ \#1}$ = 330mm (13")

II) Optimization of SCC HyFRC for Bridge Columns

SCC HyFRC for Bridge Columns

- Improve SCC HyFRC flowability (slump flow >600mm)

  Investigation and Optimization as function of:

  - admixture dosage,
  - long fiber content,
  - cement paste content,
  - aggregate content and
  - CA/FA ratio

- Conduct SCC tests to investigate effect of rebar spacing on fiber pile-up, fiber distribution and fiber alignment

Characterization of SCC HyFRC Flowability in presence of rebars

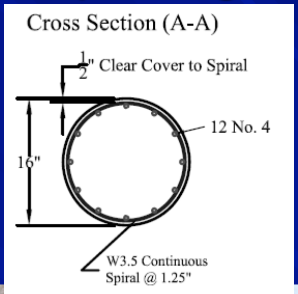
- <u>J-Ring Test</u>
  → Measures: Passing ability, presence of fiber pile-up as function of rebar spacing

  Consists of a ring of reinforcing bars that fits around the base of a standard slump cone. SCC HyFRC is forced to flow between the reinforcement. Measure difference in slump flow with and without J-Ring.

  Flow reduction ≤ 100 mm;

  Ht. difference ≤ 20 mm

- Custom designed J-ring with same rebar spacing as bridge columns



Conclusion: The volume fraction of long fibers had to be reduced to ensure sufficient flowability and homogenous fiber dispersion due to the close rebar spacing of the bridge columns

Improve SCC HyFRC Flowability

- Slump Flow of SCC HyFRC for bridge columns >600mm.

