12. APPENDIX D – DETAILS OF BEAM TESTING

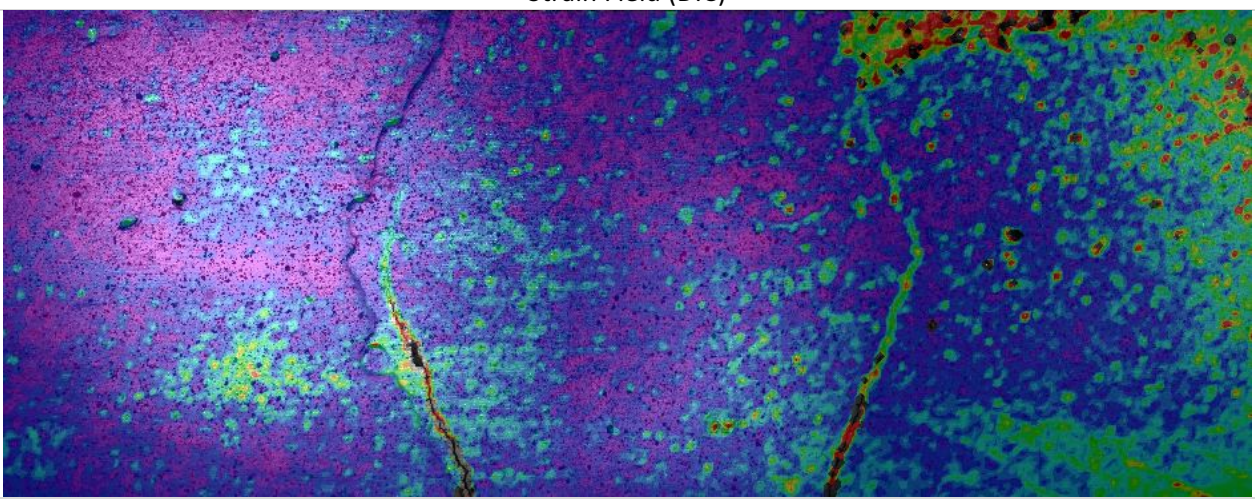
This appendix lists detailed photos from the beam testing series as outlined in Chapter 6. The images are listed as assigned by test name and number. Each set contains an images recorded from the actual test, prior to the loading (shown first) as well as at the peak load (shown second). Additionally, an image as seen through the digital image correlation camera is shown (shown third). For the relevant tests, the strain (%) in the bars vs. load (KN) plots is provided (shown last).

F-100-1P-1	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	1%
Loading Scheme:	Pure Flexure

Prior to Test

At Peak Load

Strain Field (DIC)

