# CEE 485
# Reinforced Concrete Design
# Fall 2018

## Lab Beam Design for Flexure and Shear Compared with Beam Test Results

# Laboratory Beam Tests

- CEE485 – Reinforced Concrete Design
- Senior level course – 4 credits (1 for lab)
- Fall semester – 80 students
- Lab experience involves building, testing and evaluating 12 beams in groups of 6-7 students.
- Beam dimensions and reinforcement predefined to ensure desired response.
- Group reports must provide ACI-318 strength and group "educated" estimate of failure load.
- Prizes awarded to group with closest estimates

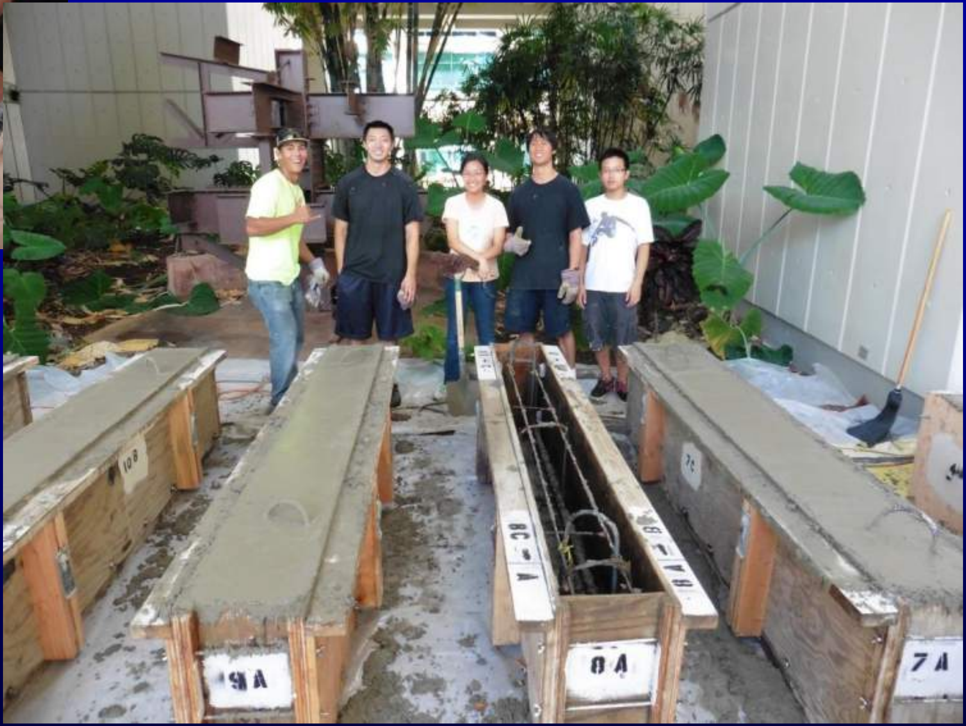
# Rebar and Formwork Fabrication



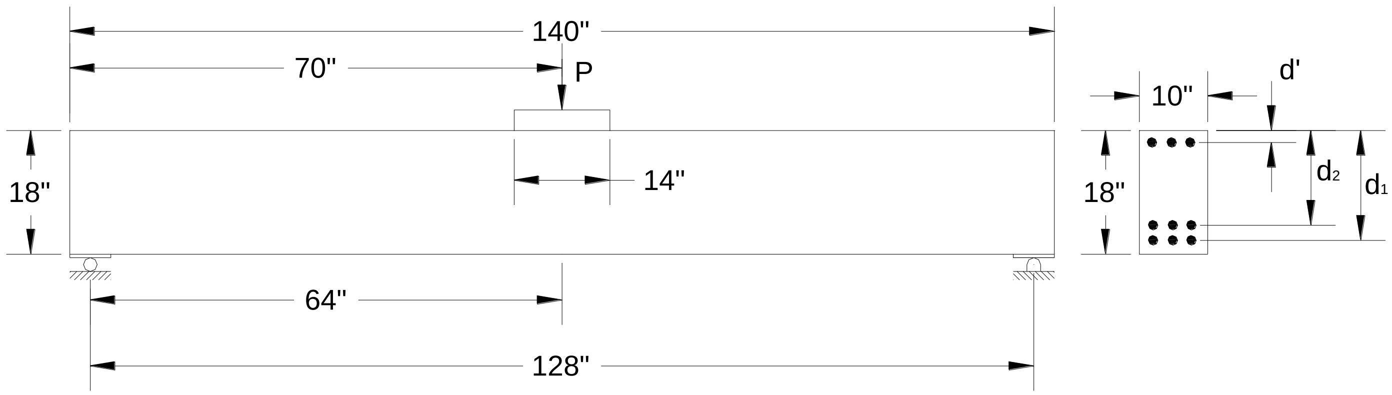

# Concrete Pour

- 4000psi 3”±1” Slump – 3/8” Aggregate
- Slump measured prior to placement