Initial SCC
HyFRC

→

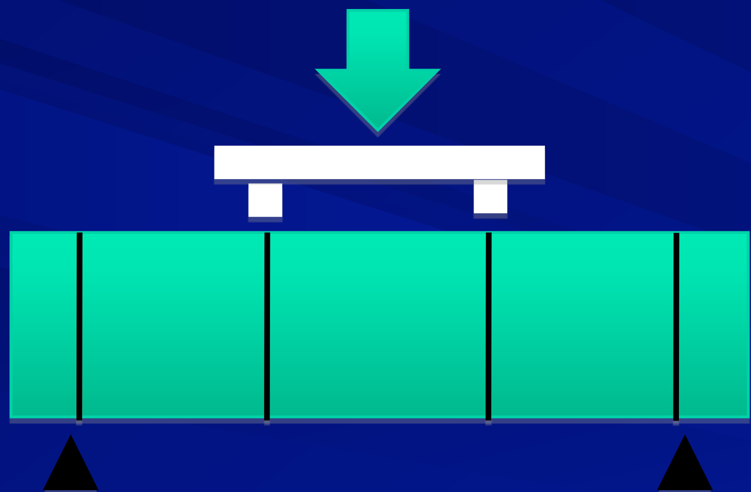
Final SCC HyFRC for bridge columns

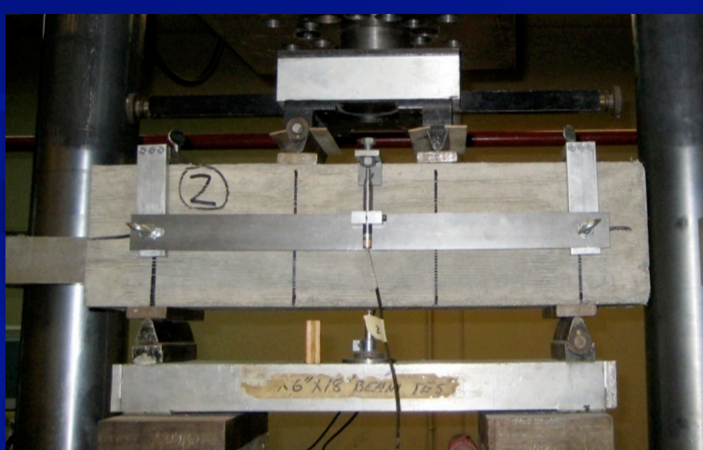
Test Results

Test Set-Up

Beam Tests: four point and three-point loading

6”x6”x24” beams



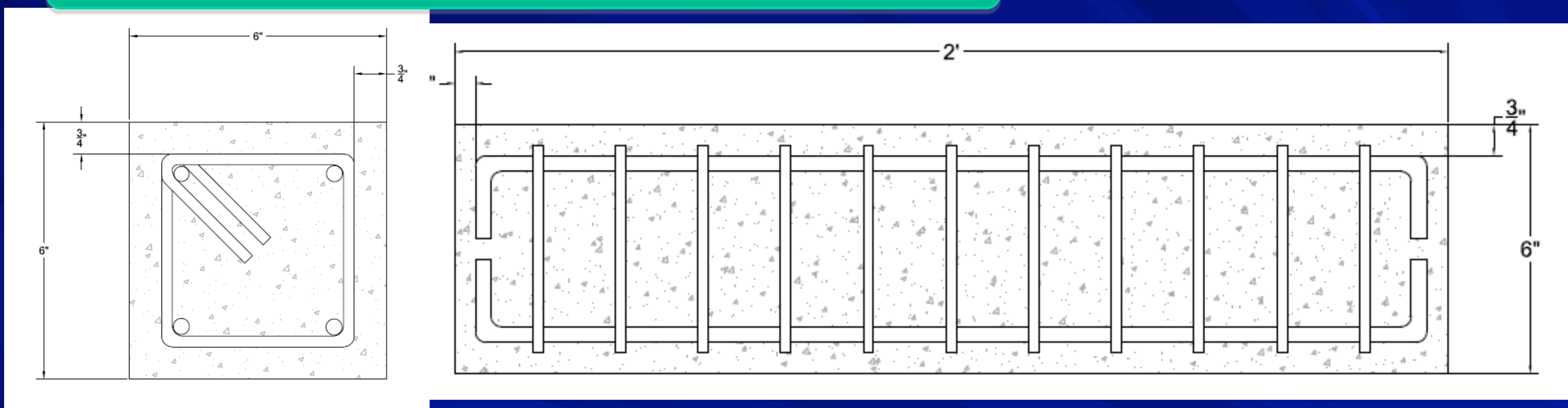


Cylinder Tests: Compression

6”x12” cylinders

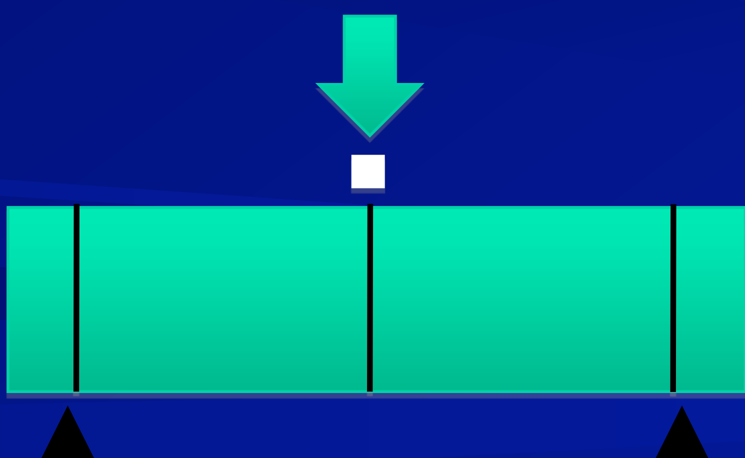
Flexure Tests

Beam Reinforcement Configuration

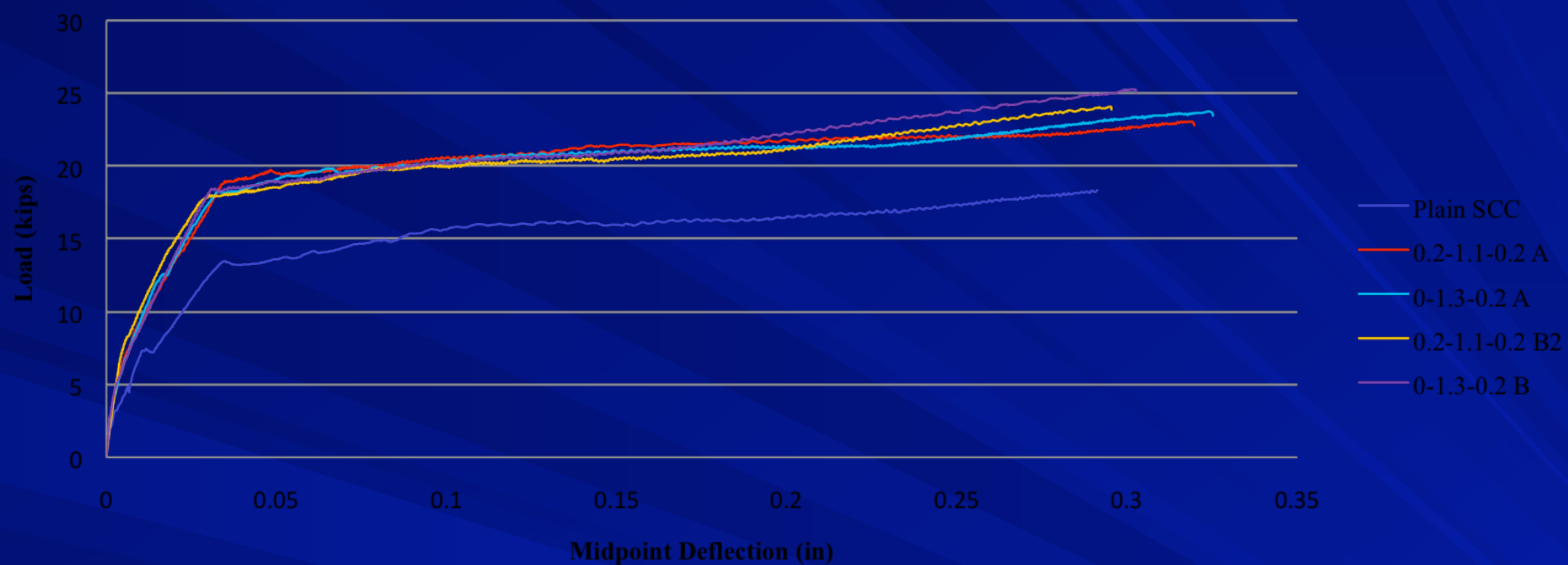


- #3 Bars
- ¼" ties

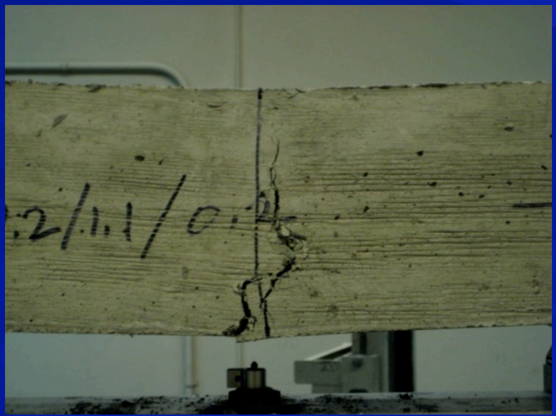
Beam Tests: mid-point loading



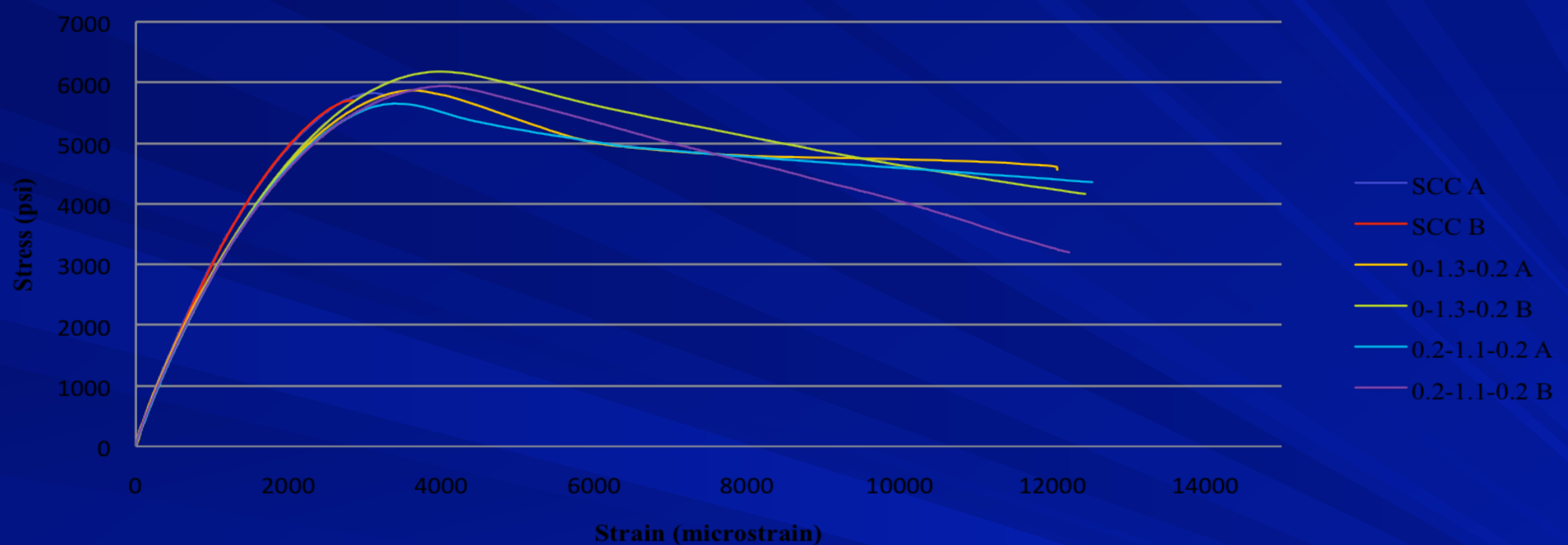
Test Results



	Plain SCC	0.2-1.1-0.2 A	0.2-1.1-0.2 B	0-1.3-0.2 A	0-1.3-0.2 B
Aprox. Load at first observed crack (Kips)	3	6	7	8	8



Compression Test Results



	SCC A	SCC B	0-1.3-0.2 A	0-1.3-0.2 B	0.2-1.1-0.2 A	0.2-1.1-0.2 B
Peak Stress (psi)	5822	5703	5869	6180	5651	5940
Axial Strain @ Peak (microstrain)	3154	2849	3645	3970	3375	4055
Lateral Strain @ Peak (microstrain)	1586	1004	985	2290	2039	2303

Initial vs Final Mix

(normalized by cement weight)

	Cement (lb)	Fly Ash (lb)	Water (lb)	FA (lb)	CA (lb)	SP (wt. % binder)	VMA (wt. % binder)	60mm (V_f)	30mm (V_f)	8mm (V_f)
Mix (#1)	1	0.33	0.6	2.47	1.24	0.46	0.84	0.8	0.5	0.2
Mix (#58)	1	0.33	0.6	2.63	1.05	0.46	2.22	-	1.3	0.2