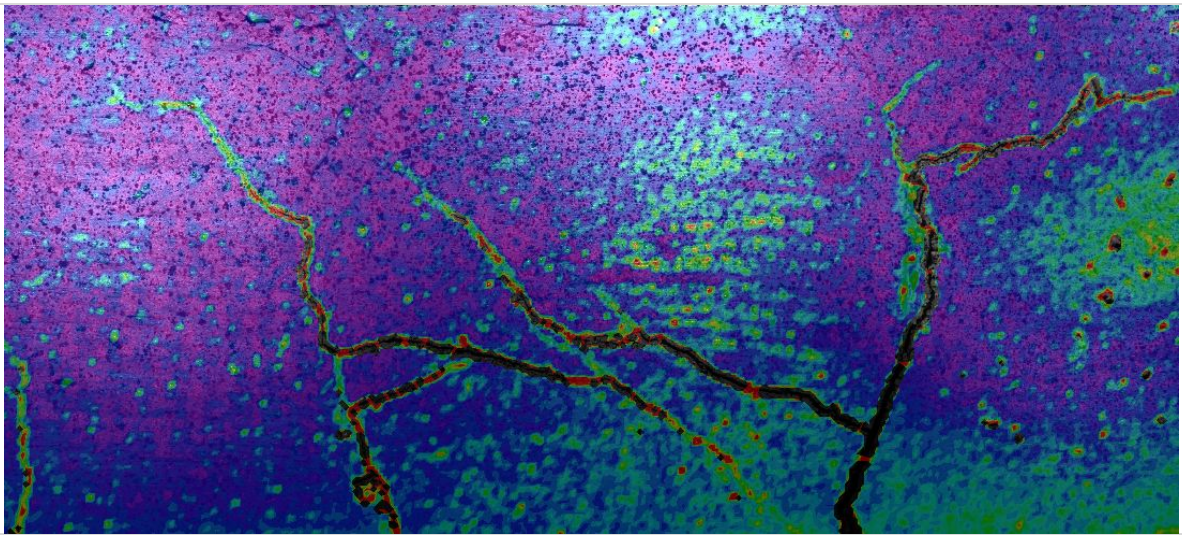


F-100-1P-2	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	1%
Loading Scheme:	Pure Flexure

Prior to Test

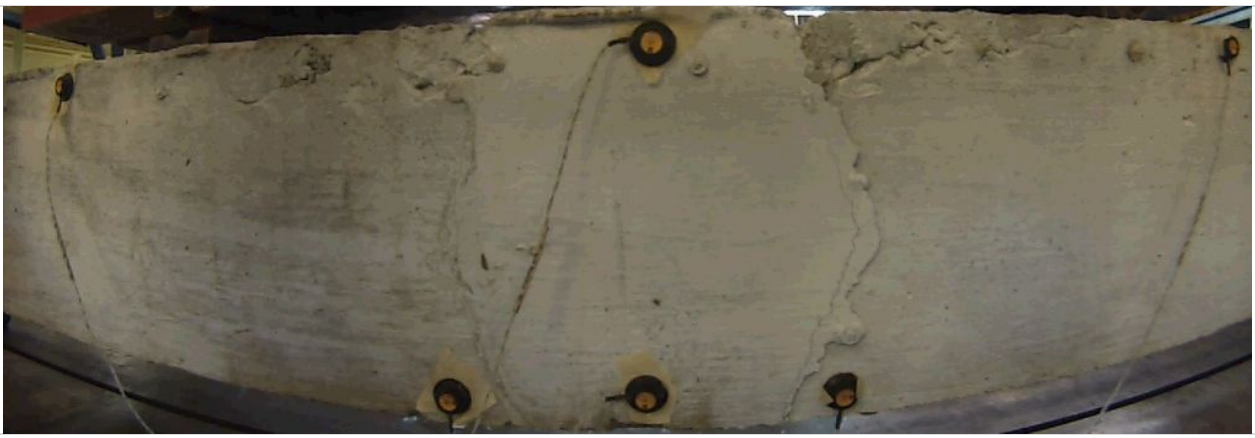
At Peak Load

Strain Field (DIC)



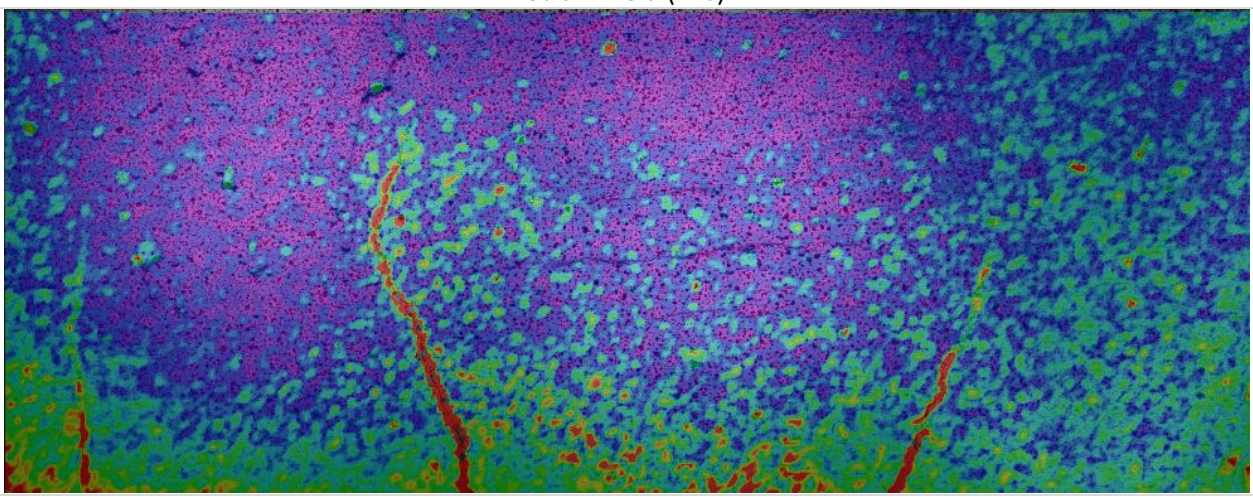
F-100-2P-1	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Pure Flexure

