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Fiber Alignment:

The Bridge Between Efficient UHPC Design & Actual Capacity

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Traditional brittle behavior of concrete

Personal photo of presenter

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Personal photo of presenter

Traditional brittle behavior of concrete

VS

UHPC exhibiting significant post-crack ductility

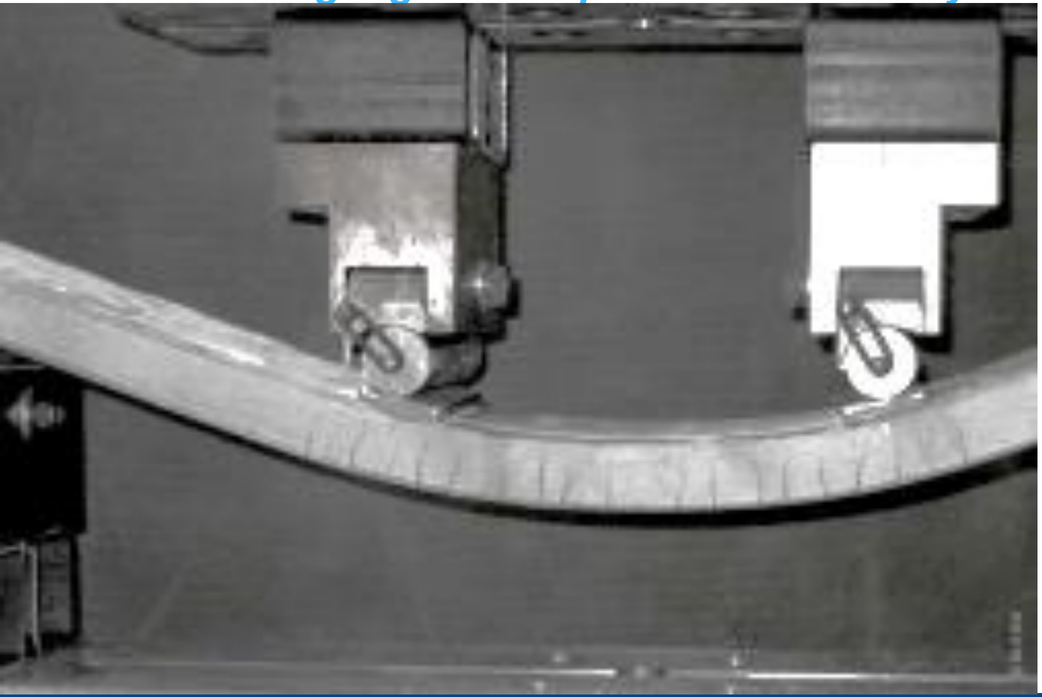
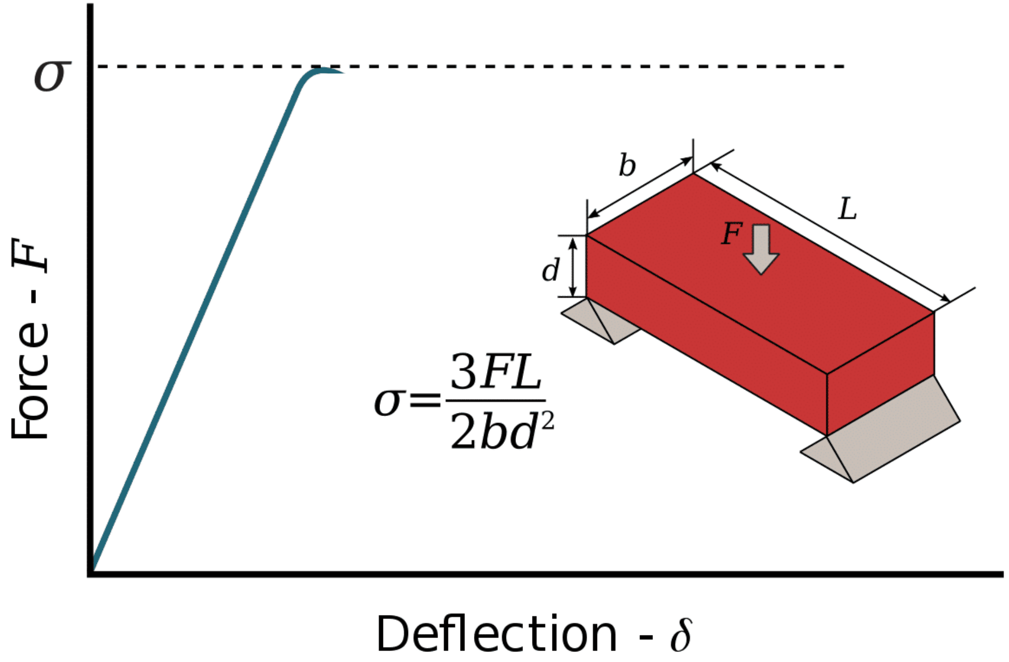


