STRUCTURAL APPLICATIONS OF STEEL FIBER REINFORCED CONCRETE

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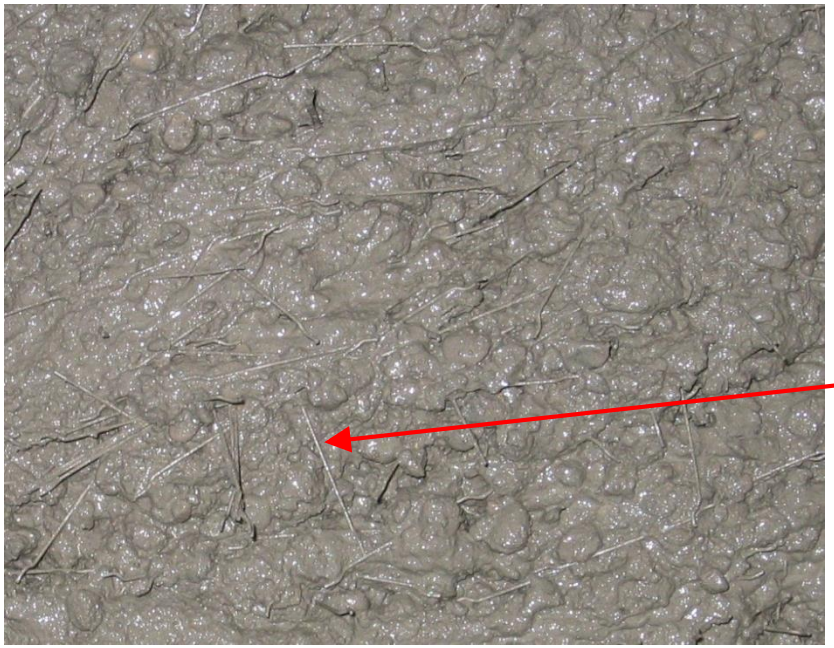
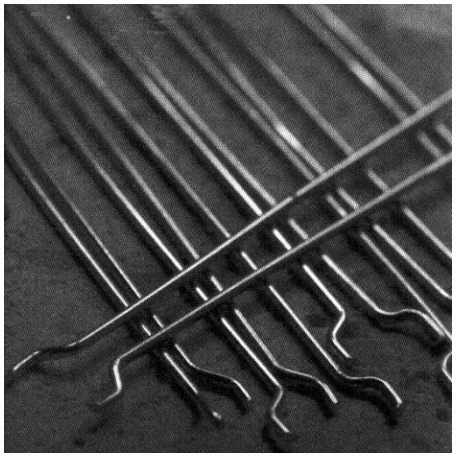
PRESENTATION OUTLINE

- Fiber reinforced concrete (steel fibers, performance)
- Applications of steel fiber reinforced concrete
  - Tunneling (precast segmental linings)
  - Slabs (on-ground and elevated)
  - Beams
  - Hollow-core slabs
  - Link or coupling beams
- Summary and conclusions

FIBER REINFORCED CONCRETE

- Concrete reinforced with discontinuous fibers
- Commonly used steel fibers have deformations to improve bond with surrounding concrete. However, most types of fibers are ultimately expected to pullout



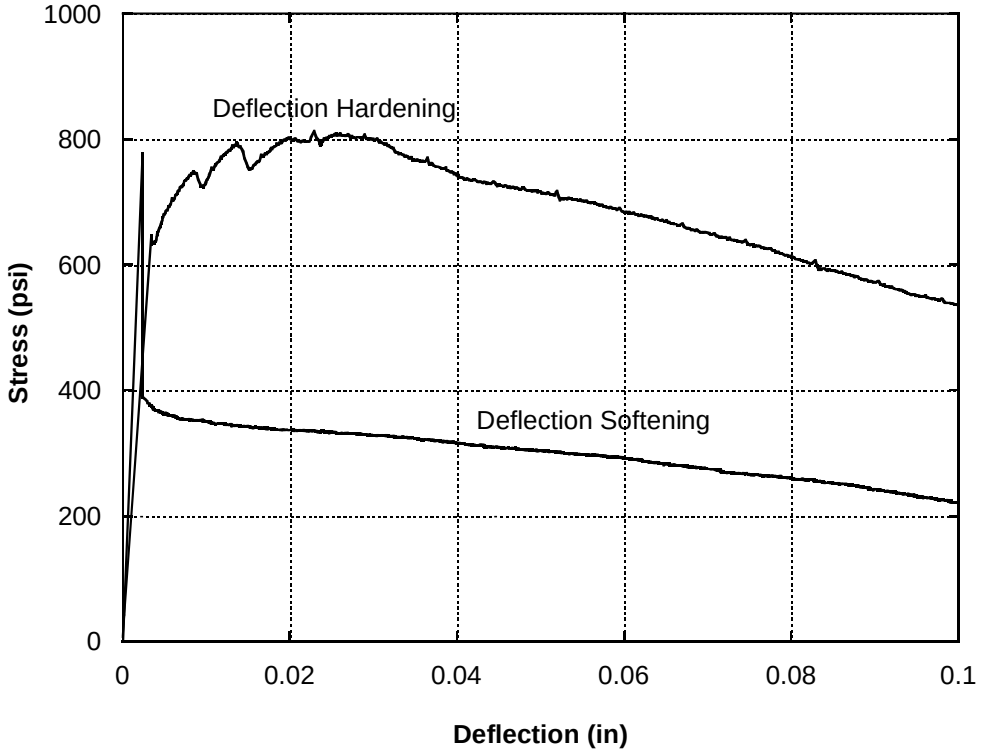


STEEL FIBERS

- Typically hooked steel fibers with tensile strength of 1100 MPa or higher
- Length = 30 – 60 mm
- Length-to-diameter ratio = 55 - 80
- Fiber volume fraction = 0.5% – 1.5%