Prior to Load



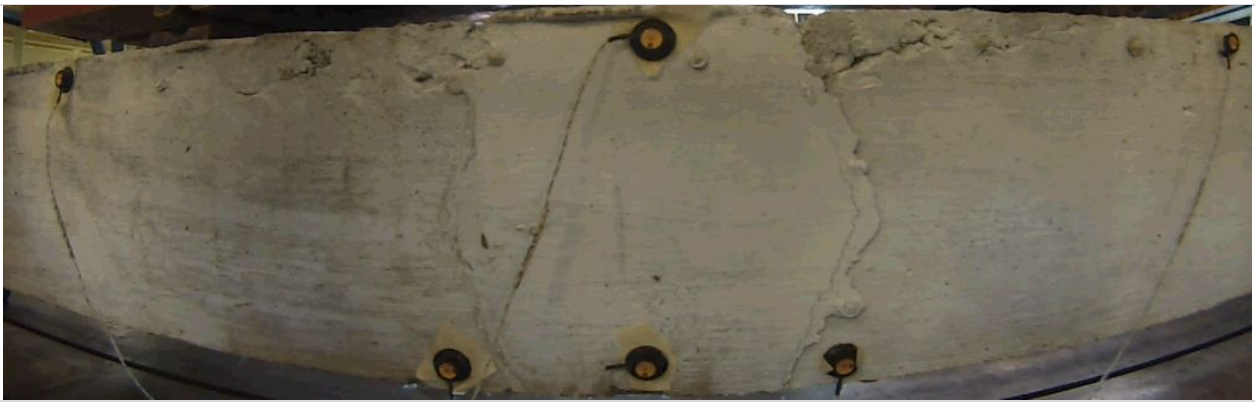
At Peak Load

Strain Field (DIC)



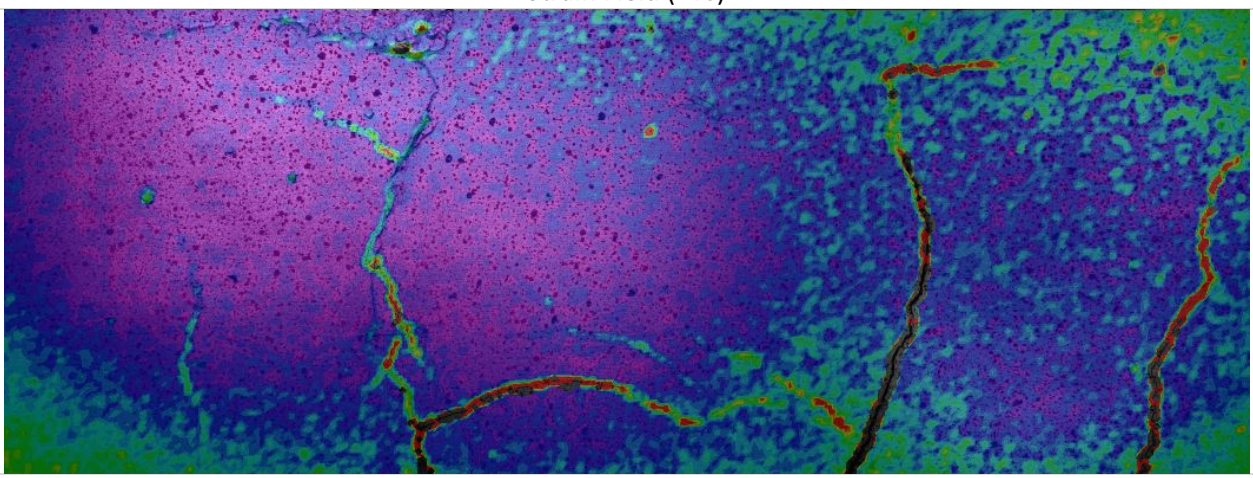
F-100-2P-2	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Pure Flexure

