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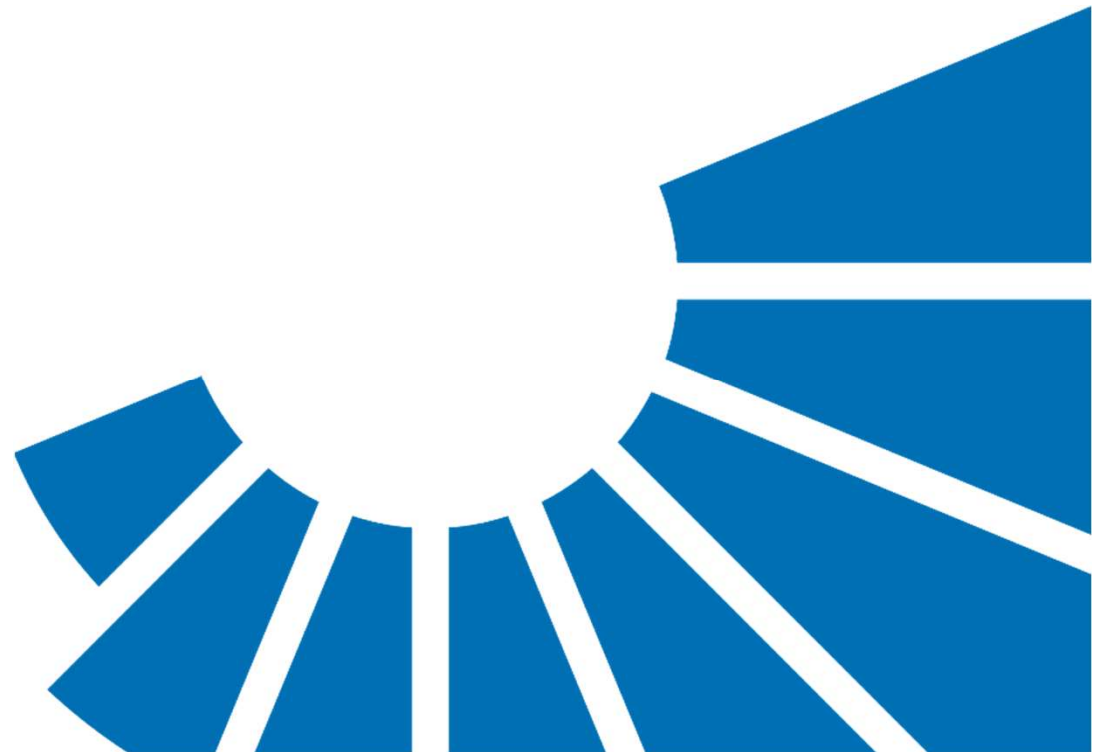
Illinois Ready Mixed Concrete Association

Fibers in Concrete – Applications and Limitations

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4.21.21

A construction products technologies company



AGENDA

General Information

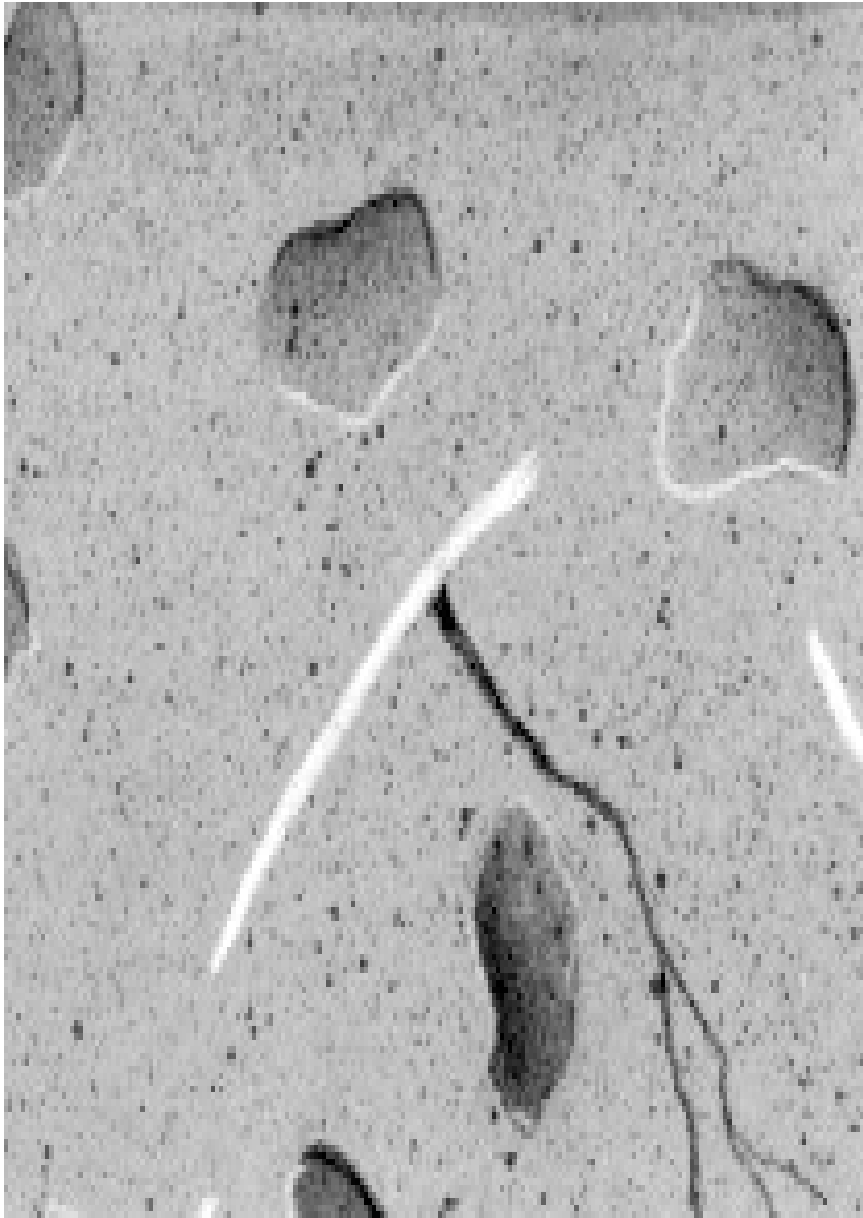
- Micro vs. Macro
- Verification Performance Testing (ASTM 1609, 1399, and 1550)
- Applications