BEHAVIOR OF FRCs

- Typically evaluated based on four-point or three-point bending tests



PRECAST SEGMENTAL LININGS

- Precast segmental linings (transportation and water storage tunnels)

(Courtesy of Jeff Novak, Bekaert Corporation)

SLABS

- Industrial floors (slabs-on-ground or slabs-on-piles) represent the largest application of steel fiber reinforced concrete
  - Steel fibers are used as replacement for shrinkage and temperature reinforcement; they also allow elimination of joints

- Applications in elevated slabs are less common
  - Steel fibers have been used as nearly total replacement of bar reinforcement

SLABS

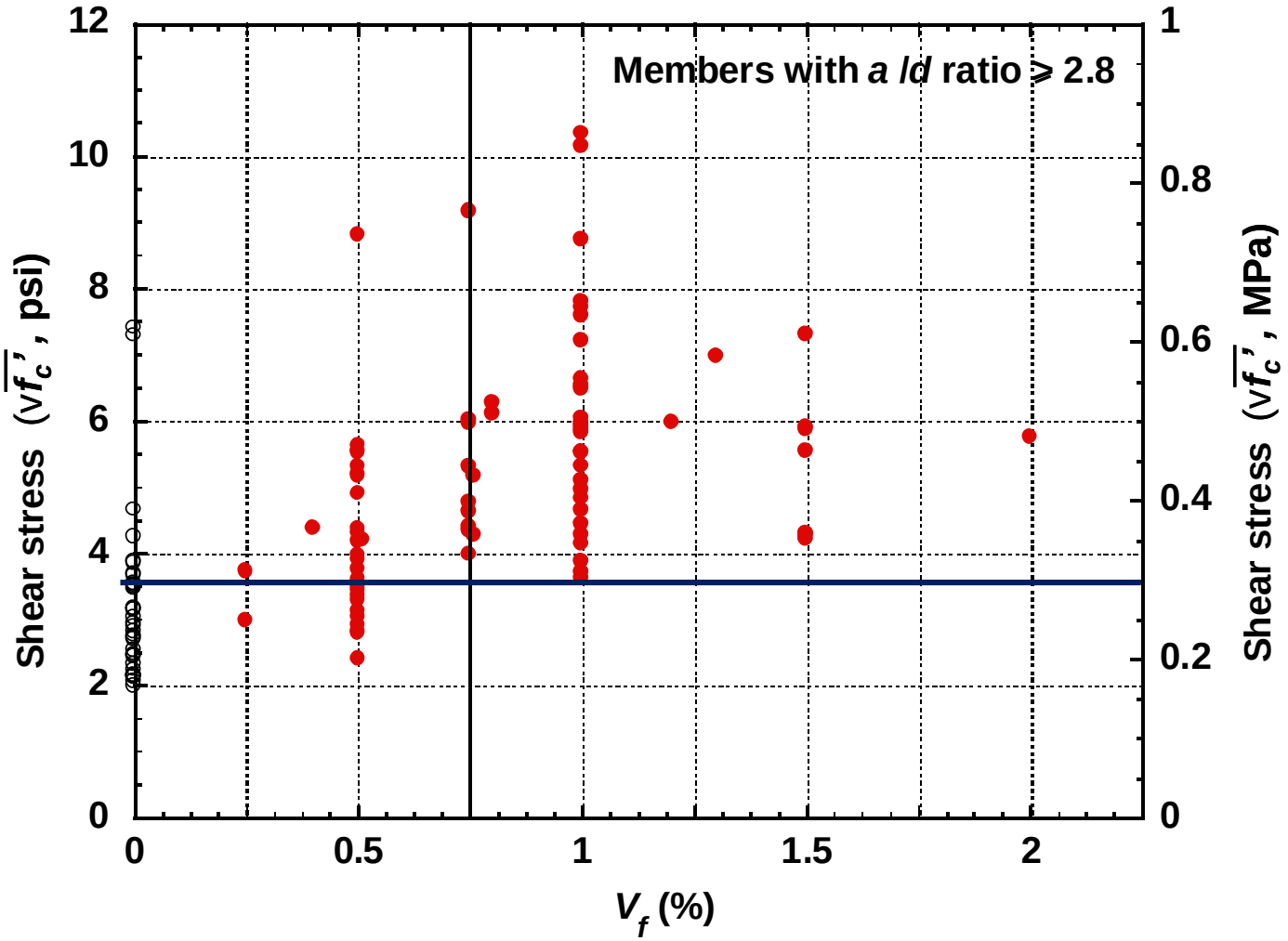
- Slabs on piles

(Courtesy of Jeff Novak, Bekaert Corporation)

FIBERS AS SHEAR REINFORCEMENT IN BEAMS

- Fibers increase shear strength by:
  - Providing post-cracking diagonal tension resistance
  - Enhancing crack distribution and controlling the opening of diagonal cracks, which increases aggregate interlock
- Shear strength ≥ $0.3\sqrt{f_c}$ (MPa) for volume fractions ≥ 0.75%
- ACI 318-14 allows use of steel fiber reinforced concrete as minimum shear reinforcement in beams under certain conditions