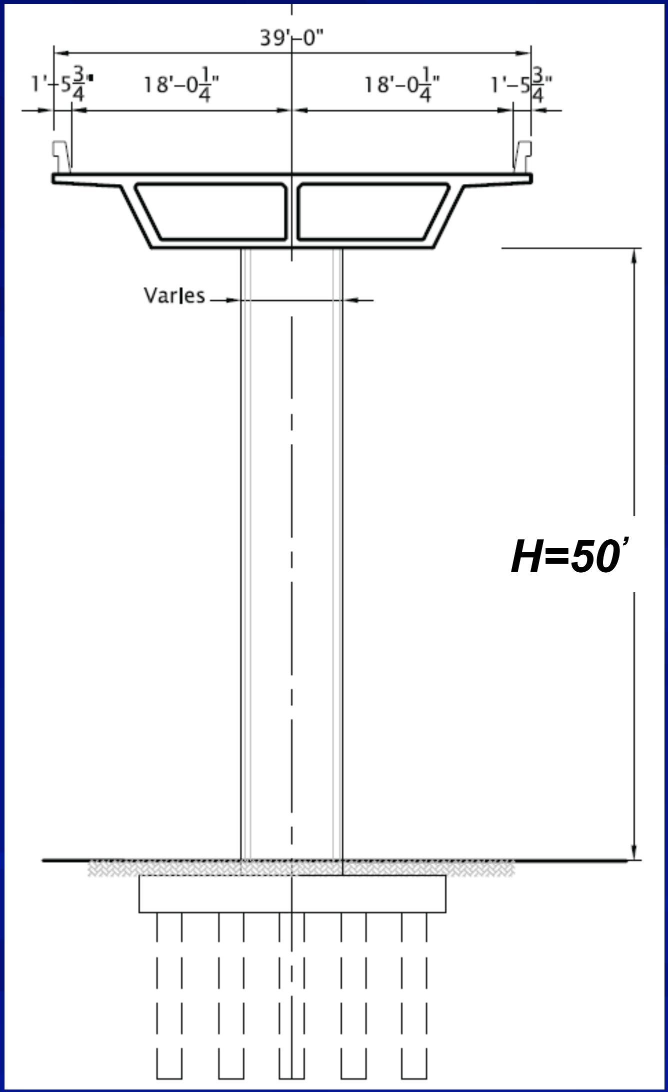
- The total fiber volume fraction remains constant, with the current mix design utilizing 30mm steel fibers and a replacement for 60mm steel fibers
- The volumetric ratio of cement paste to aggregate remains constant at 0.76:1
- The ratio of fine to coarse aggregate has increased from 2:1 to 2.5:1
- More VMA was required to achieve slump flow and cohesiveness of mix and to prevent fiber segregation.

IV) DESIGN AND TESTING OF Hybrid FRC BRIDGE COLUMNS considering :

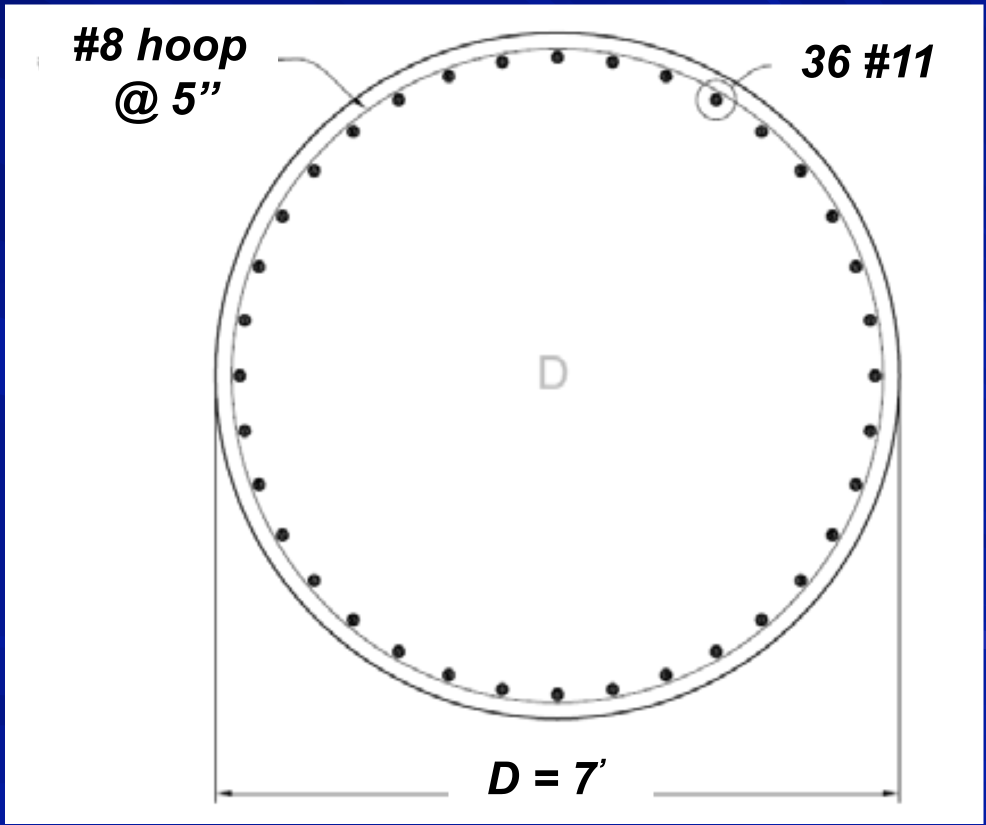
Mechanical characteristics of FRC in tension and compression : Relaxation of transverse reinforcement requirements.