Slab on Ground & Pavement Design Software

- Capabilities of elimination of steel
- VE into projects



What is the Mechanism for Crack



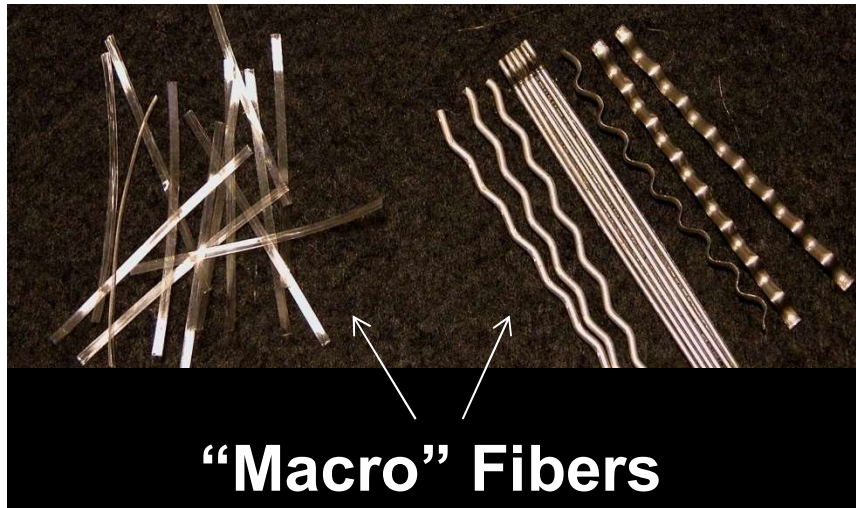
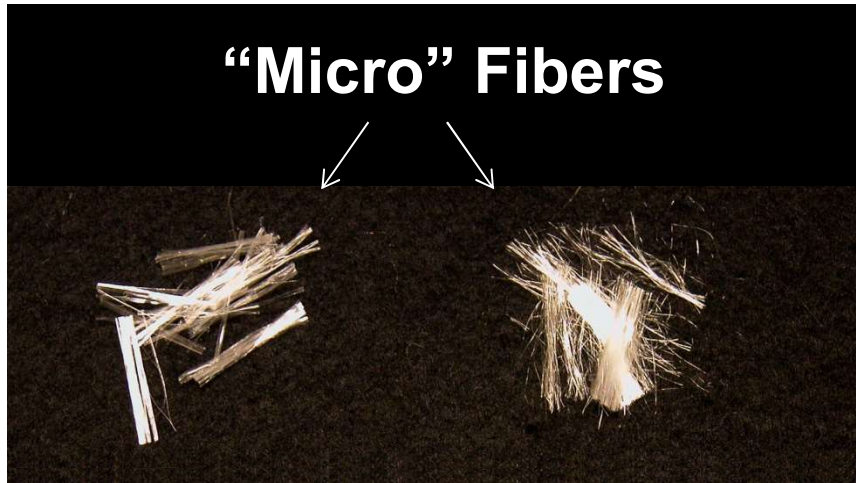
Fibers will intersect cracks when they initiate. This allows for a uniform distribution of the shrinkage stresses that develop and will lessen cracking problems later on....

“Micro” vs. “Macro” Fibers

- Micro (Low Volume Addition) Fibers
 - Diameters < 0.004” (0.1 mm)
 - Polypropylene, Nylon, Carbon, Cellulose
 - 0.03 – 0.1% volume (0.5-1.5#/cy)
 - **Mainly control plastic shrinkage cracking**
- Macro (High Volume Addition) Fibers
 - Diameters: 0.008 – 0.03” (0.2 – 0.8 mm)
 - Synthetic, Steel 0.2 – 1.0% volume [3 - 15#/cy (Synthetic) or 20-100#/cy (Steel)]
 - Improve concrete material characteristics
 - **Flexural toughness, Impact resistance, Fatigue resistance**
 - **NOT STRUCTURAL**



“Micro” vs. “Macro” Fibers



Benefits of Micro Fibers

- Plastic Crack Prevention Only
- Non-Corrosive
- *When to Use*
 - When structures are already reinforced
 - When slab on grades currently have crack control steel
- *When not to Use*
 - As a replacement to crack control steel for Slab on Ground
 - As a replacement to temperature/shrinkage steel for elev. structures
 - Steel replacement in walls, footings, ICF's



Benefits of Synthetic Macro Fibers

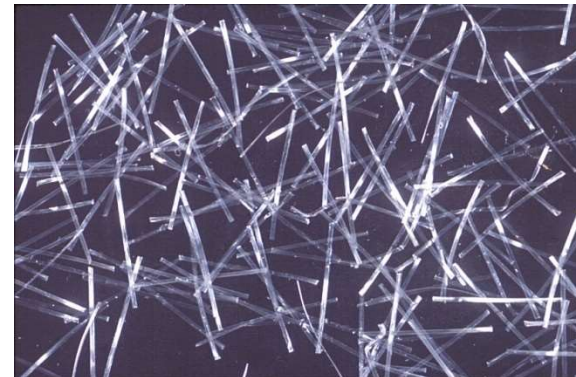
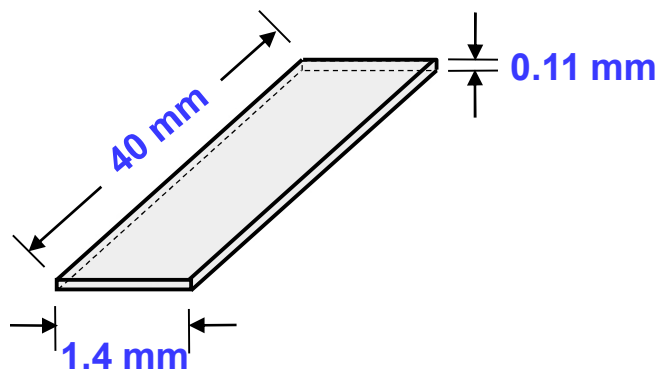
- Tight Crack Control
 - Uniform 3-D reinforcement, compared to 2-D WWM or rebar
 - Free from concerns over positioning of reinforcement
- Scheduling Advances
 - WWM / Rebar means an additional step in construction
- Corrosion - Not possible with Synthetic
- Plastic Shrinkage Control Potential with High Fiber Count Products
- Pumping – Easy on equipment
- Plastic Shrinkage Control
- Placement Simplicity (Tailgating loads)



Typical Macro Synthetic Fiber

- Polypropylene/Polyethylene Monofilament Fiber

Specific Gravity	0.92
Absorption	None
Modulus of Elasticity	9.5 GPa (1378 ksi)
Tensile Strength	620 MPa (90 ksi)
Melting Point	160°C (320°F)
Ignition Point	590°C (1094°F)
Alkali, Acid & Salt Resistance	High

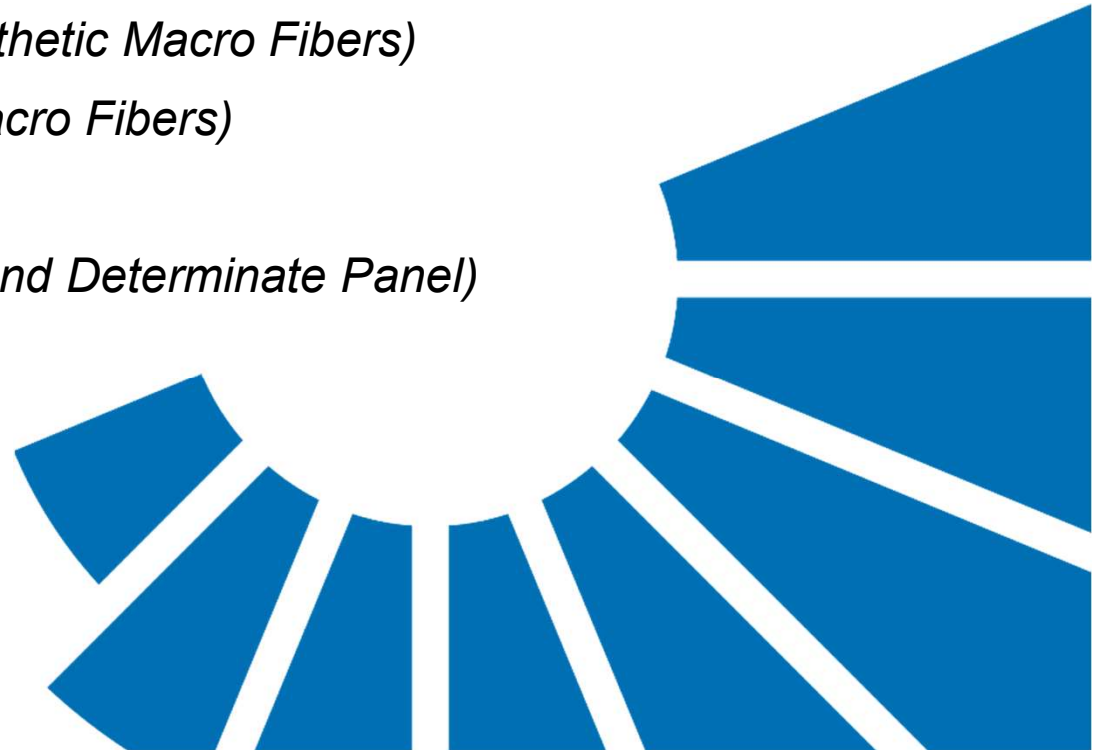




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Verification Performance Testing