SHEAR TEST DATA FOR SFRC BEAMS



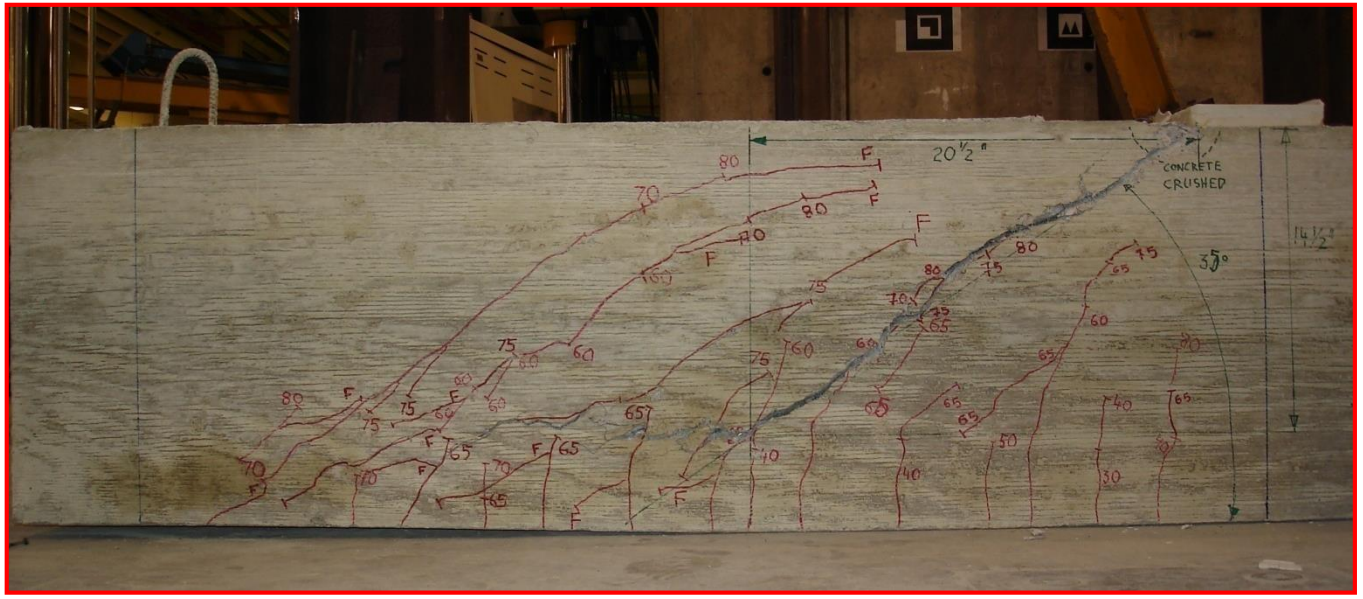
(Parra-Montesinos, 2006)

RC vs. SFRC BEAMS (no stirrups)

No fibers

Type 1 fibers

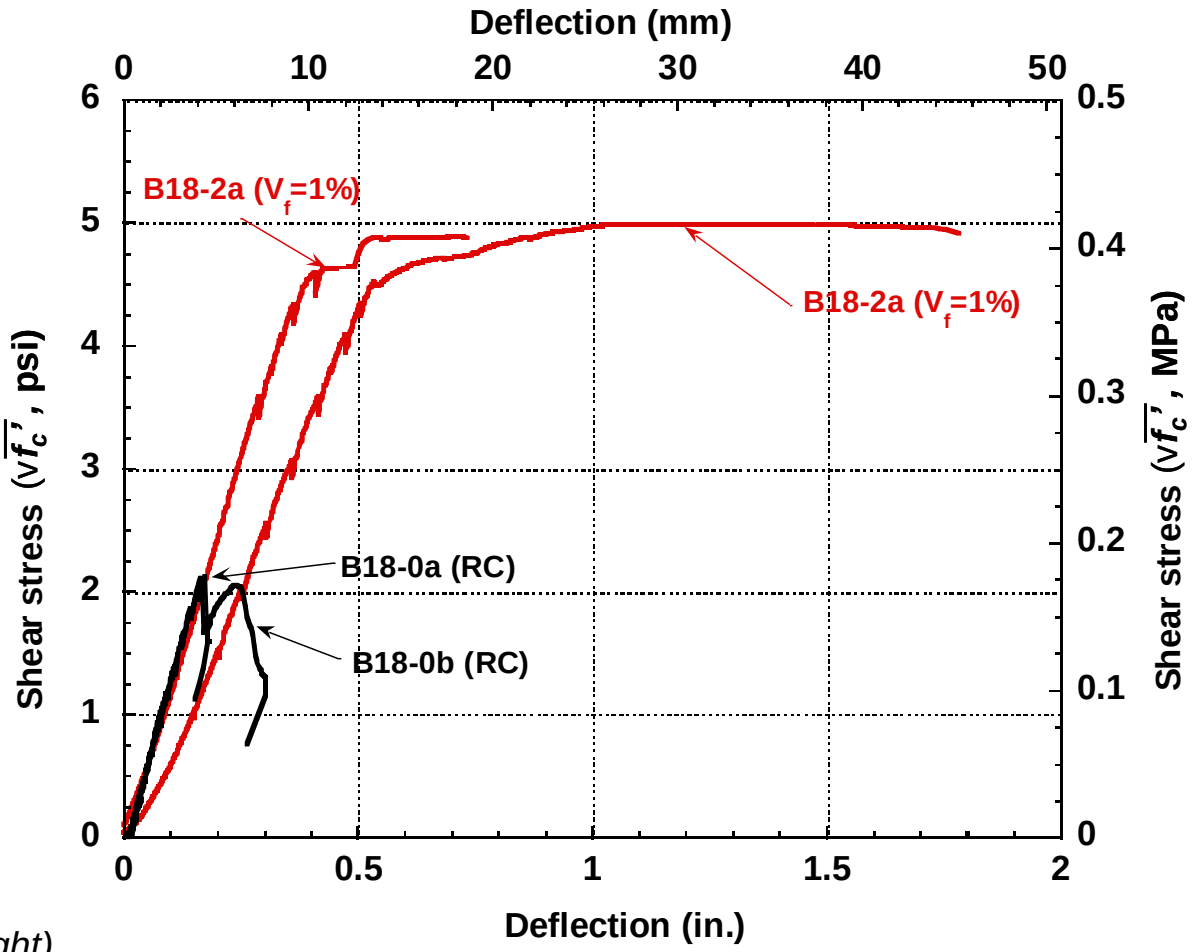
(V_f = 0.75%)