- Poured 10 beams
- Add 7.5lb/cuyd Ferro Fiber and Glenium 3030 to re-activate original slump
- Pour FRP beam 1
- Add 40lb/cuyd Helix Fibers and Glenium 3030 to re-activate original slump
- Pour FRP beam 2

# Beam Pour

# Flexural (Long) Beams 1-6




Long Beam Test Dimensions

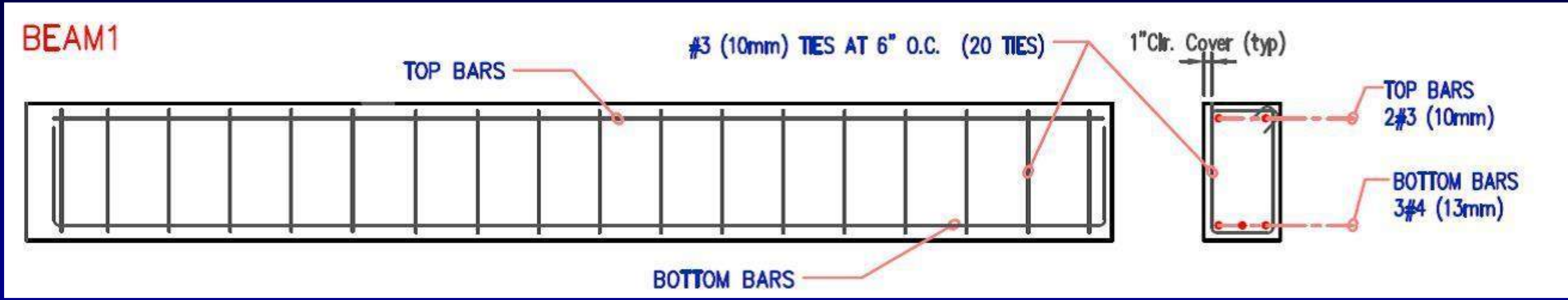
$$M_{cr} = \frac{f_r I_g}{y_t} = \frac{7.5\sqrt{4000} \times \frac{10 \times 18^3}{12}}{9}$$

$$\therefore M_{cr} = 256{,}000\ in - lb = 21.3\ ft - kip$$

and $M_{max} = PL/4$

So, $P_{cr} = \frac{4M_{cr}}{L} = \frac{4 \times 21.3}{128/12} = \mathbf{8.0\ kips}$

# Beam 1




(3) #4 bottom bars

(2) #3 top bars (ignore for flexural strength calculation)

#3@6" o.c. stirrups

$$d = h - \text{cover} - \phi_{st} \text{ -1/2 } \phi_{\text{bar}} = 18 - 1 - 0.375 - 0.25 = 16.375 in$$