- *ASTM C1609-10 (Synthetic Macro Fibers)*
- *ASTM C820 (Steel Macro Fibers)*
- *ASTM C1399-11*
- *ASTM C1550-10 (Round Determinate Panel)*



Verification Test Method

ASTM C1609-12 test procedure

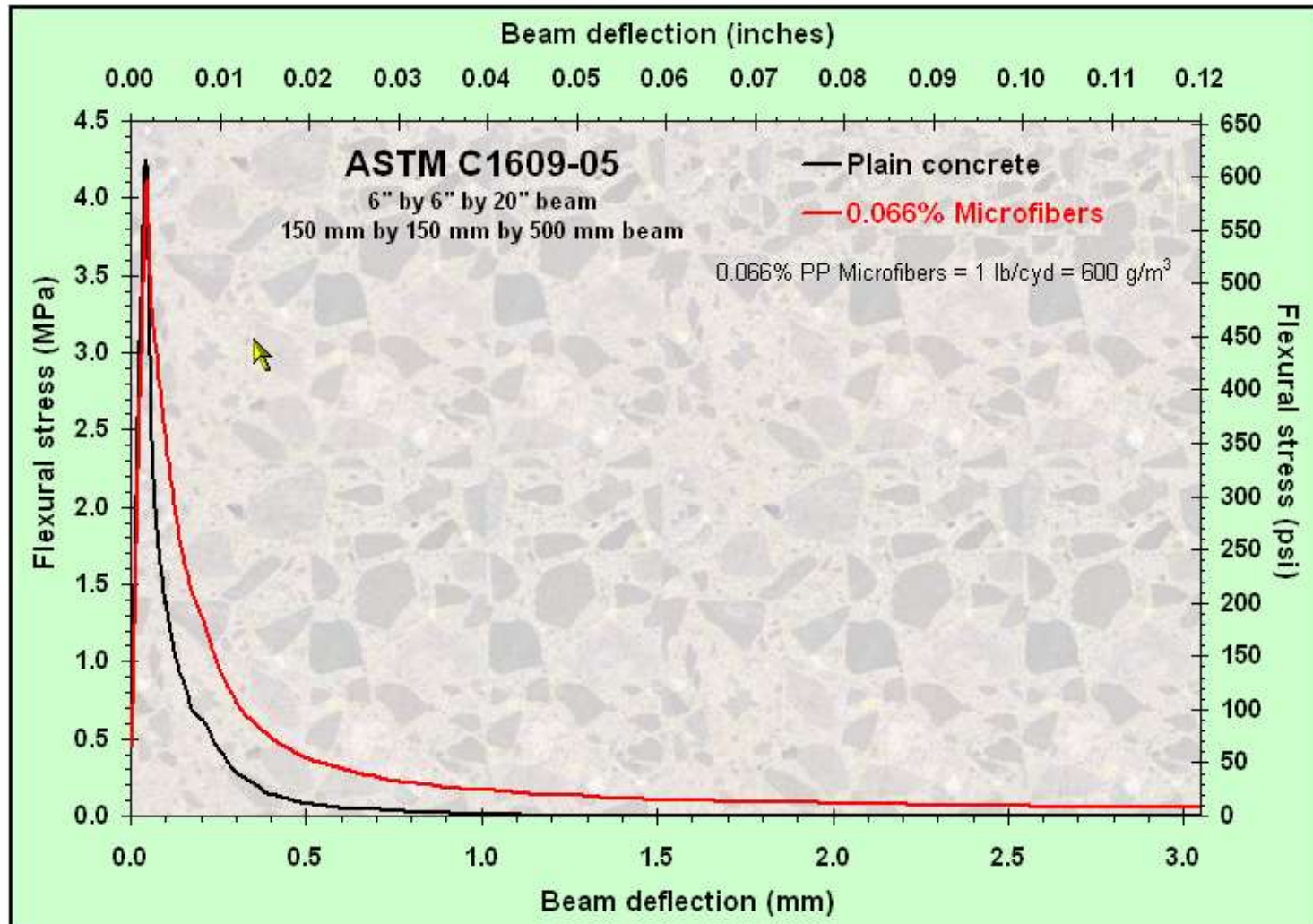


Third Point Loading Test (ASTM C 1609-12)

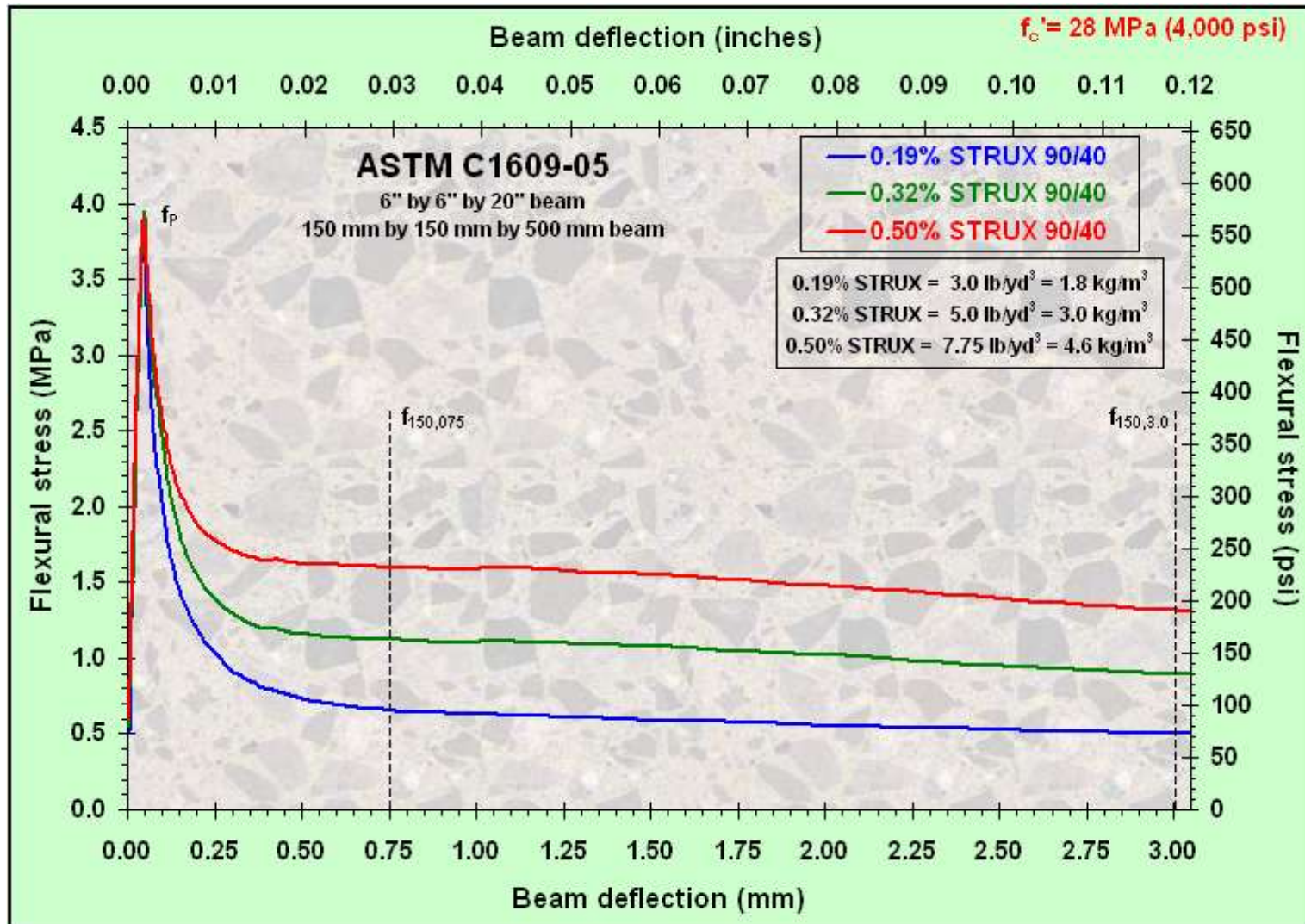
- Closed Loop System
- Sample Size: 6" x 6" x 20" (150mm x 150mm x 500mm)