(Dinh, Parra and Wight)

RC vs. SFRC BEAMS (no stirrups)

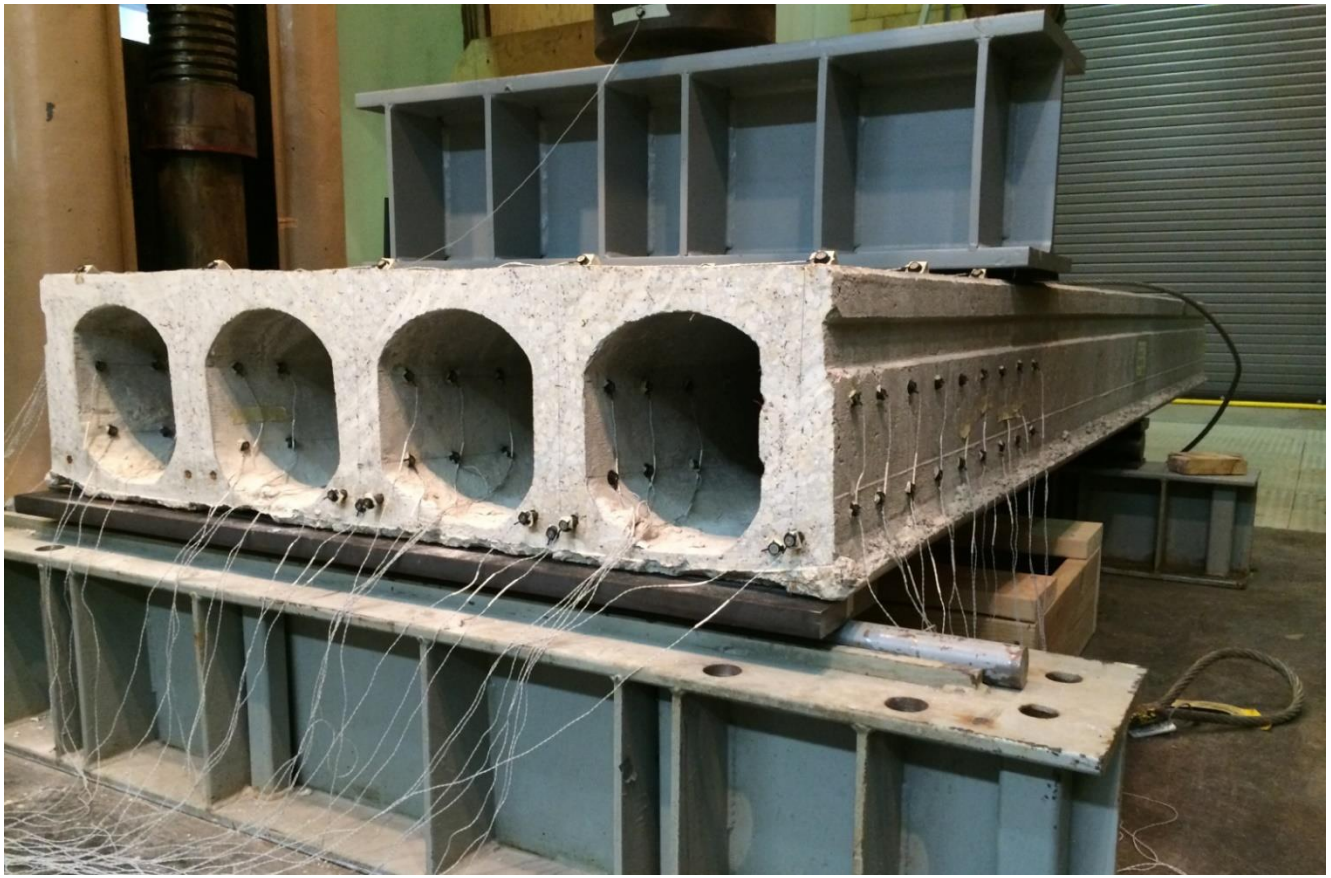
- Increase in shear strength and ductility with addition of hooked steel fibers



(Dinh, Parra and Wight)