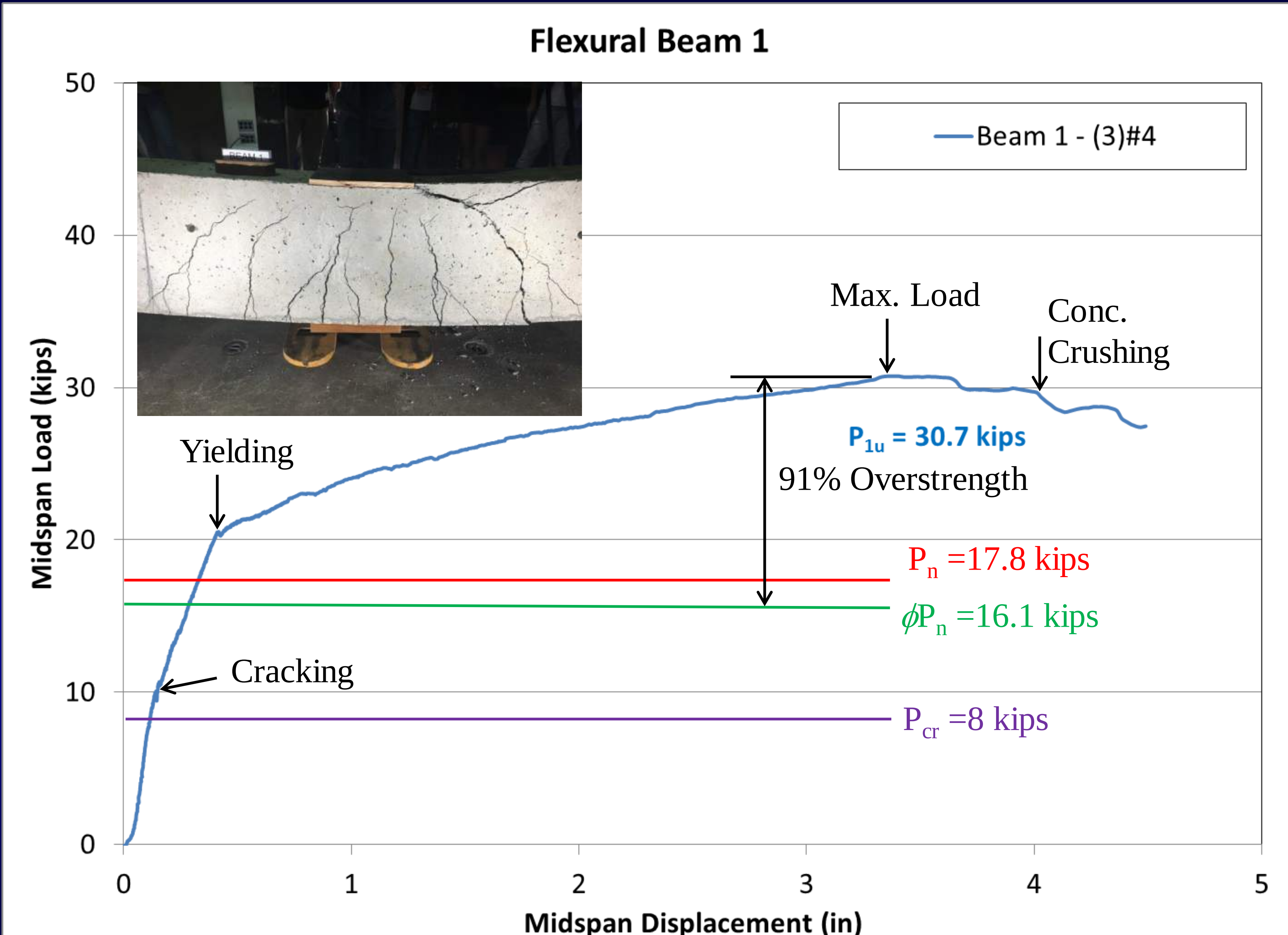
$$A_{s,\min} = \frac{200}{f_y} b_w d = \frac{200}{60000} \times 10 \times 16.375 = 0.546 \text{ in}^2$$

$$A_{s,prov} = 3 \times 0.2 = 0.6 \text{ in}^2 > 0.546 \text{in}^2, \therefore \text{okay.}$$

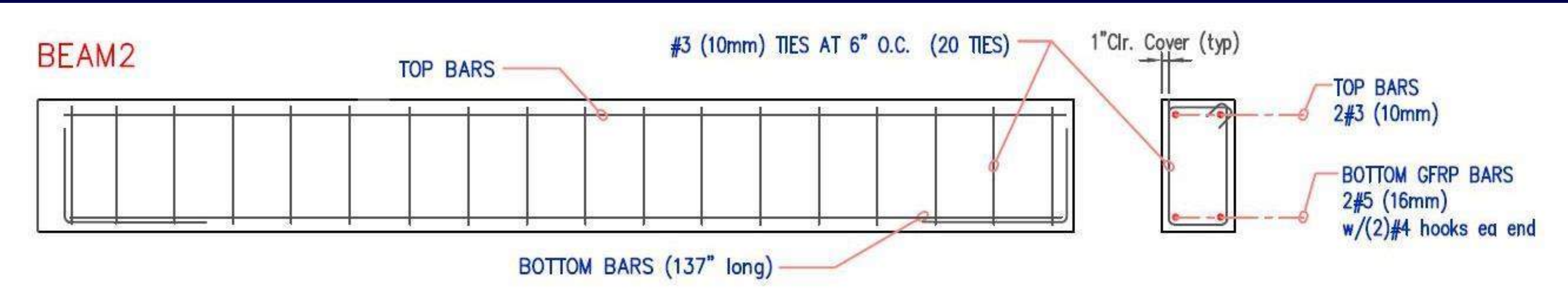
$$\rho = A_s / b_w d = 0.6 / (10 \times 16.375) = 0.00366 = 0.37\%$$

$$M_n = 47.6k - ft \ \text{(Equiv to } P = 17.8 kips\text{), and } \phi M_n = 42.8k - ft$$