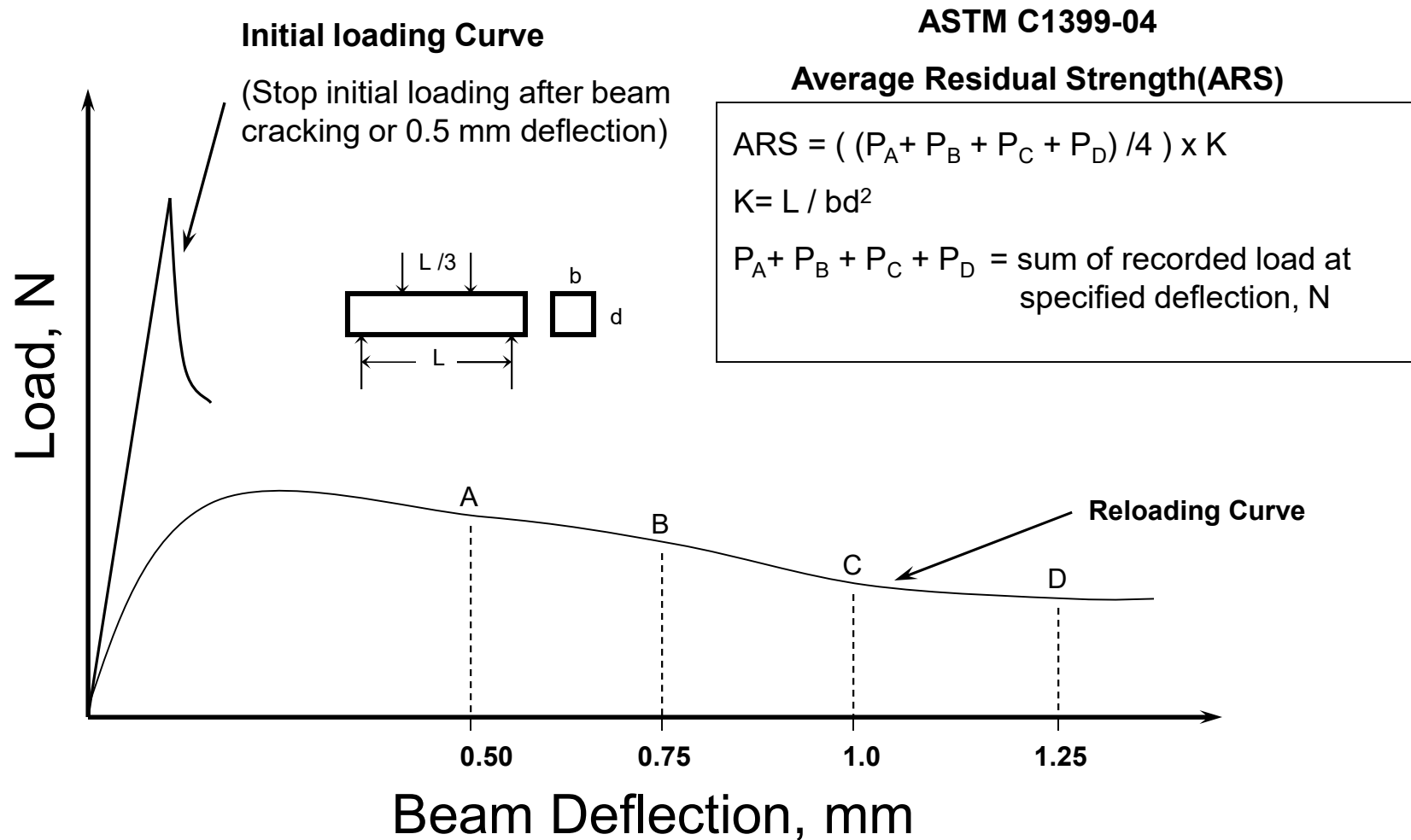
Micro- fibers



Macro-Fibers



Average Residual Strength Evaluation ASTM C1399-11



Australian Round Determinate Panel Test (ASTM C1550-10)

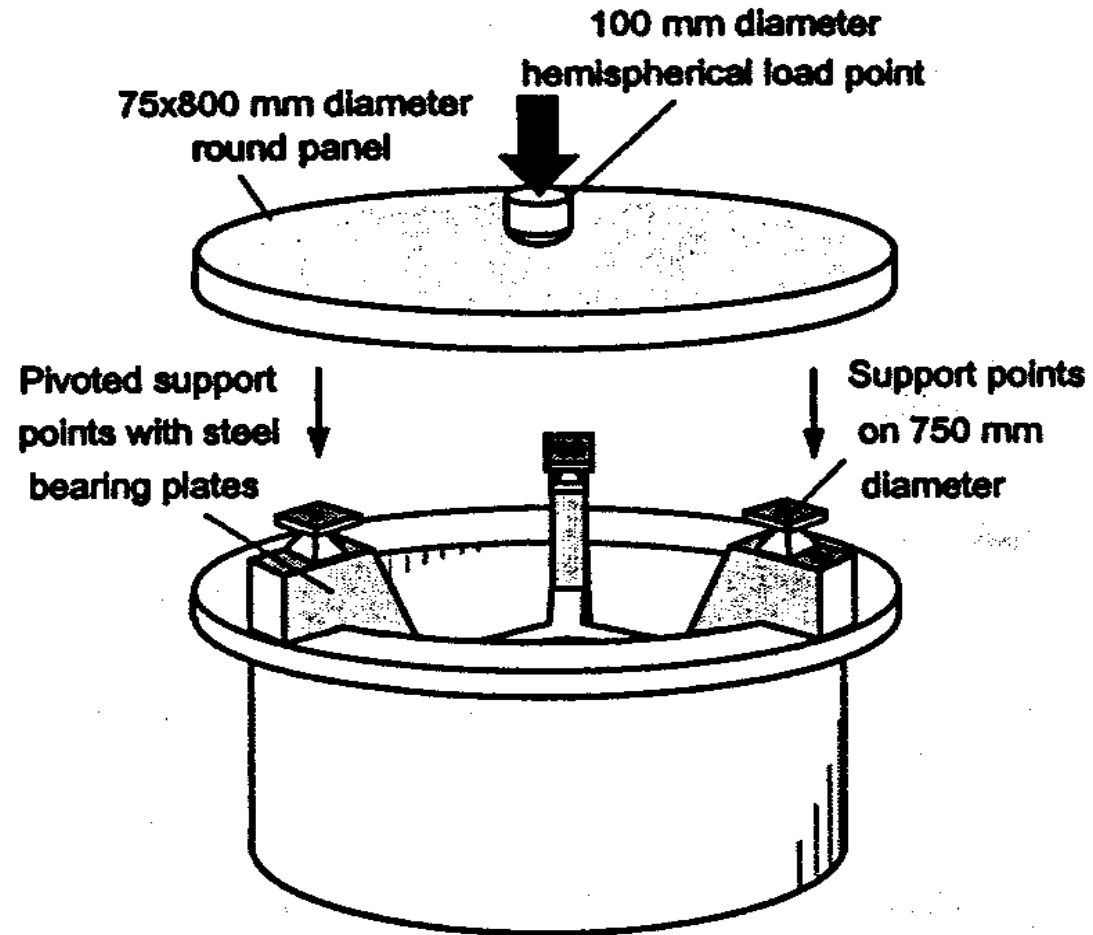


***Mode of failure
dominated
by flexure.***

***This can test
higher
deflections
compared to
ASTM C1609***

32'' (810 mm) diameter x 3'' (76 mm) thick panel
Wire mesh will perform better in thin elements