Image courtesy of FHWA



Traditional brittle behavior of concrete

ASTM C78 Load-Deflection Curve

https://theconstructor.org/structural-engg/modulus-rupture-concrete-beam/26215/

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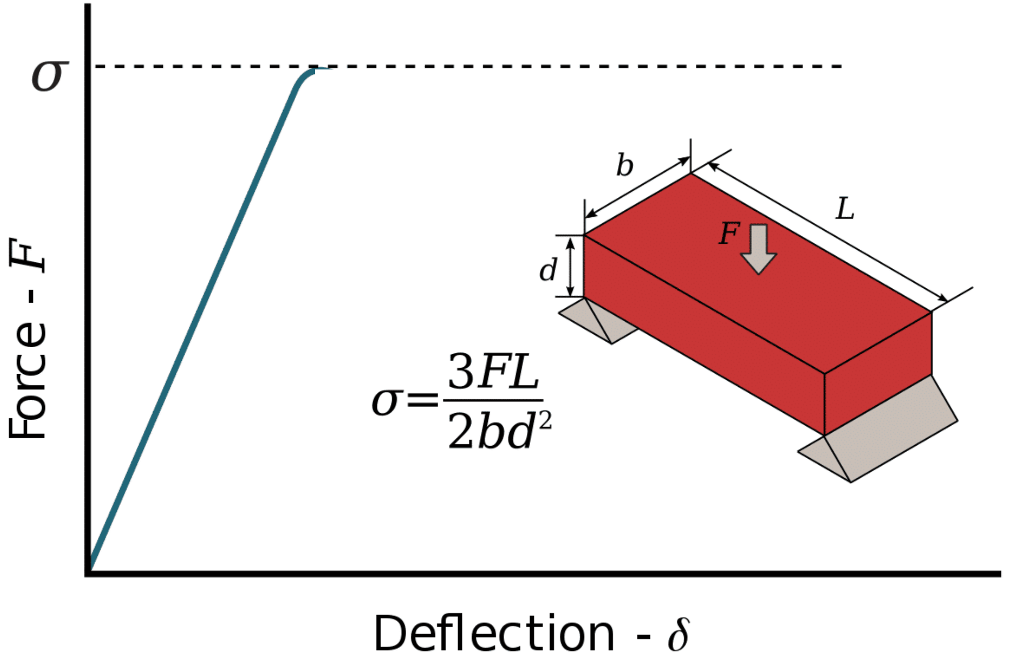

Traditional brittle behavior of concrete

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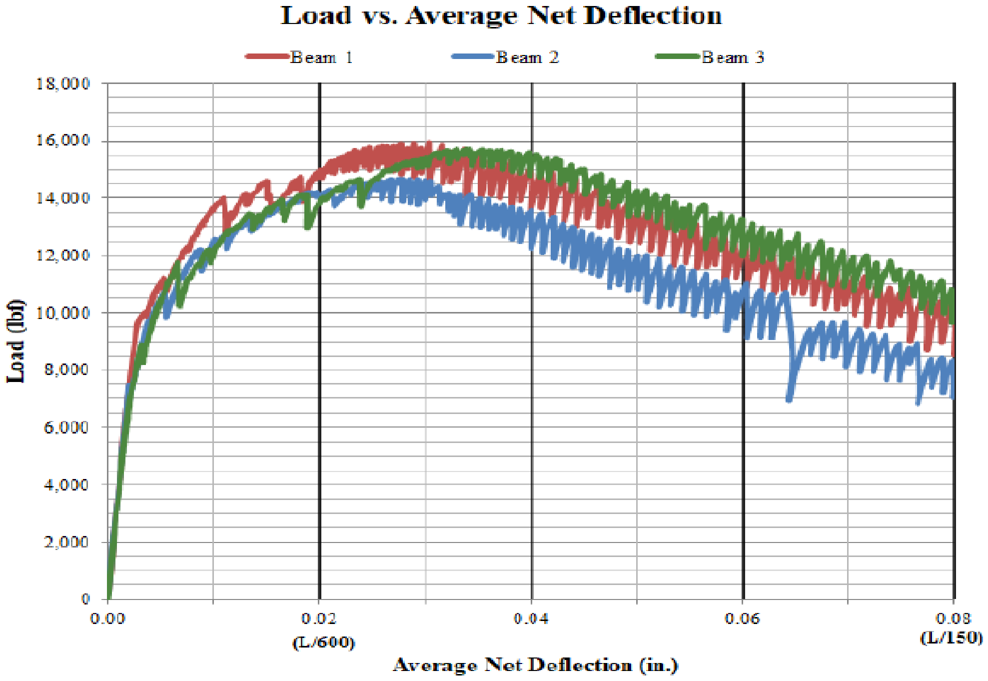