HOLLOW-CORE SLABS

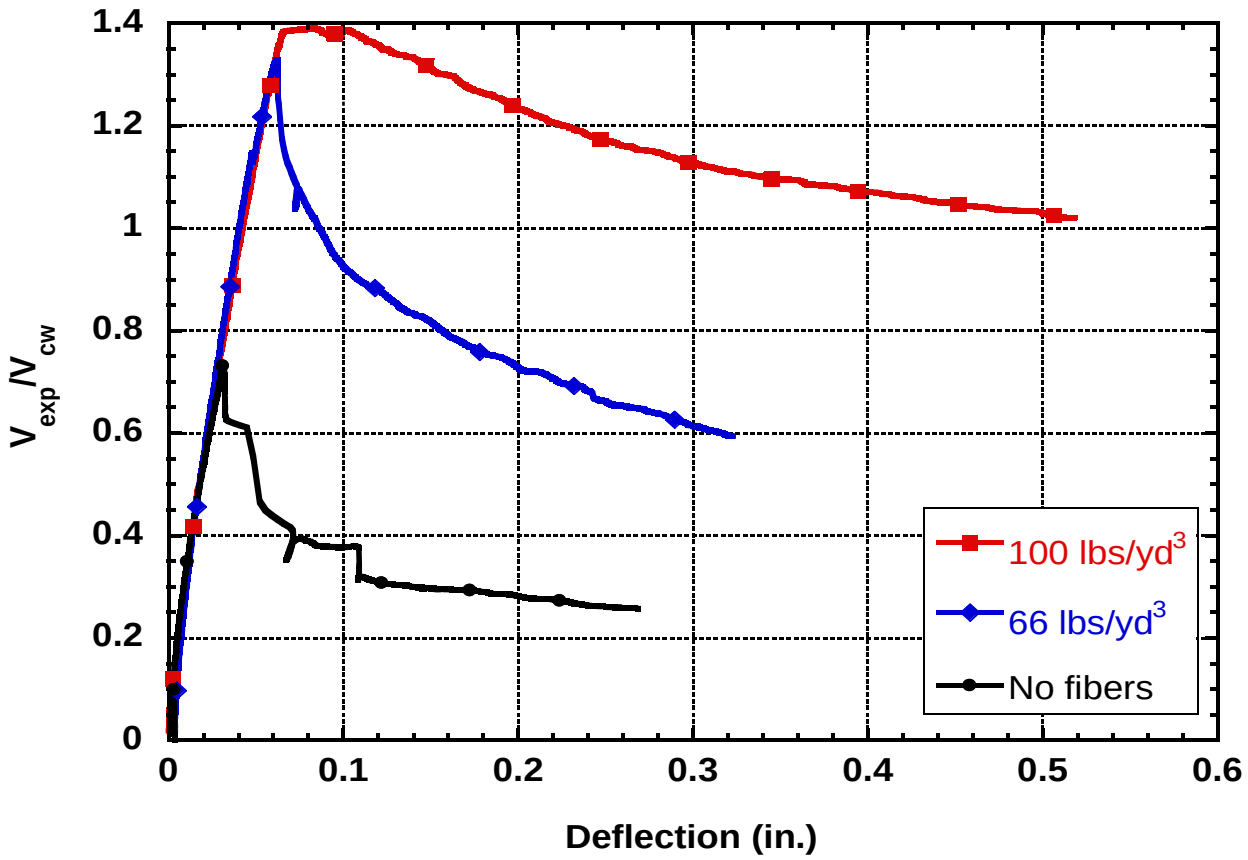
- Deep (300 mm or deeper) prestressed concrete hollow-core slabs may exhibit lower web-cracking shear strengths than shallower slabs



(Dudnik, Milliman and Parra)

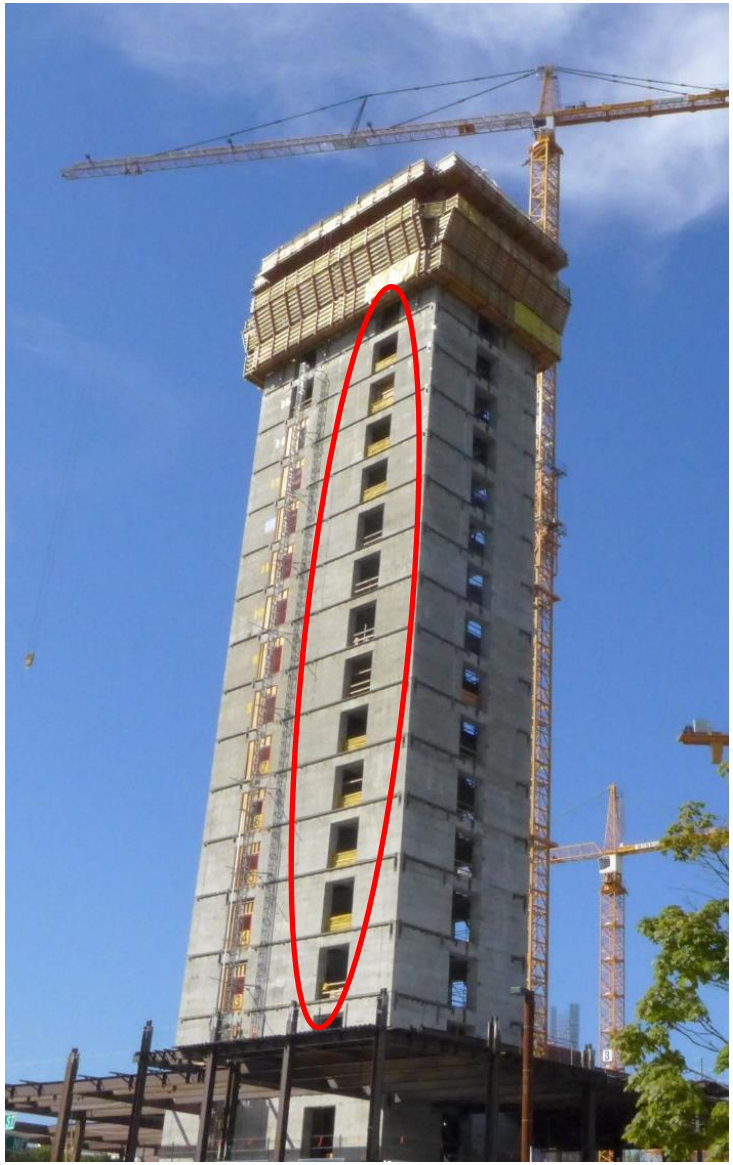
HOLLOW-CORE SLABS

- Behavior of 400 mm deep hollow-core slabs (regular concrete vs. SFRC)