New Panel Test ASTM C 1550 - 10

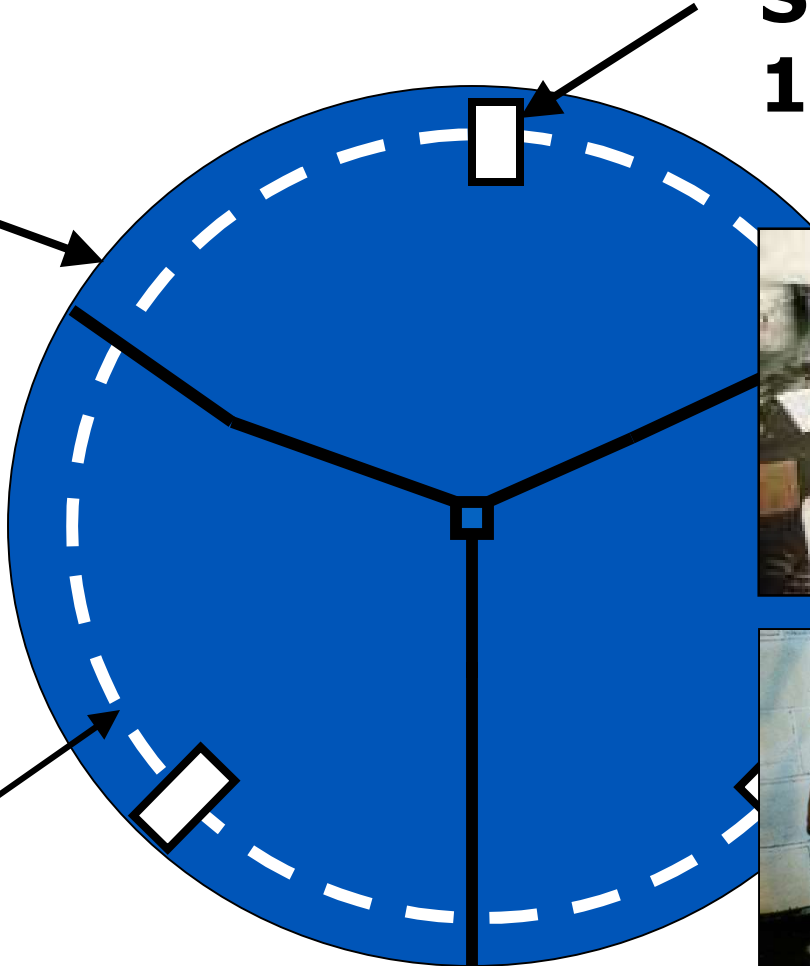


ASTM C 1550-10 Round Panel

**Supports at
120 Degrees**

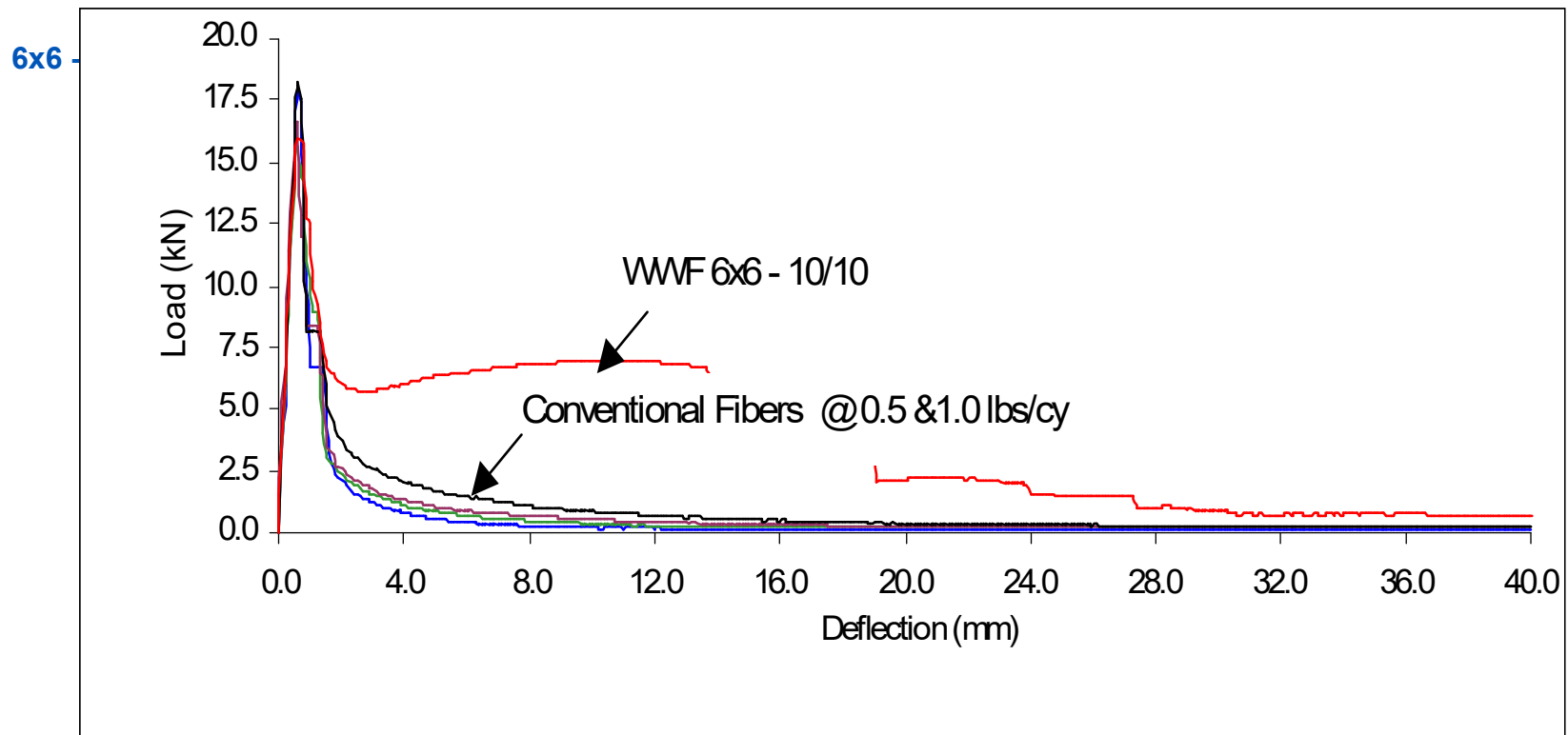
**32 inch
Diameter
Panel
(3" thick)**

**On 30 inch
Diameter
Support**



Round Determinate Panel Results

(up to 40 mm (1.57") deflections)



Applications

Where have Macro Fibers been used?



Precast Concrete Applications



Steps

**Parking
Curbs**



**Septic
Tanks**



Pipes



Manholes



**Insulated
Wall Panels**

Also: Burial Vaults & Catch Basins



Shotcrete



Tunnel Linings



Slope Stabilization



Radiant Heat Slab



Driveway



2-inch Overlay Maintenance Garage



Department of Transportation Acceptance

- Iowa
 - Utah
 - Texas
 - Illinois
 - Kansas
 - Oregon
 - Arizona
 - Colorado
 - California
 - Washington
 - South Dakota
- Applications: *Whitetoppings, Bonded Overlays, Driveway Entrances, Drainage Ditches, Bridge Deck Overlays, Full Depth Bridges*



Iowa DOT Whitetopping / 4 lbs/cy



CURBS





Finishing Expectations

- *Interior Slabs: Burned in Potential* (absolutely no fibers protruding; although they may be seen at surface below paste)
- *Interior Slabs: w/o vibration* (potential to see them increases)
- -----
- *Outside: Bull float, light broom finish with several passes (angled at 10% to the horizontal)*
- *Likely fibers will appear; cracks much unlikely to appear*



Macro Fiber Finishing Requirements



- Power Trowel: Fiber free surfaces are routinely achieved.
- Hand Trowel & Broom Finish: Some fibers on floor surface.