Prior to Load



At Peak Load

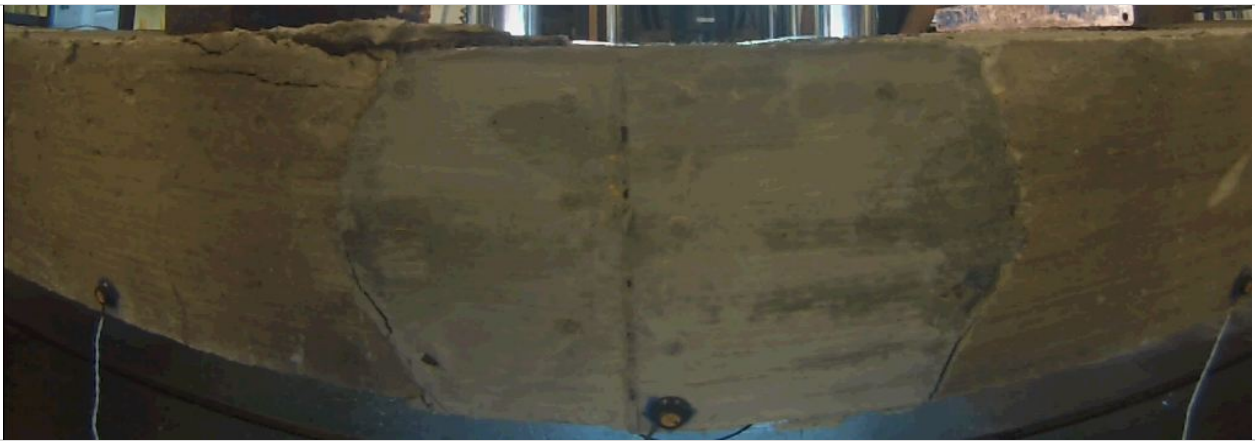
Strain Field (DIC)