(Dudnik, Milliman and Parra)

LINK OR COUPLING BEAMS



CURRENT PRACTICE

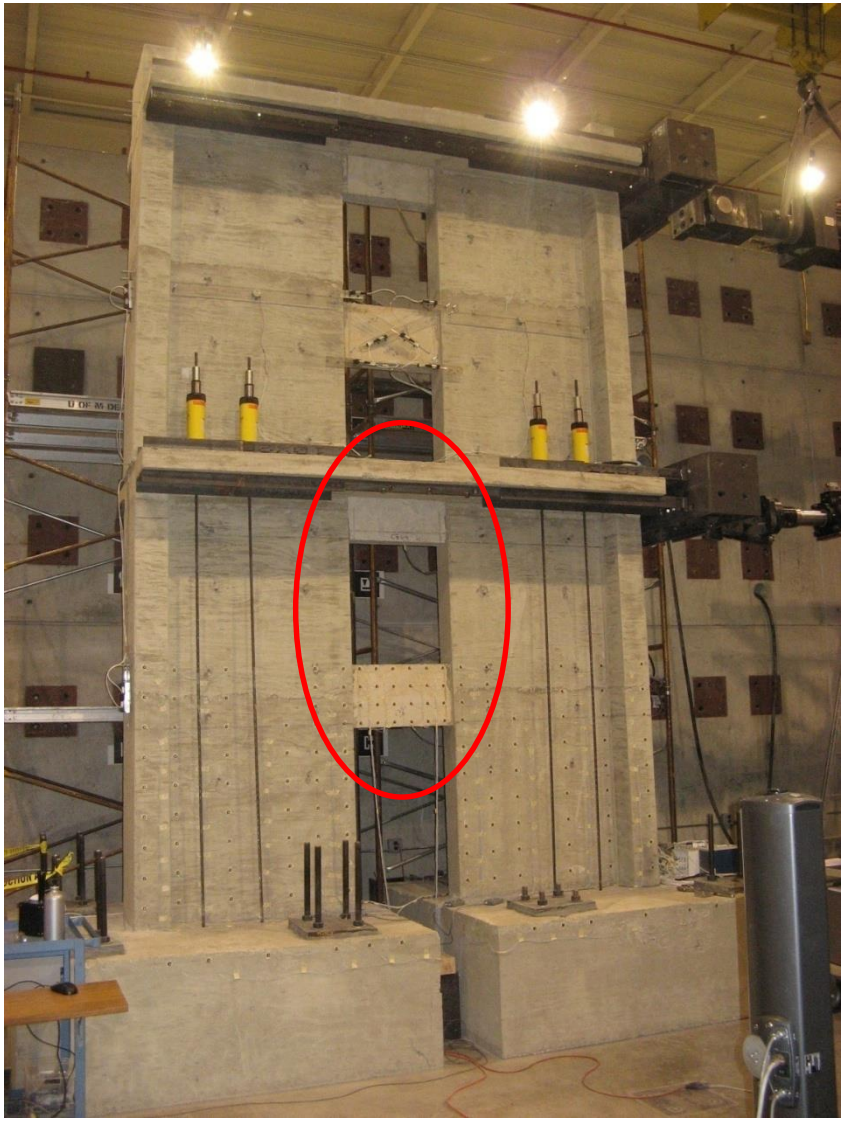
(Courtesy of Rémy Lequesne)

SFRC COUPLING BEAMS

- Use of steel fibers allows elimination of diagonal bars and reduction in confinement reinforcement

(Setkit, Parra and Wight)

EVALUATION OF SFRC COUPLED WALL BEHAVIOR

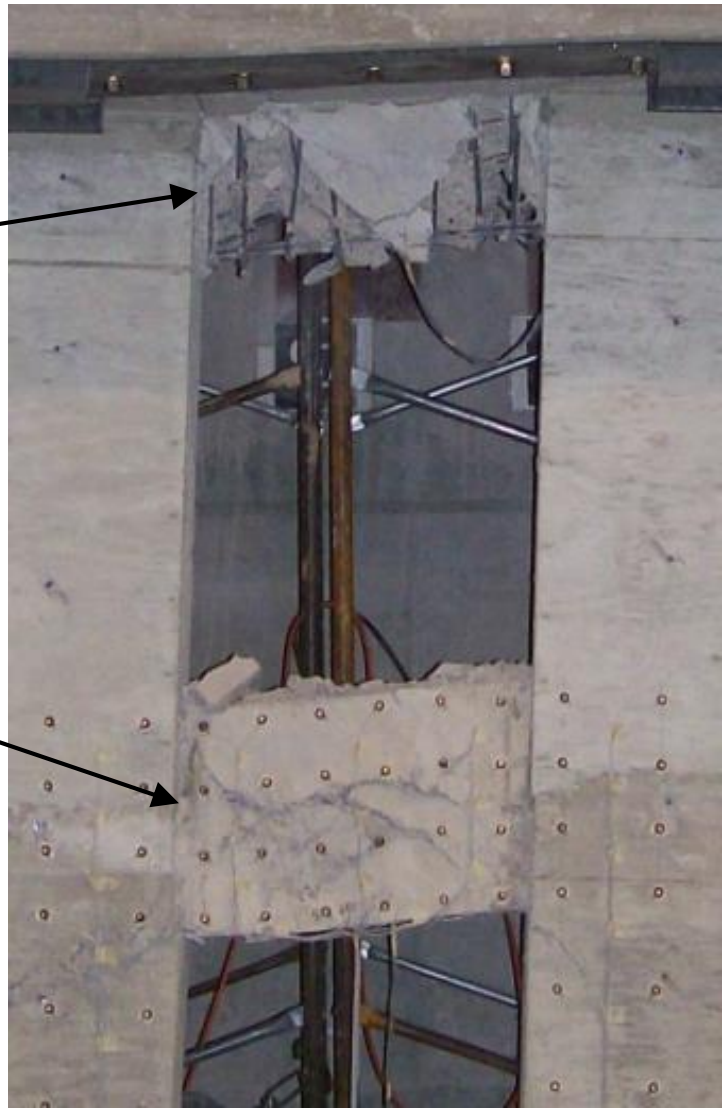


(Lequesne, Parra and Wight)