ASTM C1609 Load-Deflection Curve

GUIDE TO DESIGN WITH FIBER-REINFORCED CONCRETE (ACI 544.4R-18)

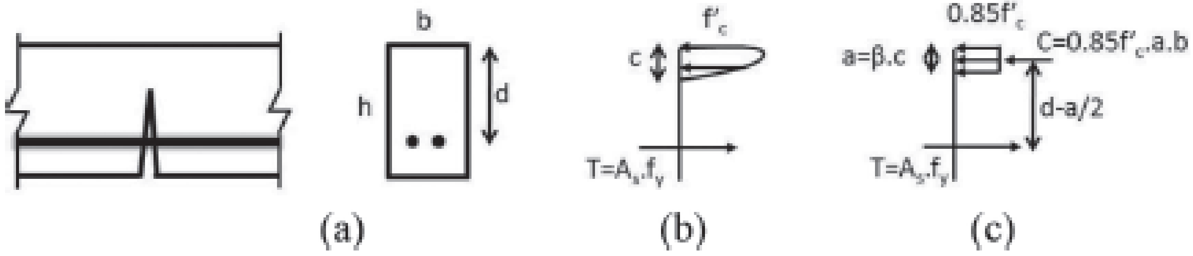
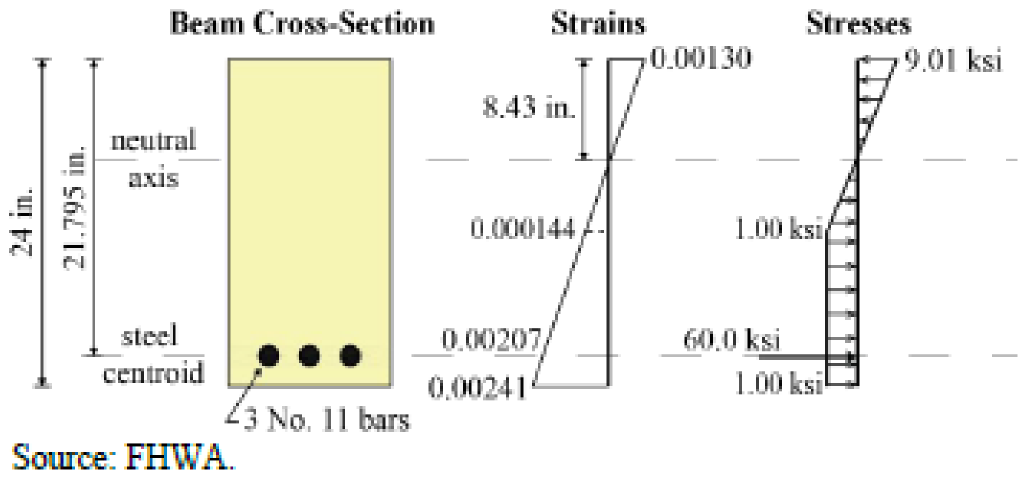


Fig. 4.4—Schematics of stress block for a cracked reinforced concrete flexural member without fibers: (a) reinforced concrete beam section; (b) actual distribution of normal stresses; and (c) simplified distribution of normal stresses.

Traditional Sectional Response of Reinforced Concrete

ACI 544.4R-18, Figure 4.4
Traditional Reinforced Concrete Sectional Response in Bending

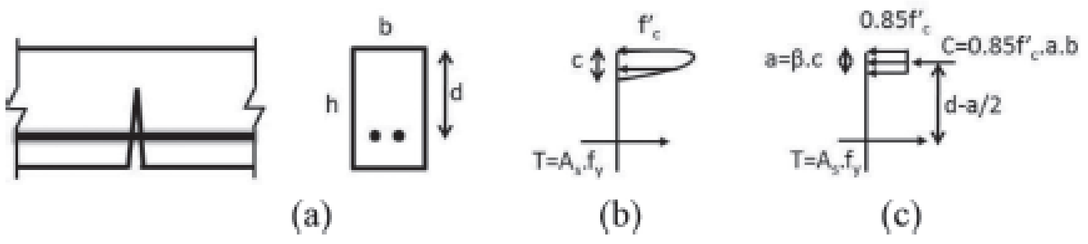
Convert Behavior into Section Design Response