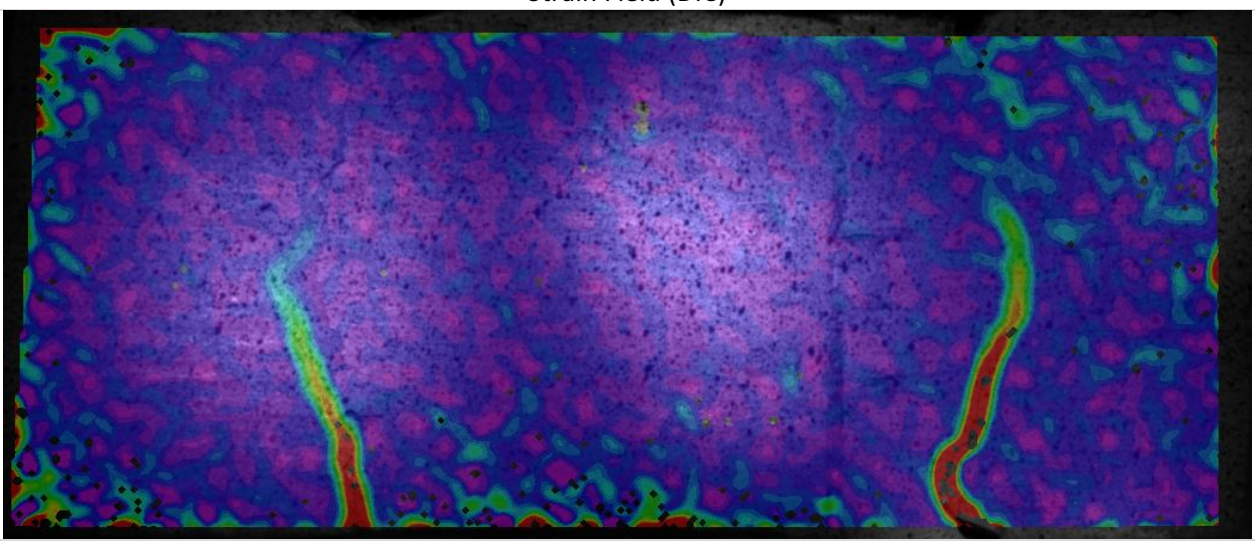
F-150-2P-1	
Joint Width:	6 inches (150 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Pure Flexure