Demonstrate the behavior of a "tension-controlled" ductile RC beam.


Flexural Beam 1
Beam 1 - (3)#4
Max. Load
Conc. Crushing
Yielding
Cracking
$P_{1u}$ = 30.7 kips
91% Overstrength
$P_n$ =17.8 kips
$\phi P_n$ =16.1 kips
$P_{cr}$ =8 kips
Midspan Load (kips)
Midspan Displacement (in)
0
10
20
30
40
50
0
1
2
3
4
5

# Beam 2




(2) #5 Glass FRP bottom bars

(2) #3 top bars (ignore for flexural strength calculation)

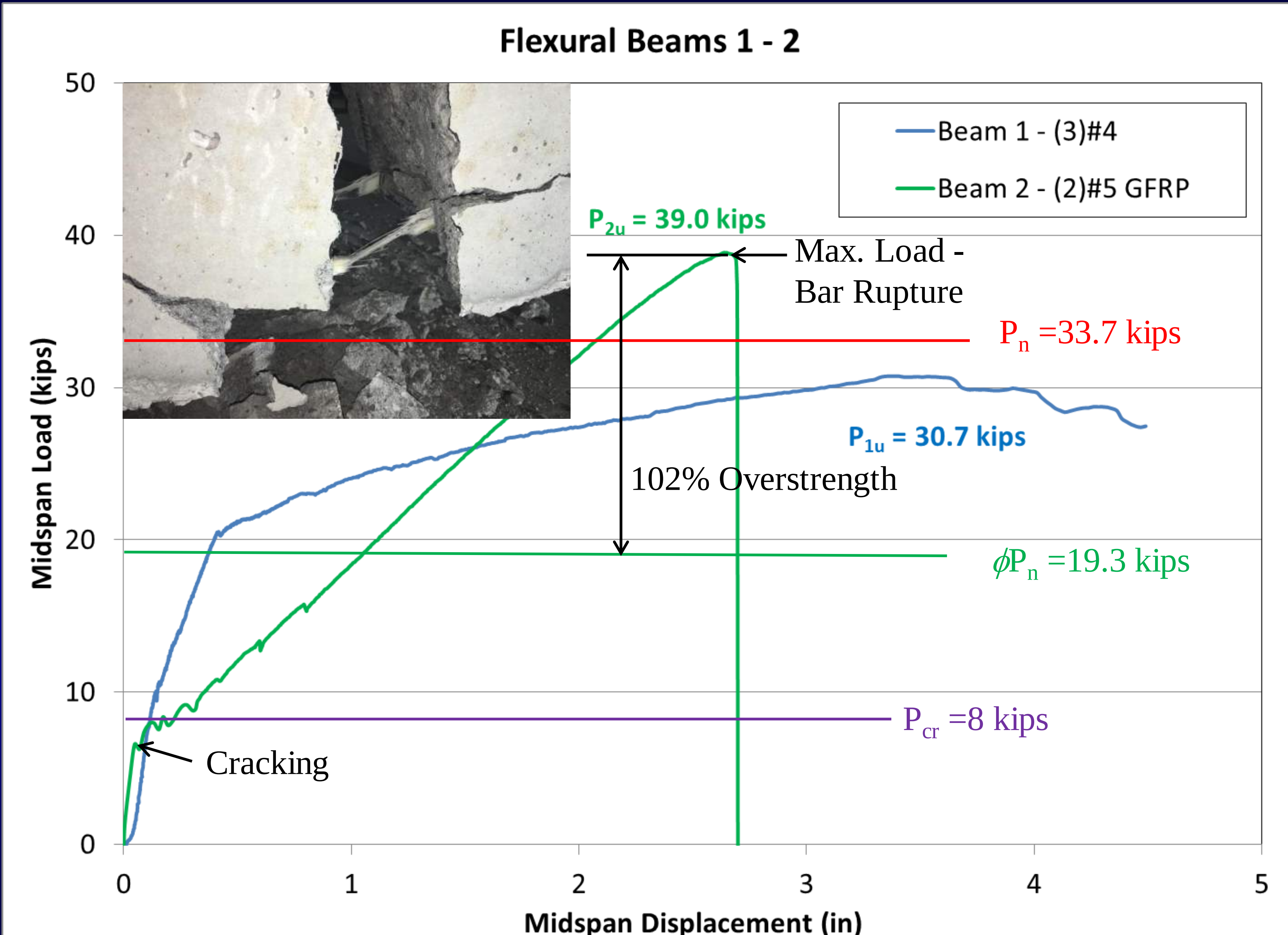
#3@6" o.c. stirrups

$$A_{s,prov} = 2 \times 0.31 = 0.62\,\text{in}^2$$

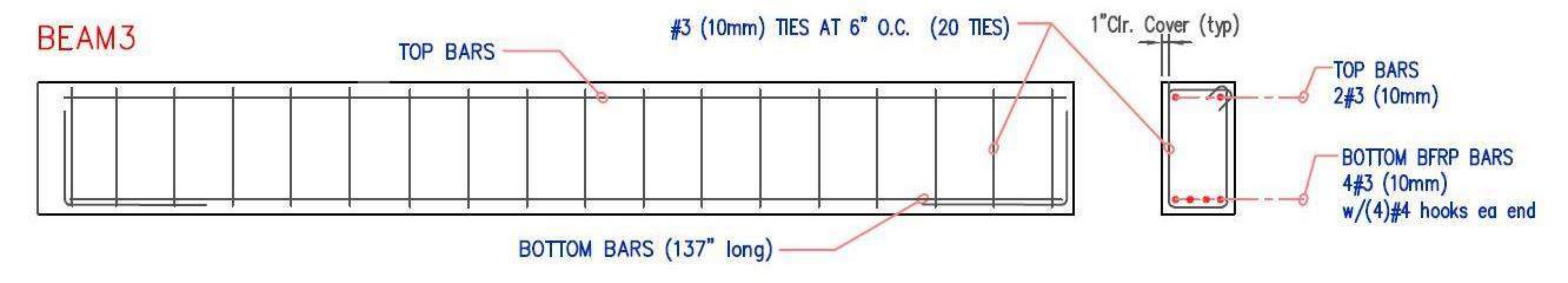
$$\rho = A_s / b_w d = 0.62/(10 \times 16.375) = 0.38\%$$

$$M_n = 90k - ft \;\; (\text{Equiv to } P = 33.7 kips), \text{ and } \phi M_n = 51.7k - ft$$

Demonstrate the behavior of a concrete beam reinforced with Glass Fiber Reinforced Polymer (GFRP bars) equivalent to Beam 1.


Flexural Beams 1 - 2
Beam 1 - (3)#4
Beam 2 - (2)#5 GFRP
P2u = 39.0 kips
Max. Load - Bar Rupture
Pn =33.7 kips
P1u = 30.7 kips
102% Overstrength
φPn =19.3 kips
Pcr =8 kips
Cracking
Midspan Load (kips)
Midspan Displacement (in)
0
10
20
30
40
50
0
1
2
3
4
5

# Beam 3




(4) #3 Basalt FRP bottom bars

(2) #3 top bars (ignore for flexural strength calculation)