FHWA-HRT-23-077, Figure B.3.2-4
UHPC Sectional Response in Bending

VS

GUIDE TO DESIGN WITH FIBER-REINFORCED CONCRETE (ACI 544.4R-18)



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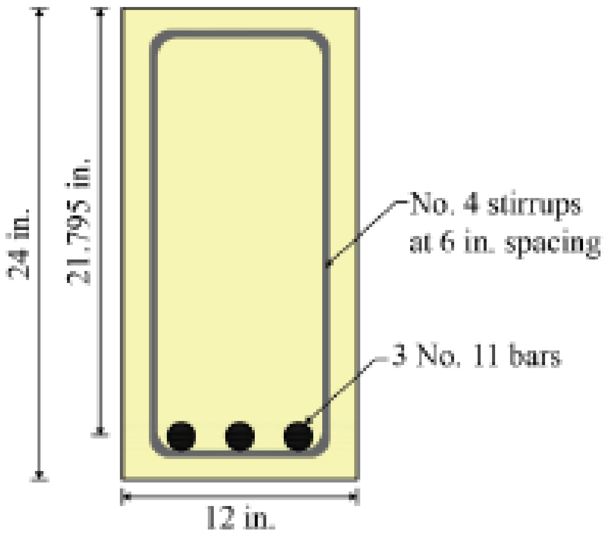
ACI 544.4R-18, Figure 4.4
Traditional Reinforced Concrete Sectional Response in Bending

UHPC Beam Design

FHWA HRT-23-077, Appendix B Rectangular Beam Example



Source: FHWA.

Figure B1-1. Illustration. Cross-section detail.

Tensile Property Reduction Factor, γ_u = **1.00**

Nominal Moment Capacity, ΦM_n = **514.4 k-ft**

Flexural Contribution:

➢ ***Tension from (3) #11 Bars =***	***280.8 kips***	***60.2%***
➢ ***Tension from UHPC @ Localization =***	***185.3 kips***	***39.8%***
➢ ***Height of Shape in Tension (Post-Crack) =***	***15.44 inches***	***64.3%***

Shear Contribution:

➢ ***Shear Resistance from #11 Stirrups @ 6" =***	***114.5 kips***	***23.2%***
➢ ***Shear Resistance from UHPC =***	***379.9 kips***	***76.8%***

Fibers Matter!

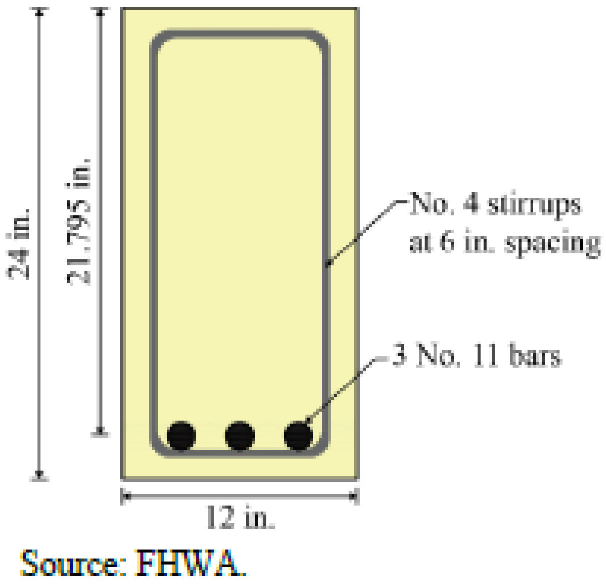


Figure B1-1. Illustration. Cross-section detail.

Tensile Property Reduction Factor, γ_u = **0.85**

Nominal Moment Capacity, ΦM_n = **492.7 k-ft [-4.3% capacity]**

Flexural Contribution:

- ***Tension from (3) #11 Bars = No change***
- ***Tension from UHPC @ Localization = - 13.8%***
- ***Height of Shape in Tension (Post-Crack) = 1.6% taller crack***

Shear Contribution:

- ***Shear Resistance from #11 Stirrups @ 6" = - 20.6%***
- ***Shear Resistance from UHPC = - 13.6%***

Fibers Matter!