SFRC vs. RC COUPLING BEAMS

RC Coupling Beam

SFRC Coupling Beam



(Lequesne, Parra and Wight)

SFRC COUPLING BEAMS IN PRACTICE

- 24-story residential building in downtown Seattle, WA
- Core-wall system
- Structural design by Cary Kopczynski & Co.

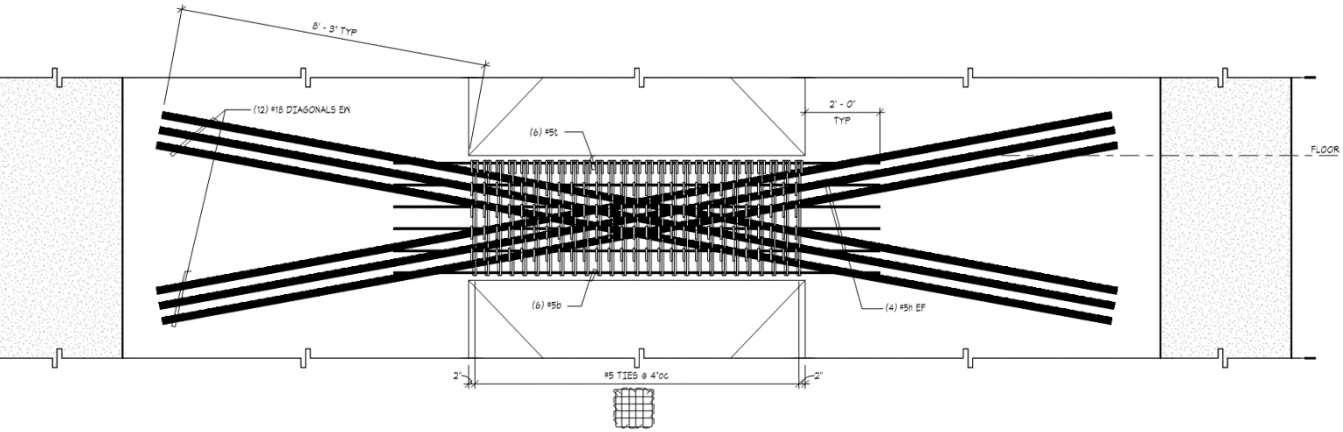
Courtesy of Cary Kopczynski & Co.

CASTING OF SFRC COUPLING BEAMS

Lincoln Square Expansion

BELLEVUE, WASHINGTON

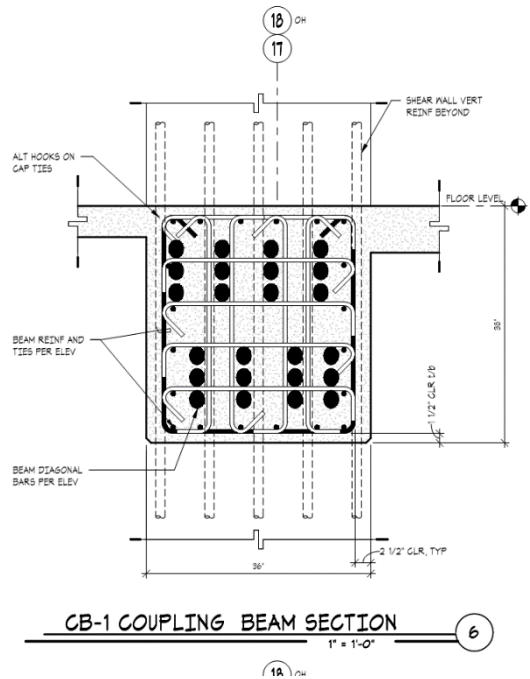
Courtesy of Cary Kopczynski & Co.



CB-1 COUPLING BEAM ELEVATION

1/2" = 1'-0"