Jointing Procedures and Limitations

- *Interior or Exterior (2-3 Ft. x Thickness in Inches)*
- *Base Material and its reaction to the concrete it supports (k-value)*

- *Limit any Restrained Shrinkage*
- *Poly Sheathing*
- *Zip Strips*
- *Isolation of Penetrations*
- *Cut Control Joints Deep (much deeper than unreinforced)*
 - *The joint must release (avoid dominant joint effect)*

-



Macro Fiber SOG Projects in NA







Macro Fiber SOG Design Software

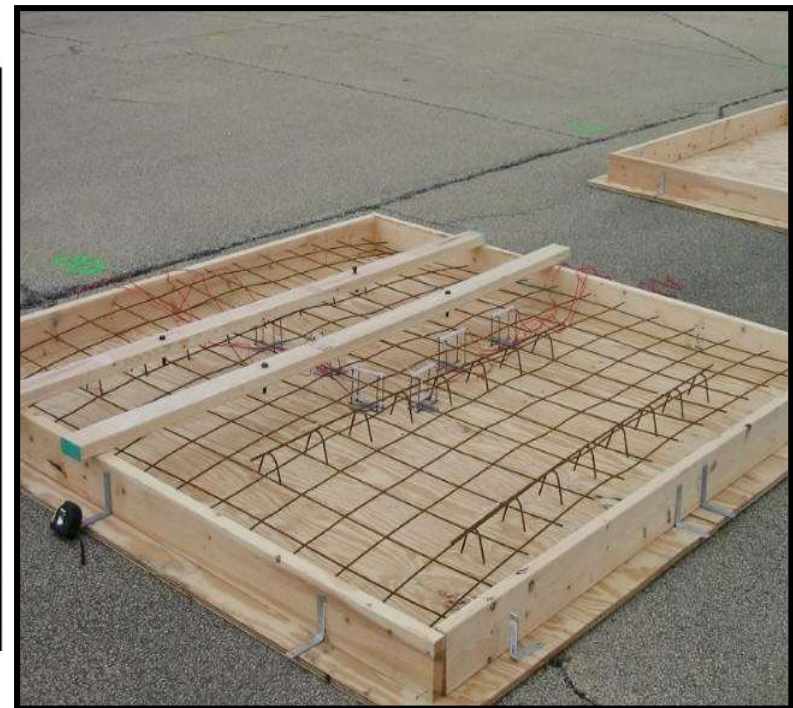


Large Scale SOG Test

University of Illinois

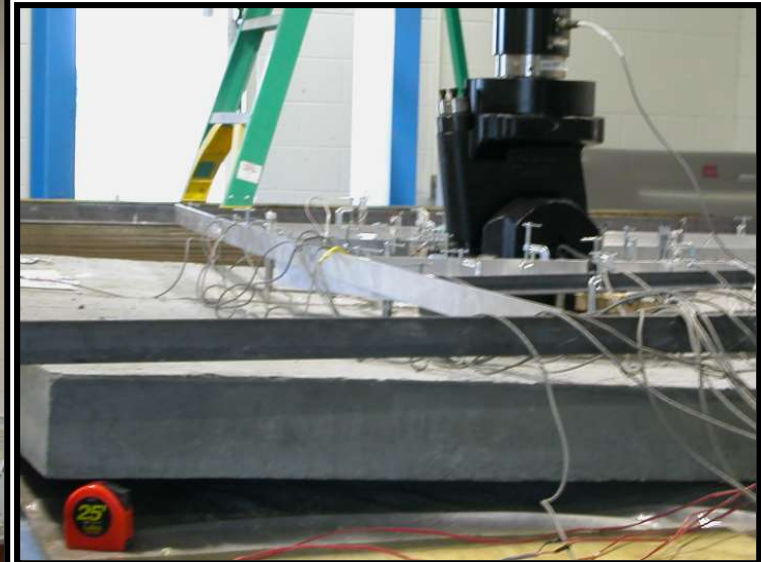
- 7.2' x 7.2' x 5.1" Slabs (2.2 m x 2.2 m x 132 mm)
 - WWM: 6 x 6 – W2.9 (positioned at top-third of the slab)
 - Macro Fiber – 0.33% vol: 5 lbs/cyd (3 kg/m³)
- Ready Mixed Concrete

Materials	WWM Mix		Macro Fiber Mix	
	lbs/cyd	kg/m ³		
Coarse Aggregate	1,678	995		
Fine Aggregate	1,388	823	1,359	806
Cement	612	363	607	360
Water	300	178	307	182
W/C Ratio	0.49		0.51	
% Air	1.8%		2.9%	
f'c	5,960 psi	41.1 MPa	5,235 psi	36.1 MPa

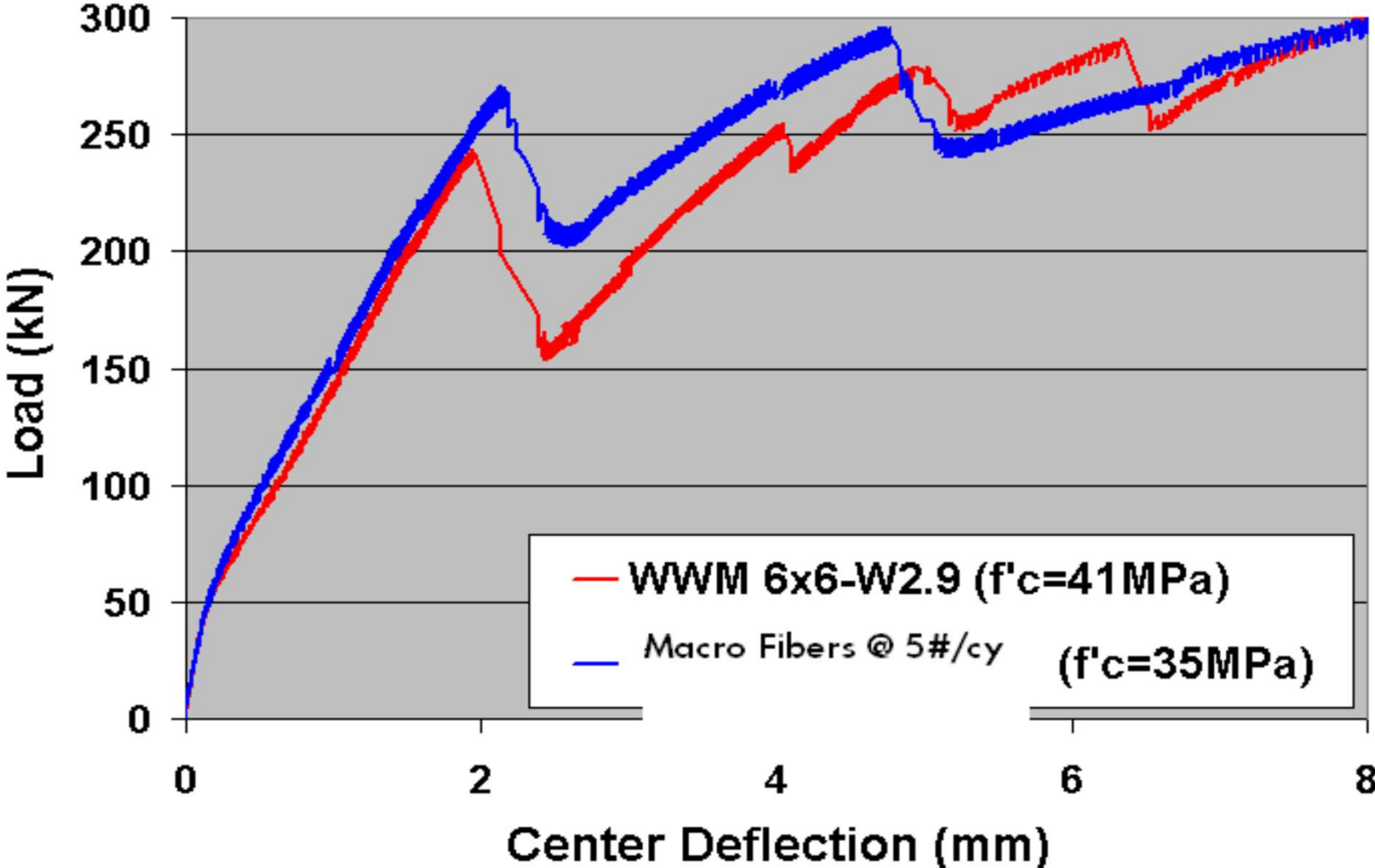


Large Scale SOG Test

- Subgrade: 8" (203 mm) thick compacted clay
- 500 kN capacity MTS Hydraulic Actuator
- Center Loading until Puncture Failure