FHWA HRT-23-077, Section 1.1.2 – Design Philosophy

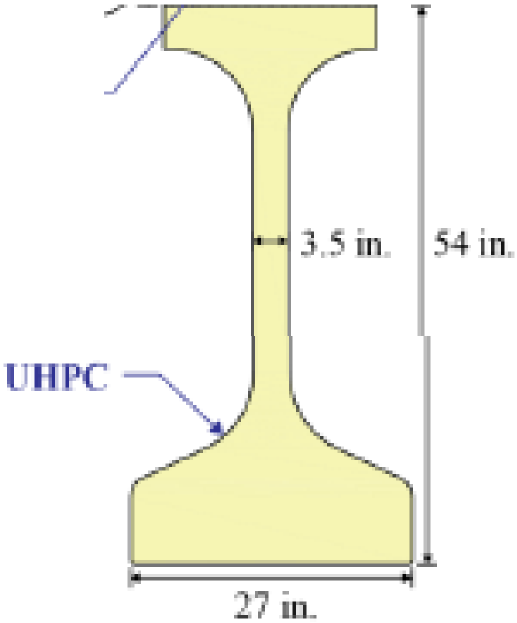
"The tensile resistance behavior of UHPC depends on the distribution and orientation of the fiber reinforcement in the UHPC. These provisions rely on the use of appropriate construction methods to ensure that the fiber reinforcement is evenly dispersed through the member and that adverse fiber orientation effects have been avoided."

Fibers Matter!

Practical Example

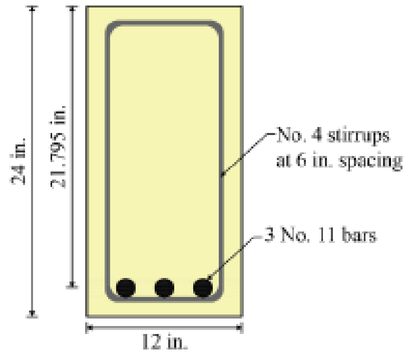
	Placing Method # 1	Placing Method # 2
Parallel to placement	-28%	*27.4 MPa**
Perpendicular to placement	-43%	*29.8 MPa*

Impact is Directly & Exponentially Correlated With Height



54” UHPC Prestressed Girder Shape

FHWA HRT-23-077, Appendix C



24” UHPC Rectangular Beam

FHWA HRT-23-077, Appendix B

Example:
Prestressed Bridge Girder

FHWA HRT-23-077, Appendix C Example

(a)

Total Fiber Count:
1.8 billion

Figure 4 from El-Helou, R., & Graybeal, B. (2023). Shear Design of Strain-Hardening Fiber-Reinforced Concrete Beams. *ASCE Journal of Structural Engineering*.

Example:

Shear Critical Section

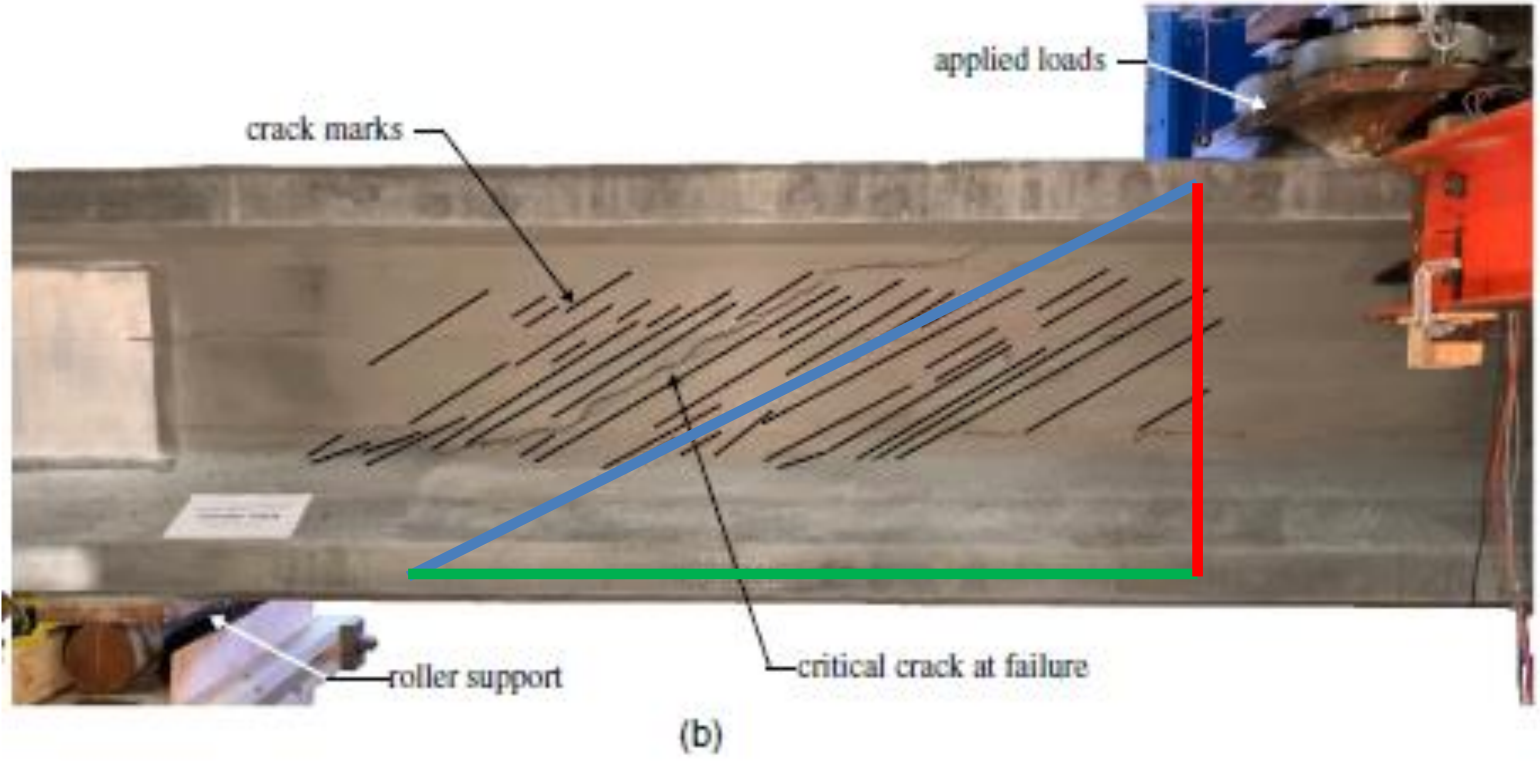
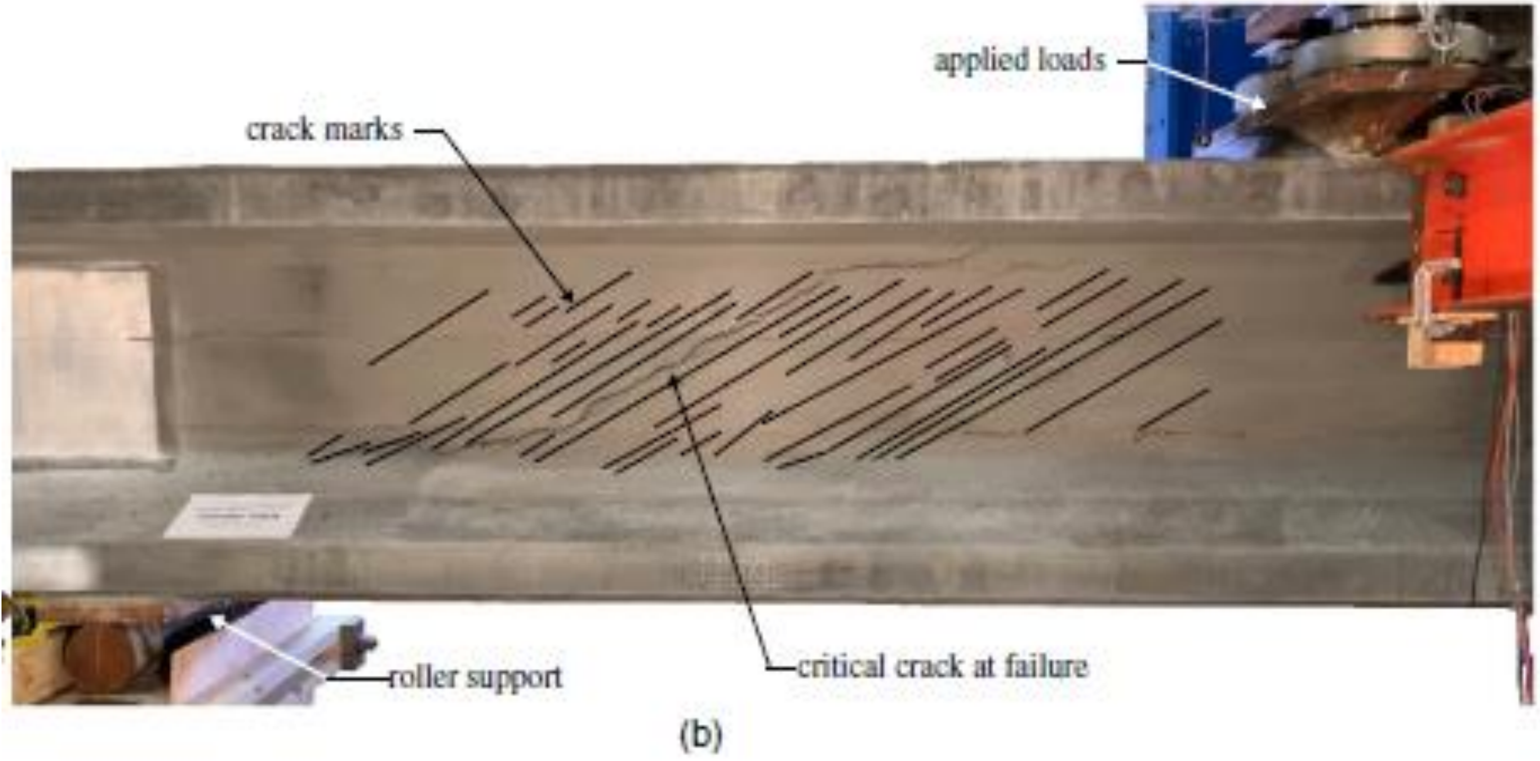