Prototype Column (*Ketchum et al., 2004*)

- Aspect Ratio H / D ≈ 7
- Longitudinal steel ratio ρ_l = 1%
- Transverse steel ratio ρ_t = 1.2 %
- Axial load ratio $N / (f_c' A_g) = 0.1$



ELEVATION



COLUMN SECTION

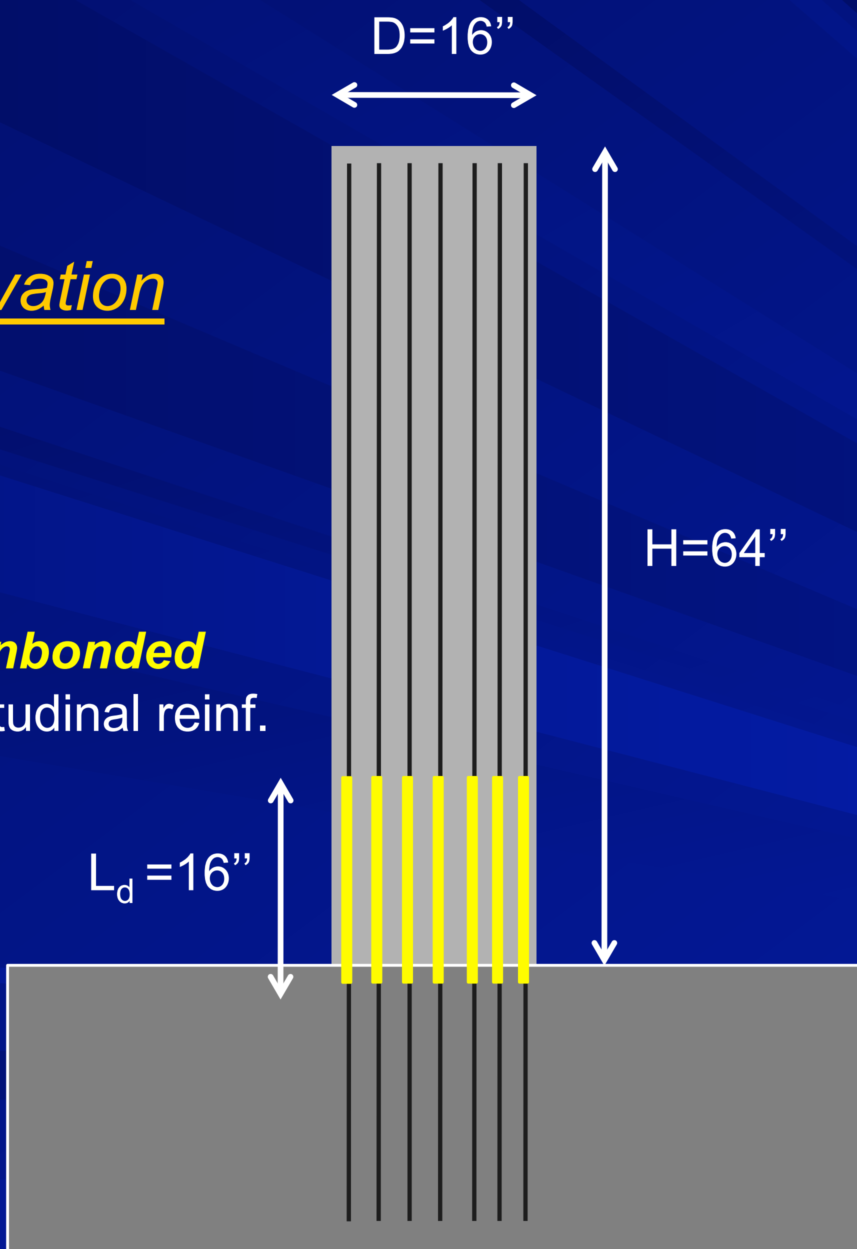
Test Specimen 1 – ***Unbonded*** Longitudinal Reinforcement