Large Scale SOG Test



Macro Synthetic vs. WWM



HVSF $\approx 1/16$ " (1.6 mm)

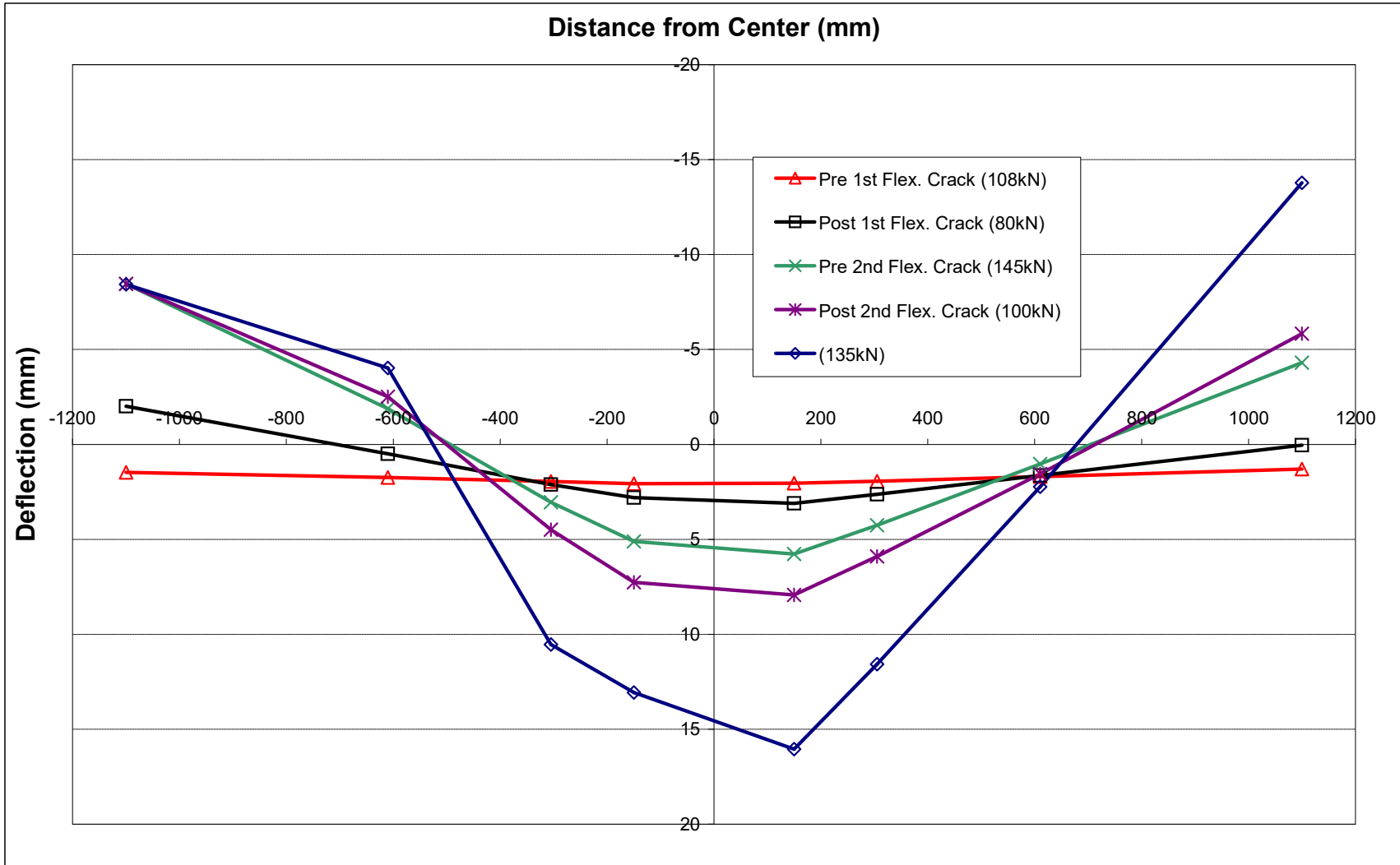


WWM $\approx 3/16$ " (4.8 mm)