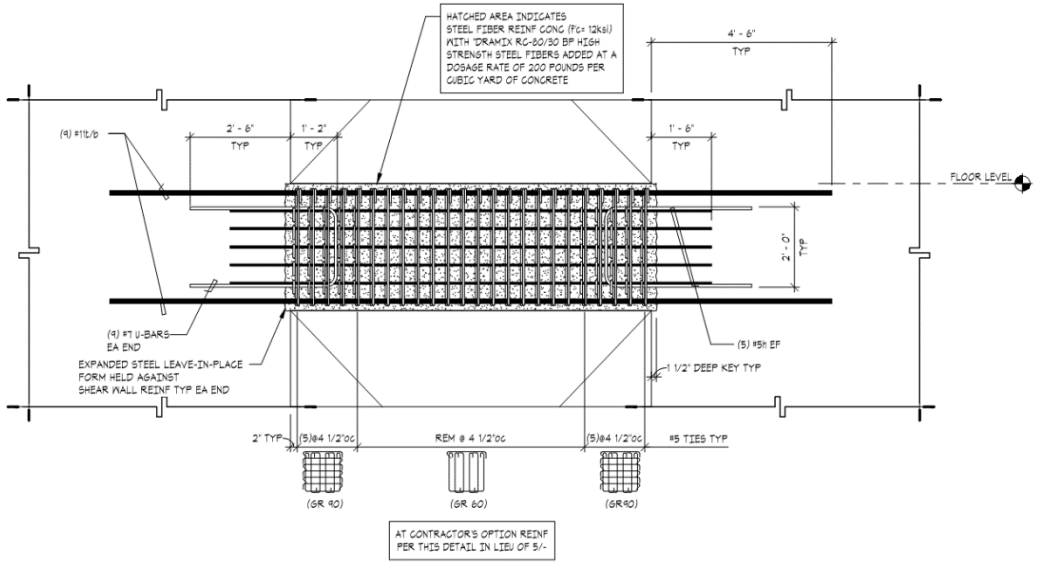
5



CB-1 COUPLING BEAM SECTION

1" = 1'-0"

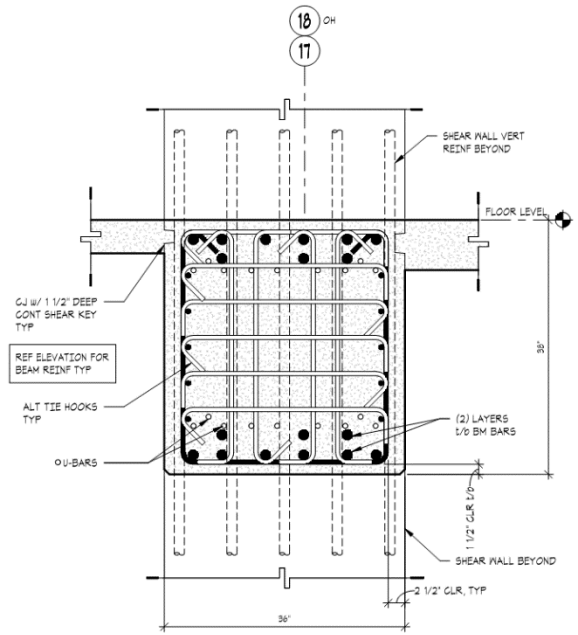
6



FRC ALTERNATE CB-1 BEAM ELEVATION

1/2" = 1'-0"

17

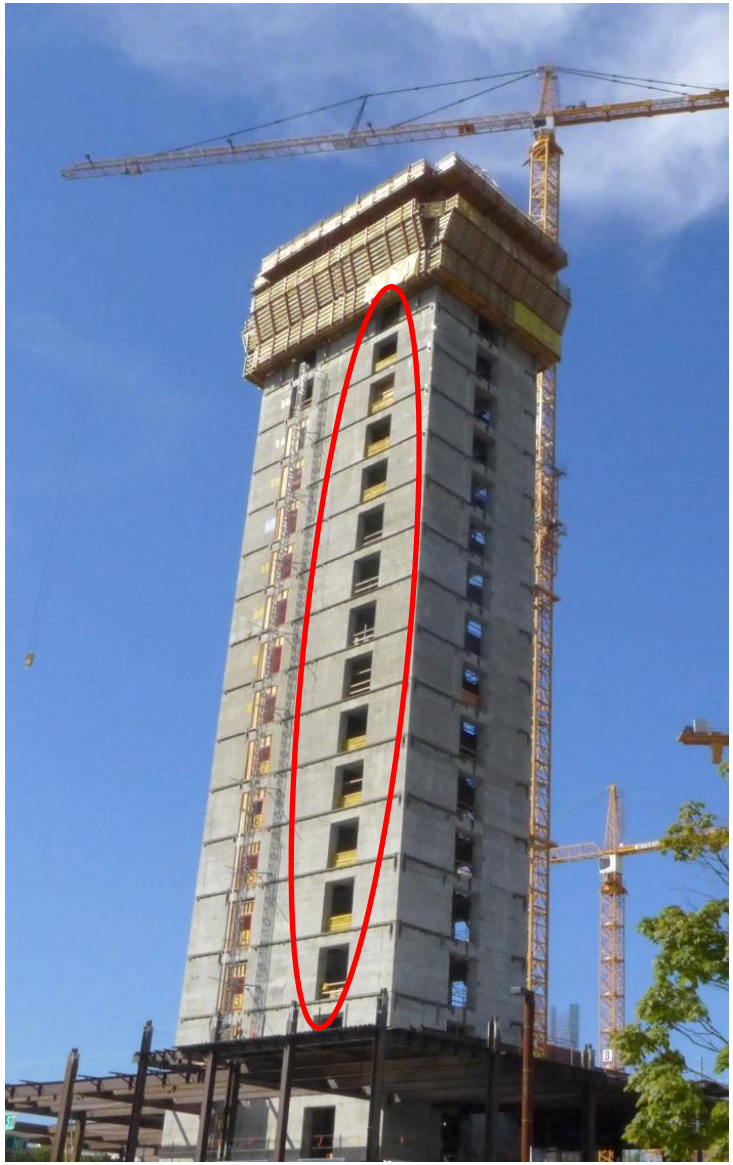


FRC ALT CB-1 BEAM SECTION

1" = 1'-0"

18

LINCOLN SQUARE EXPANSION



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SUMMARY AND CONCLUSIONS

- Steel fibers can effectively be used as shear and confinement reinforcement, particularly where intricate reinforcement detailing is required to ensure adequate behavior
- Recent practice has shown that steel fiber reinforced concrete can be used in large-scale applications with fiber dosages of up to 1.5% by volume
- As design provisions for steel fiber reinforced concrete are introduced in building codes, it is expected that steel fibers will be more widely used in structural applications

Thank you