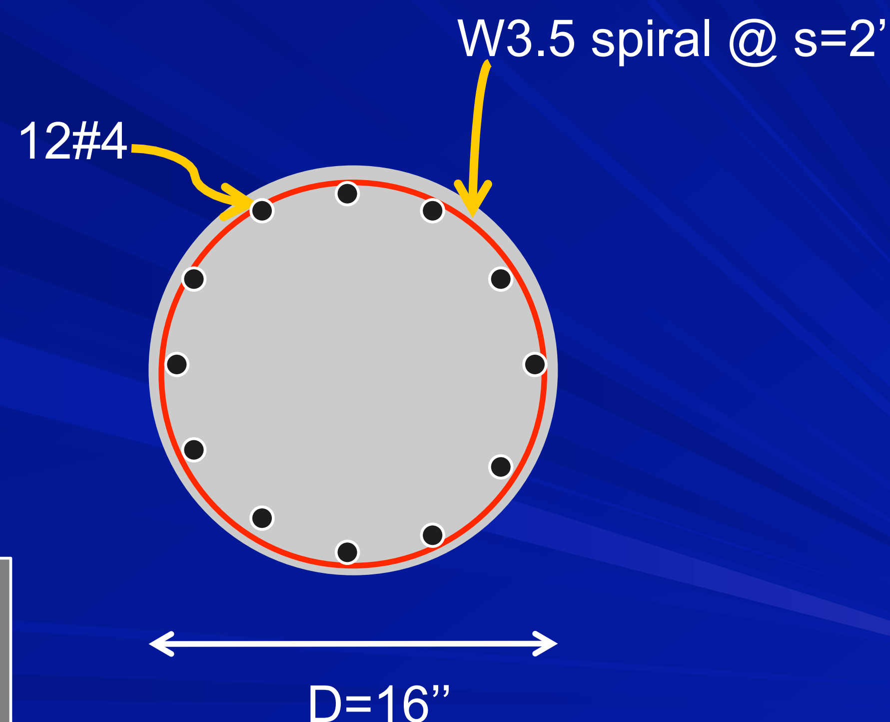
1:4.7 scale Specimens

- Longitudinal steel ratio ρ_l = 1.2%
- Transverse steel ratio ρ_t = 0.5%
- Axial load ratio N / (f_c'A_g) = 0.1

Elevation

Unbonded
longitudinal reinf.