- Crack Width Measurements for Large Scale SOG Test

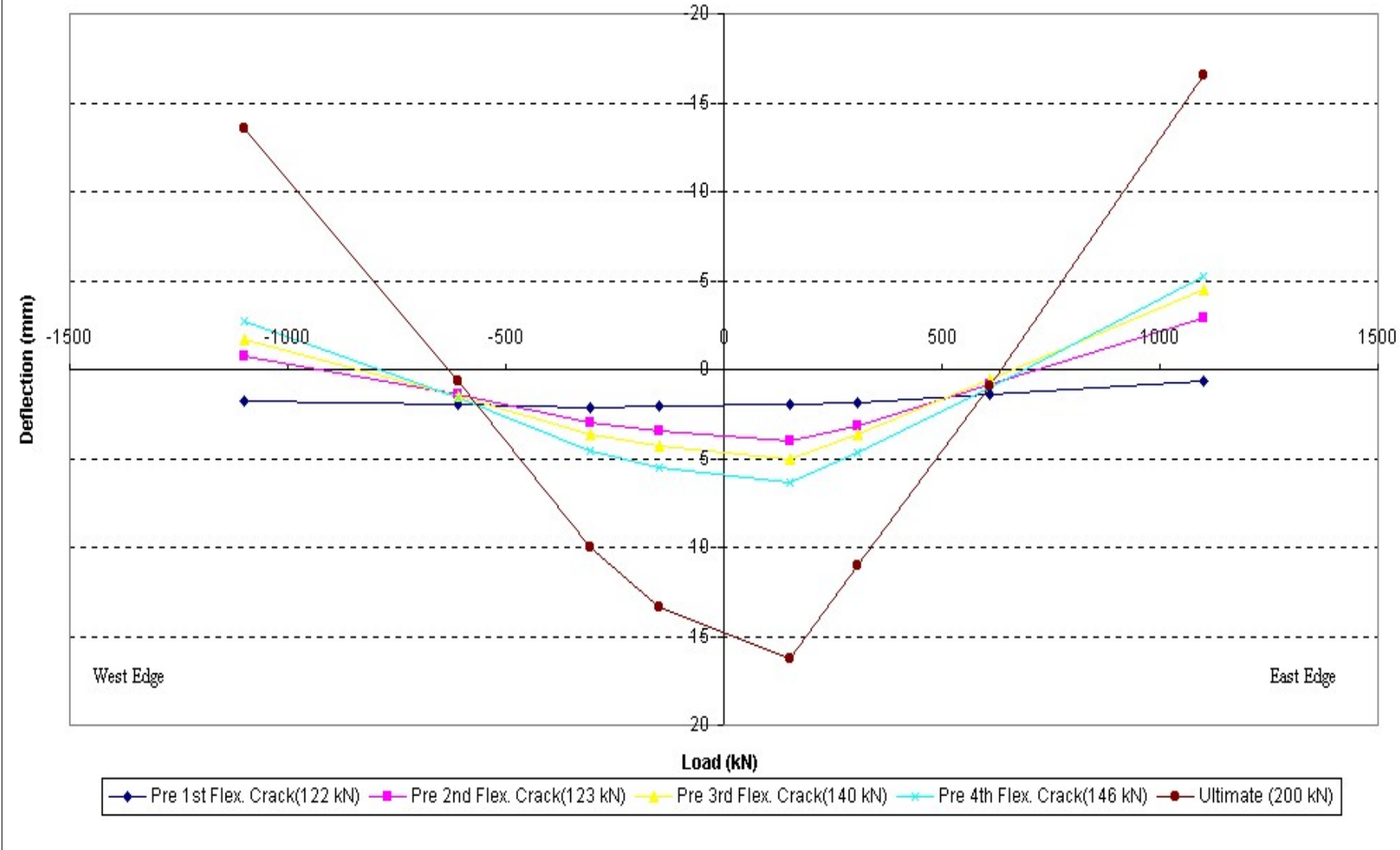
Deflection Profile

Plain Concrete Slab



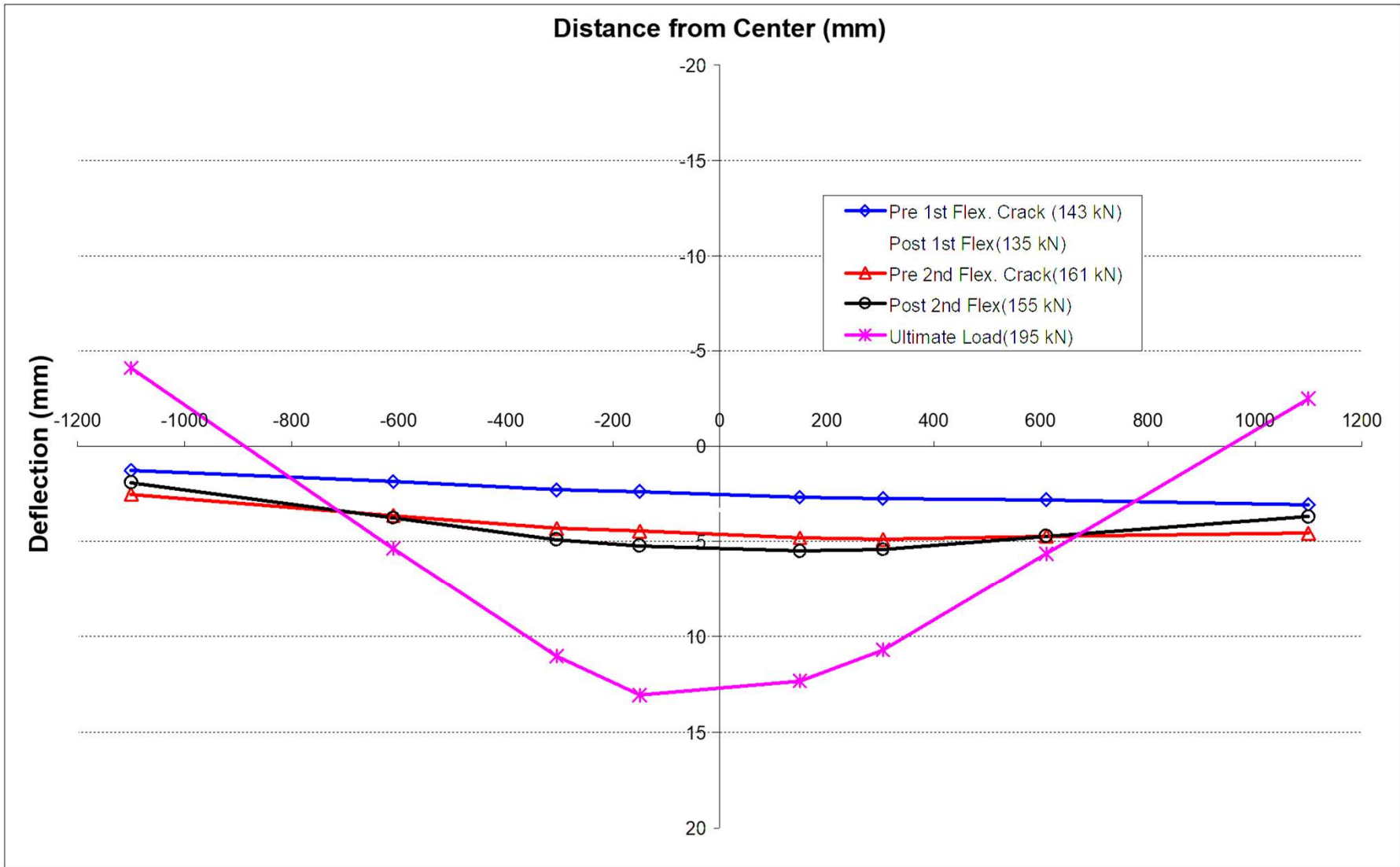
Deflection Profile

6"x6", W2.9 WWM - Concrete Slab



Deflection Profile

HVSF 0.48% - Concrete Slab



Background

- The theory of the software is primarily based on Increasing the flexural capacity of the concrete section (applied load (flexural stress) + residual load = total load)
 - “Macro” fibers increase post-cracking strength and re-distribute stresses during and after slab fracture.
 - Increased capacity of the concrete from absorbed energy during fracture (toughness).
- *“Thinner concrete section is obtainable given loading rate”*
 - *Or*
 - *“An increased load carrying capability”*



Capabilities

- This software can handle various loading cases for Interior or Exterior (Paving) applications including:
 - **Racking System** (Single Post, Multiple in a Line, Multiple in a Box)
 - Center Load
 - Corner Load
 - Edge Load (Contraction, Dowel & Free Edge Joints)
 - **Wheel Loads** (Single Wheel, Multiple Wheels on one or two axles)
 - Center Load
 - Corner Load
 - Edge Load (Contraction, Dowel & Free Edge Joints)
 - **Uniform Load**
 - **Line or Wall Load**



Slab Design Parameter Inputs

- Concrete Strength and Elasticity
 - Compressive strength or flexural strength
 - Modulus of elasticity
 - Maximum shear capacity
- Subgrade Factors
 - Modulus of subgrade reaction (K-Value or CBR, Soil Bearing Capacity)
 - Coefficient of friction (inside or outside slab – resistance of sub-grade on slab)
- Safety Factors
 - Concrete Safety Factor
 - Load Safety Factors
 - Variable Loads Factor (static)
 - Dynamic Load Factor
- Joint Spacing
- Material Factors
 - Thermal Expansion Coeff., Creep Coeff., Shrinkage, etc.



ACPA Streetpave Software

- Similar Capabilities by Utilizing Macro Synthetic Fibers



Edgewood Terrace



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Typical Dosage Rates of Macro Fibers

- 4" or Greater Slab on Grades – Pedestrian Loading
 - Basement Floors, Sidewalks (3.5 - 4#/cy)
- 4" or Greater Slab on Grades – Vehicle Traffic
 - Parking Garages, Driveways (4#/cy)
- 6" or Greater Slab on Grades - Medium Truck Loading
 - Parking Lots (4-5#/cy)
- 8" or Greater Slab on Grades – Heavy Truck Loading
 - Loading Docks, City Street Pavements, Building Drive Lanes (4#/cy)



Increasing chances of a Successful Project w/ “Field Experience”

- *Pre-construction Meetings*
- *Test Pours*
- *Best Practices for Macro Fiber Concrete*
 - *How to mix*
 - *Place*
 - *Finish*



Value Proposition

Macro Fibers

vs.

“Crack Control” Steel





Thank You

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