Figure 4 from El-Helou, R., & Graybeal, B. (2023). Shear Design of Strain-Hardening Fiber-Reinforced Concrete Beams. *ASCE Journal of Structural Engineering*.

Fiber Count:
100 million

Example:

Preferential Alignment - Random



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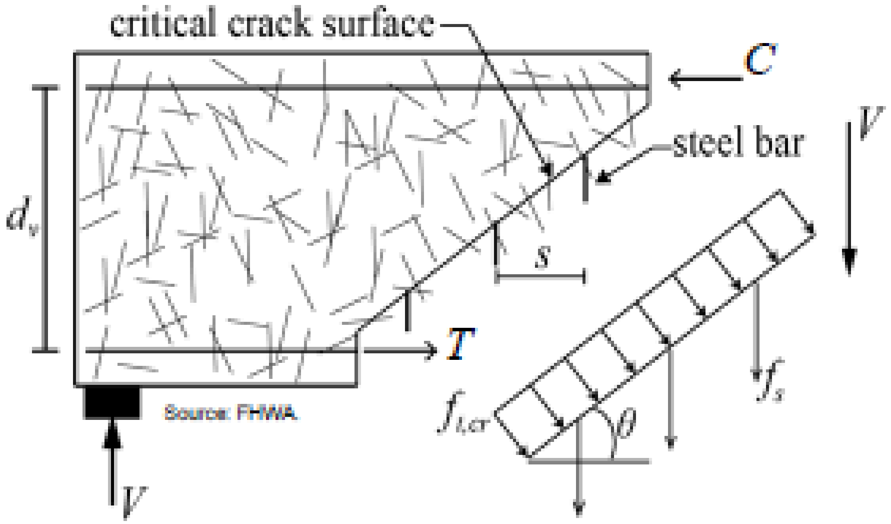
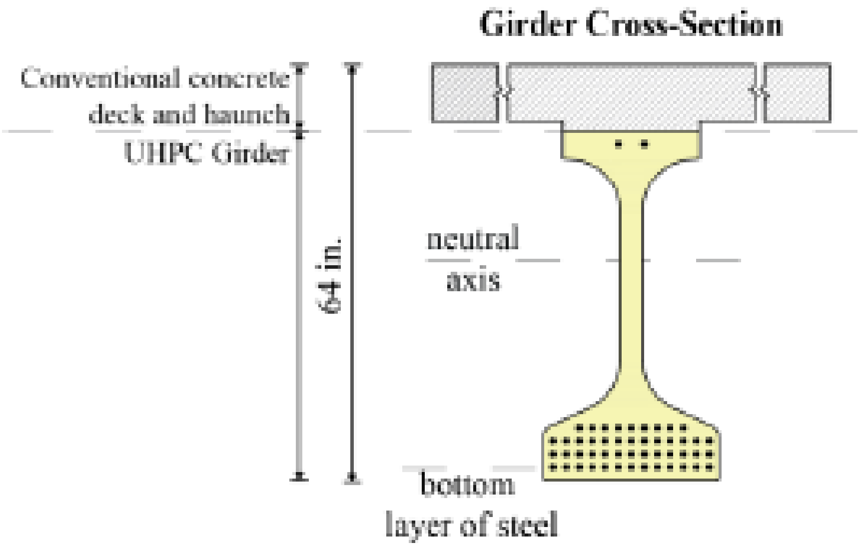


Example:
Flexural Critical Section - Midspan



Source: FHWA.