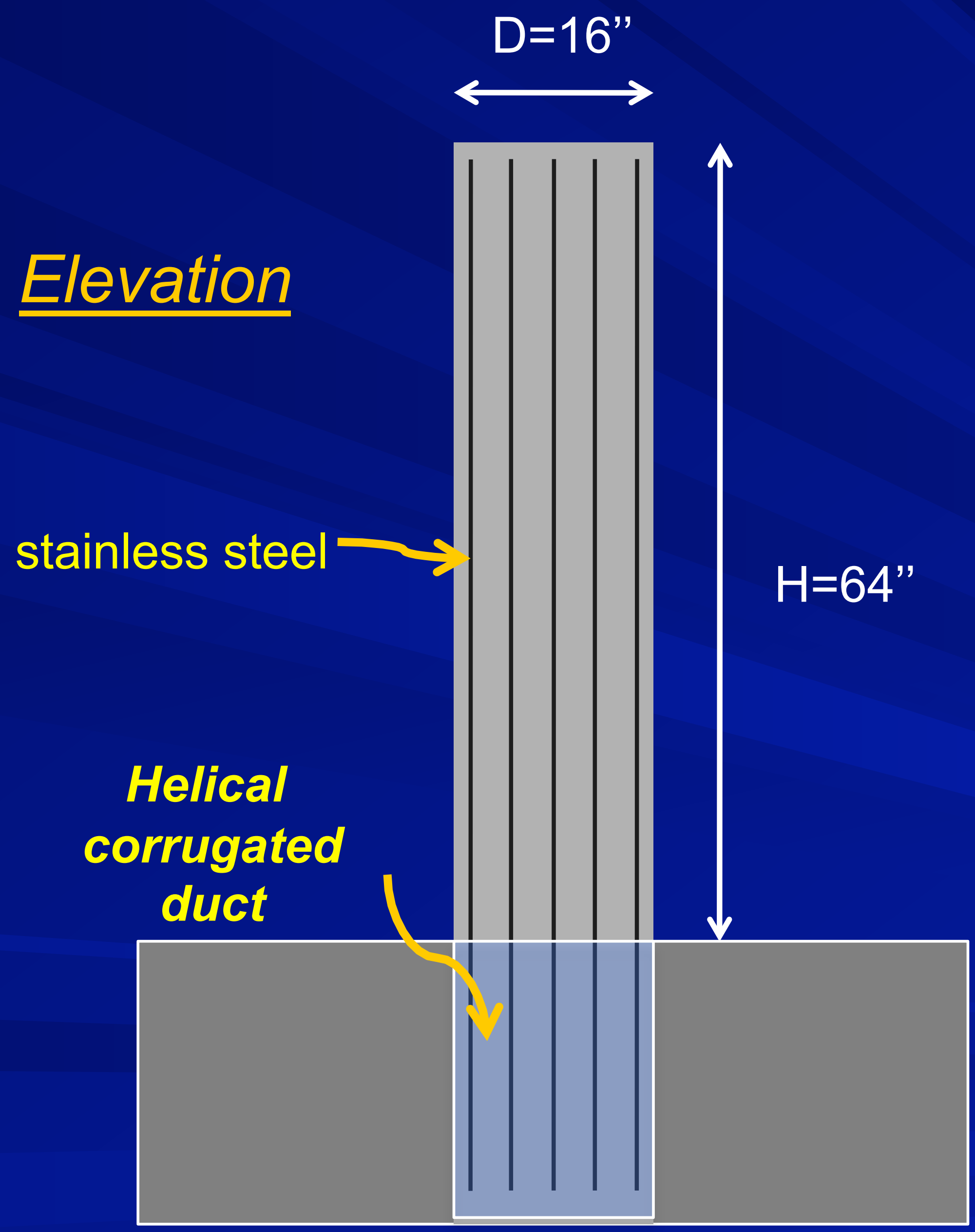


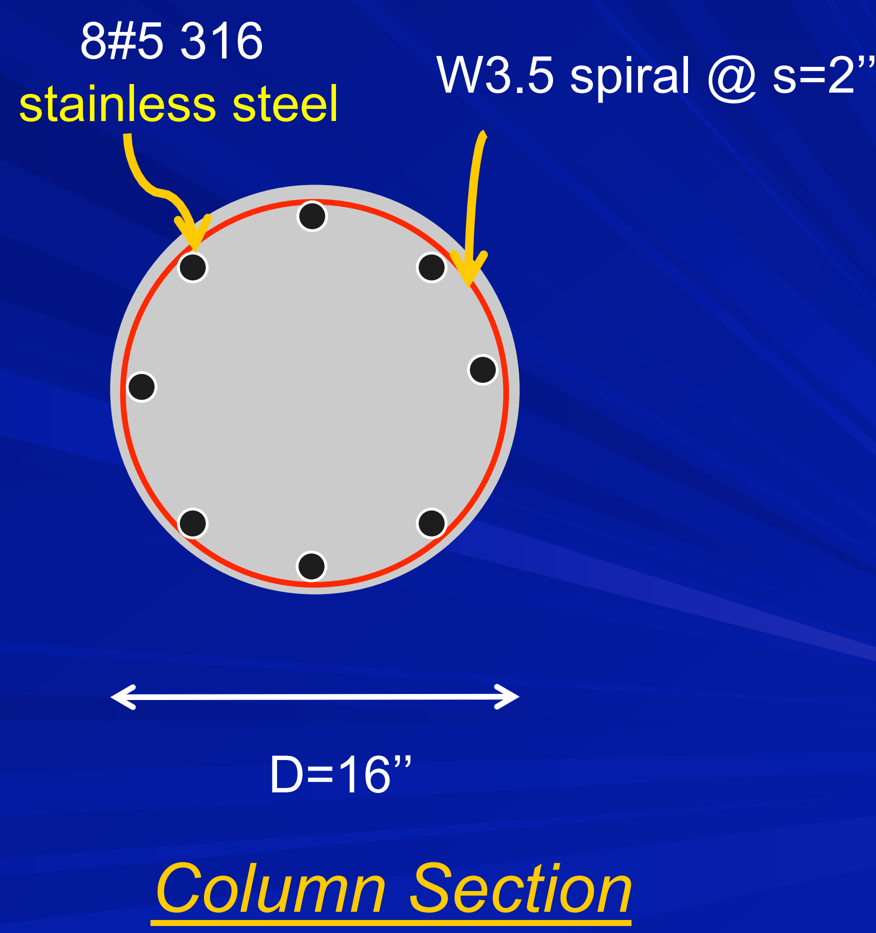


Column Section

Test Specimen 2 – ***Stainless*** Longitudinal Steel – ***Helical Corrugated Duct***