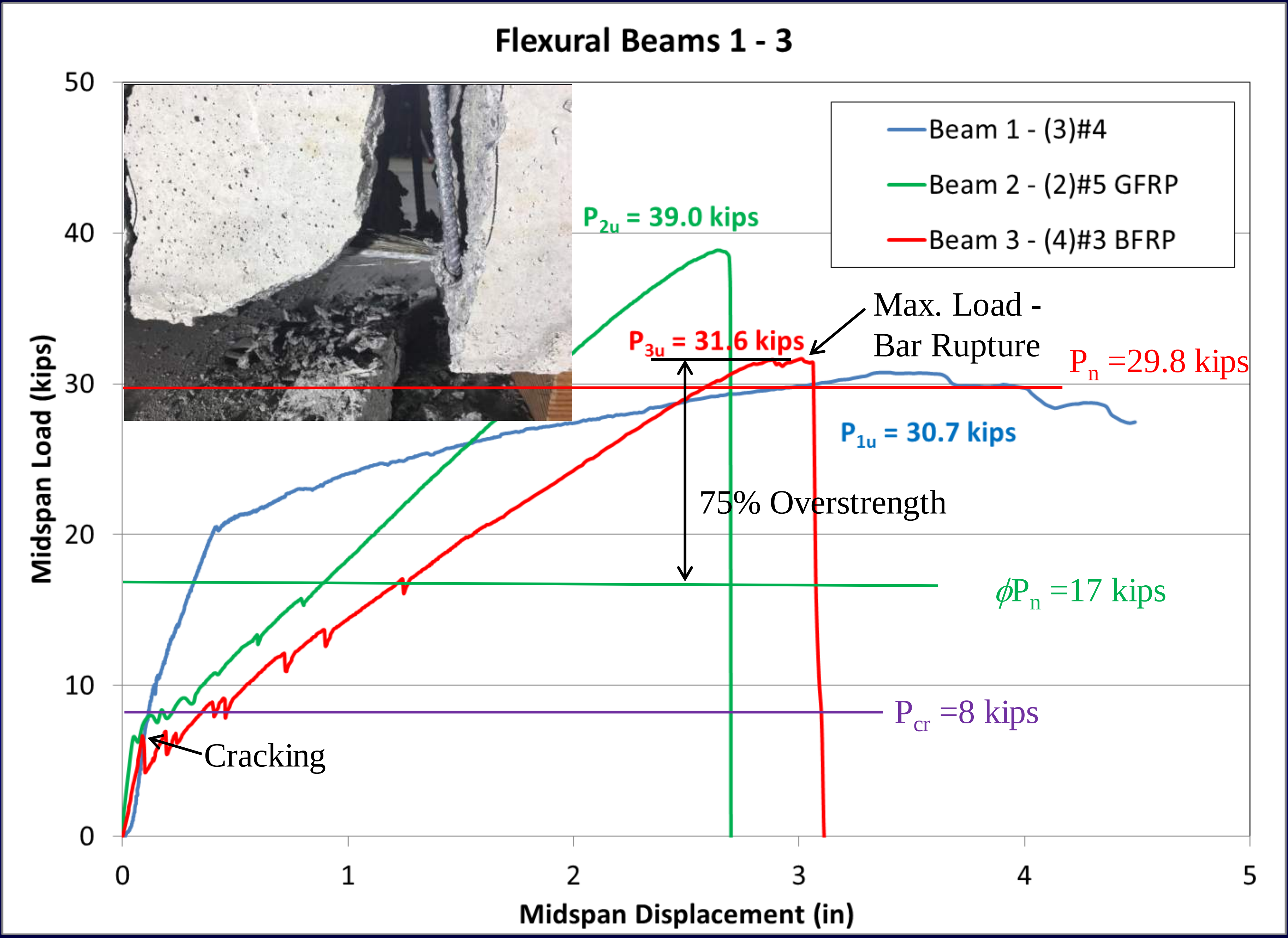
#3@6" o.c. stirrups

$$A_{s,prov} = 4 \times 0.11 = 0.44\,\text{in}^2$$

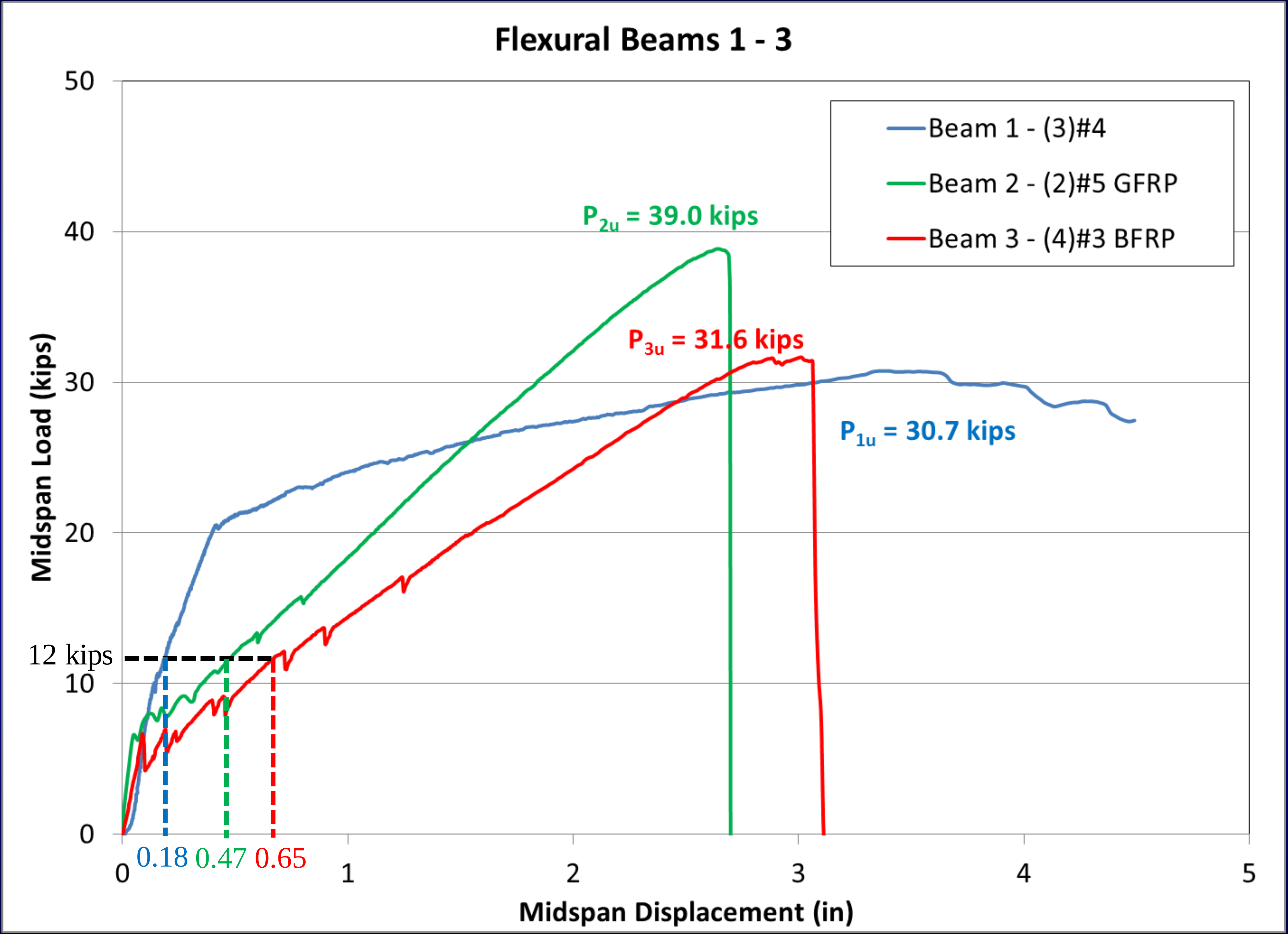
$$\rho = A_s / b_w d = 0.44/(10 \times 16.375) = 0.27\%$$

$$M_n = 79.4k - ft \;\; (\text{Equiv to } P = 29.8kips), \text{ and } \phi M_n = 45.2k - ft$$

Demonstrate the behavior of a concrete beam reinforced with Basalt Fiber Reinforced Polymer (BFRP bars) equivalent to Beam 1.



Flexural Beams 1 - 3
Beam 1 - (3)#4
Beam 2 - (2)#5 GFRP
Beam 3 - (4)#3 BFRP
P2u = 39.0 kips
P3u = 31.6 kips
Max. Load - Bar Rupture
Pn =29.8 kips
P1u = 30.7 kips
75% Overstrength
ϕPn =17 kips
Pcr =8 kips
Cracking
Midspan Load (kips)
Midspan Displacement (in)
0
10
20
30
40
50
0
1
2
3
4
5



Flexural Beams 1 - 3
Beam 1 - (3)#4
Beam 2 - (2)#5 GFRP
Beam 3 - (4)#3 BFRP
P2u = 39.0 kips
P3u = 31.6 kips
P1u = 30.7 kips
12 kips
0.18 0.47 0.65
Midspan Load (kips)
Midspan Displacement (in)
0
10
20
30
40
50
0
1
2
3
4
5

# BFRP Applications

- Excellent for non-structural flat work in any environment, including highly corrosive
  - Slab-on-grade, pavement, etc.
  - Free-standing walls, panels, guard rails, etc.
- Deflection issues will require increased reinforcement quantities
  - Structural beams
  - Structural slabs