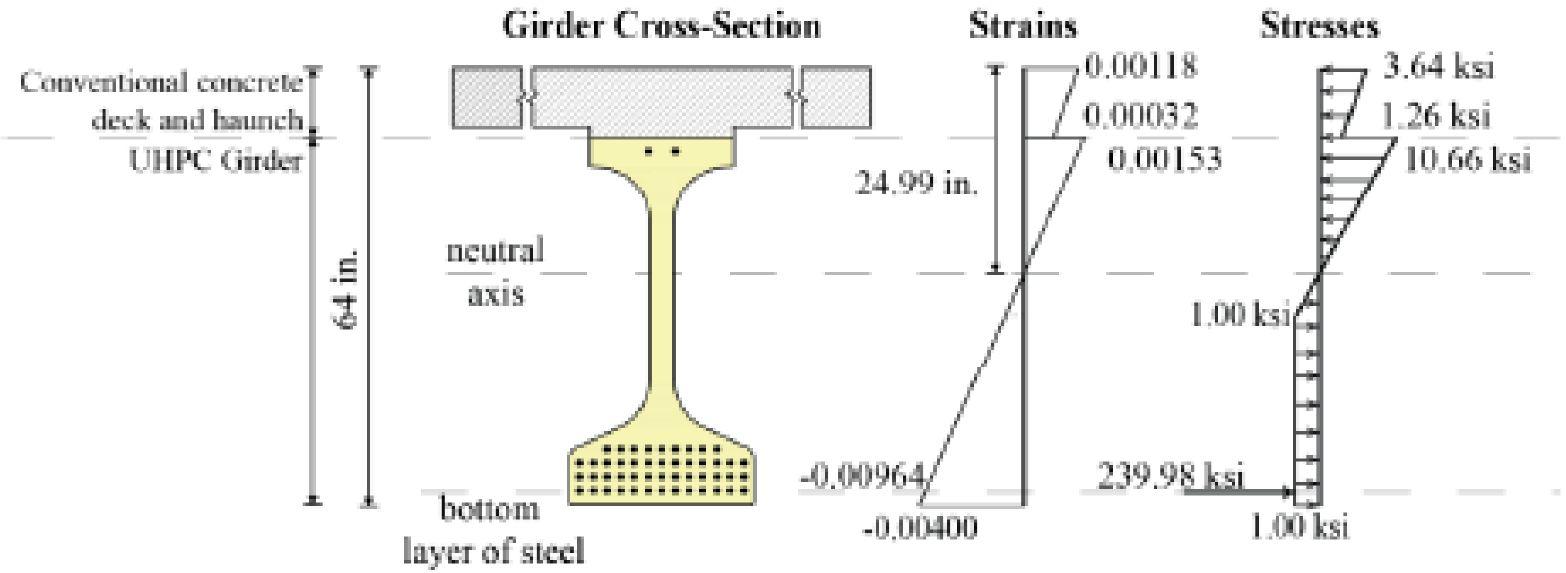
Figure C10-2. Illustration. Mode III: UHPC crack localization.

FHWA HRT-23-077, Appendix C

1440 LF of strand for 250sf of obstructed flow

Example:

Preferential Alignment – Aligned



Source: FHWA.

Figure C10-2. Illustration. Mode III: UHPC crack localization.

FHWA HRT-23-077, Appendix C

Recap:

- ***151ft beam***
- ***1.8 Billion Fibers***
- ***Poured through a 3.5" thick web***
- ***Encompassing > 1 mile worth of strand amongst 48 strands***
- ***Multiple "preferential" alignments***
- ***Can make up 40-80% of tension capacity***

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FHWA

Unique UHPC Infra LLP
https://uniqueuhpcinfra.com/uhpfrc/

FHWA & Iowa DOT

BEST PRACTICES:

LEARN!!! & PREPARE!!!

- ***Review industry precedence***
- ***Consult material supplier(s)***
- ***Perform workability tests prior***

- ***"Batch Math" – no cold joints***
- ***Have a backup plan***
- ***Mock-ups – (French Code)***

COMMUNICATE!!! & COLLABORATE!!!

- ***What does "preferred" mean to THIS member***
- ***What is & is not acceptable***

- ***Two-way feedback***
- ***Adjust as you go***

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Success is not an accident, it is designed.

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