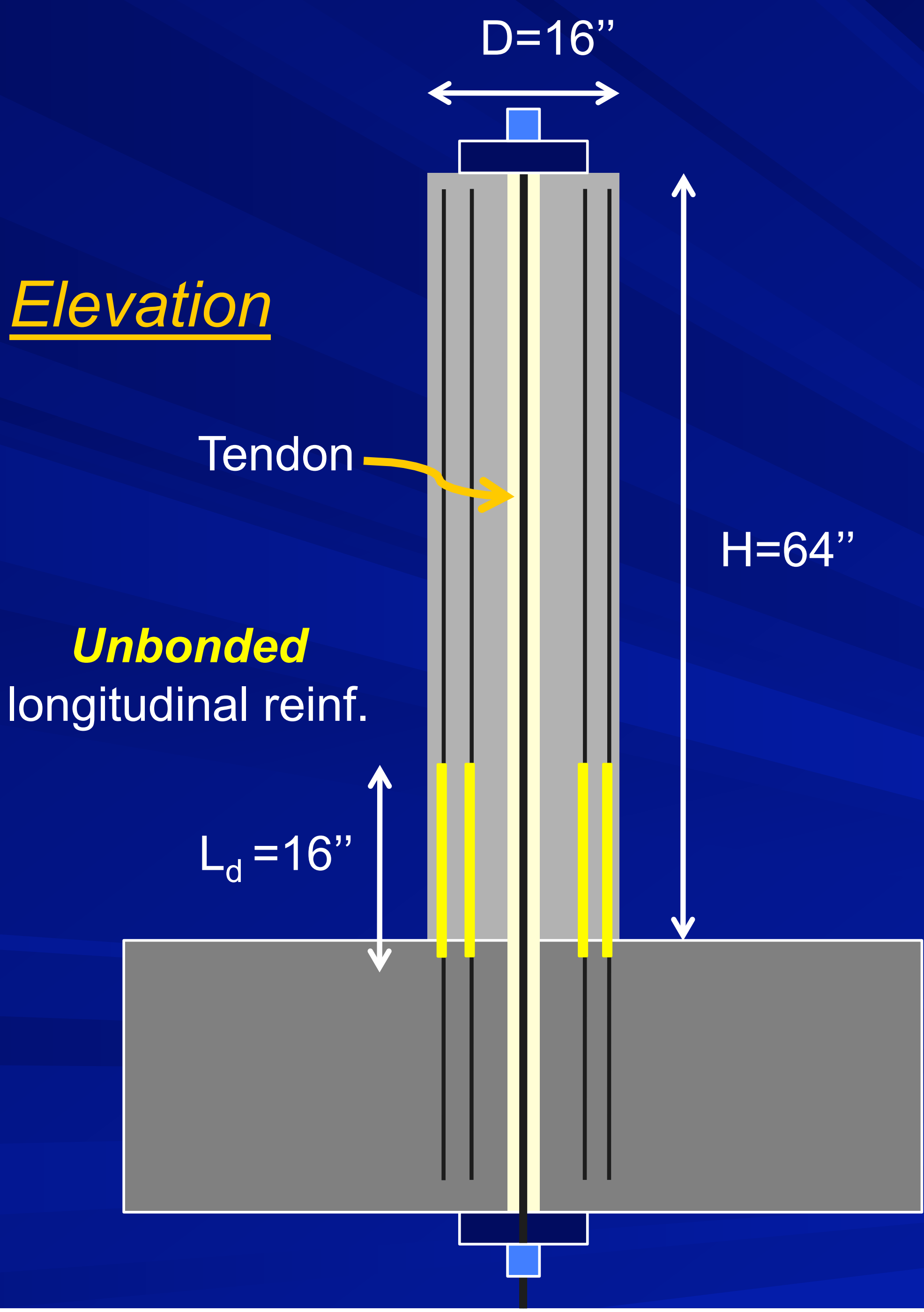
- Longitudinal steel ratio ρ_l = 1.2%
- Transverse steel ratio ρ_t = 0.5%
- Axial load ratio $N / (f_c'A_g) = 0.1$

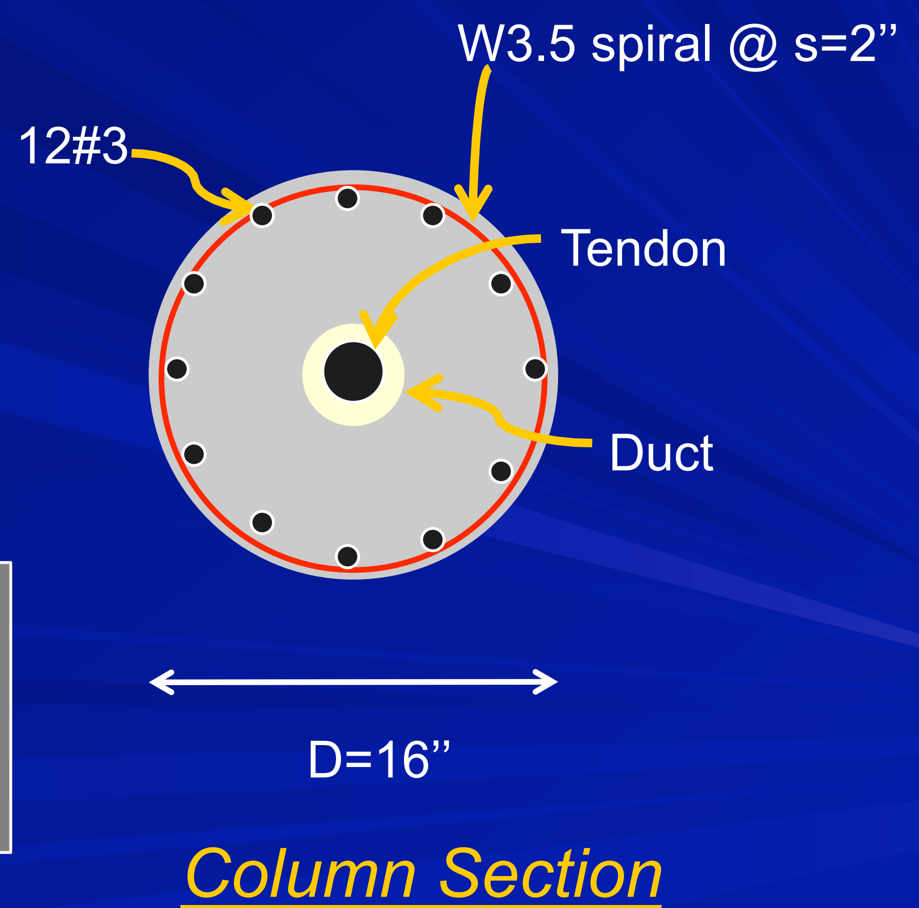




Test Specimen 3 – ***Post -Tensioning and Unbonded Long. Steel***

- Post-Tension force F_{pt} =350 kips
- Longitudinal steel ratio ρ_l = 0.6%
- Transverse steel ratio ρ_t = 0.5%
- Axial load ratio $N / (f_c' A_g) = 0.1$





Thank you