Prior to Load

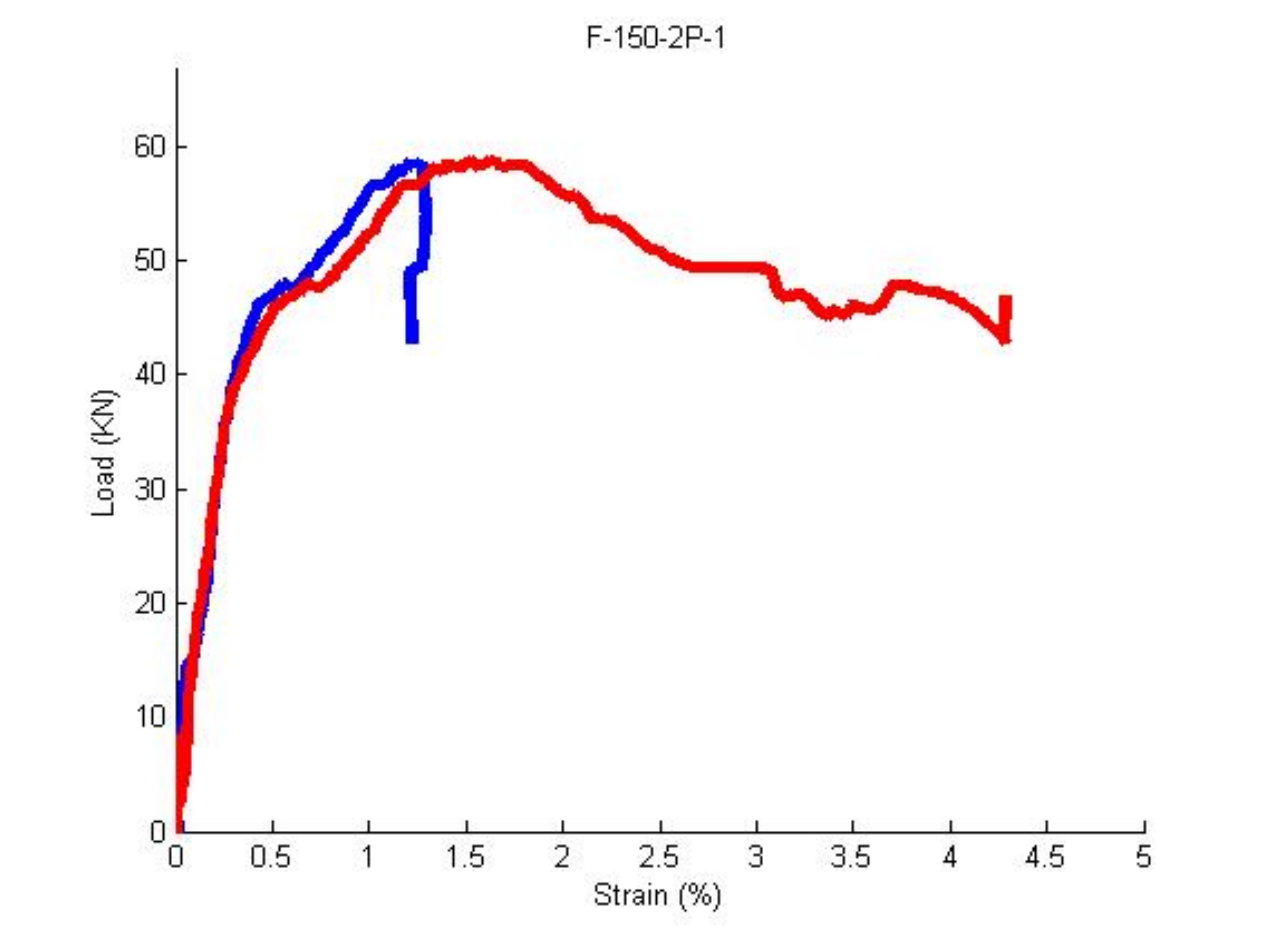
At Peak Load



Strain Field (DIC)



Strain (%) in Bars vs Load (KN)

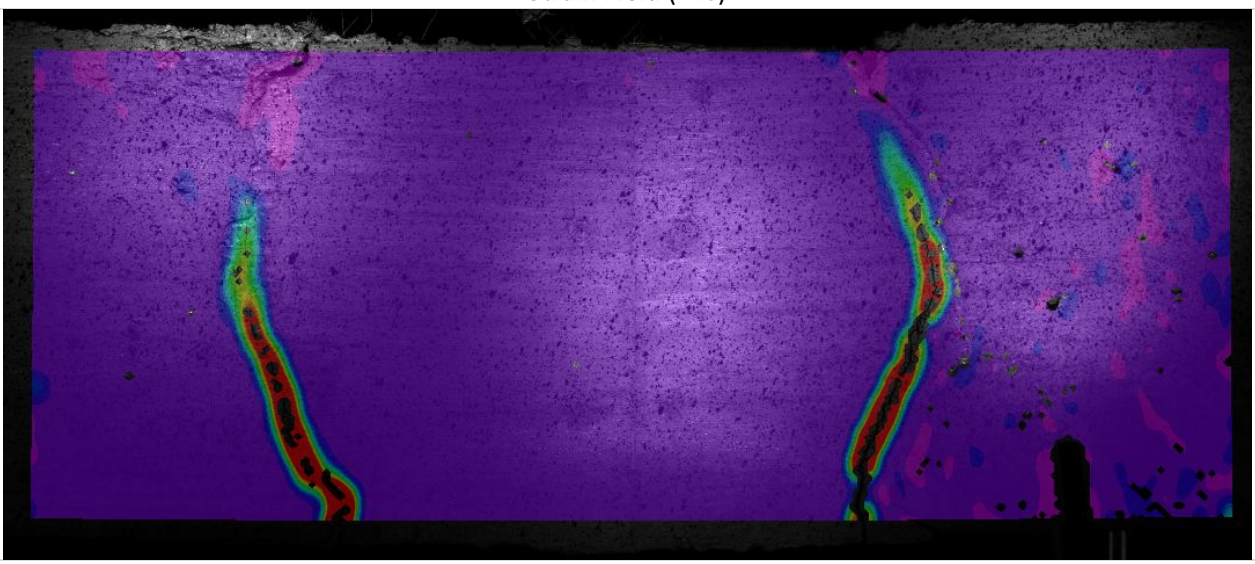


F-150-2P-2	
Joint Width:	6 inches (150 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Pure Flexure

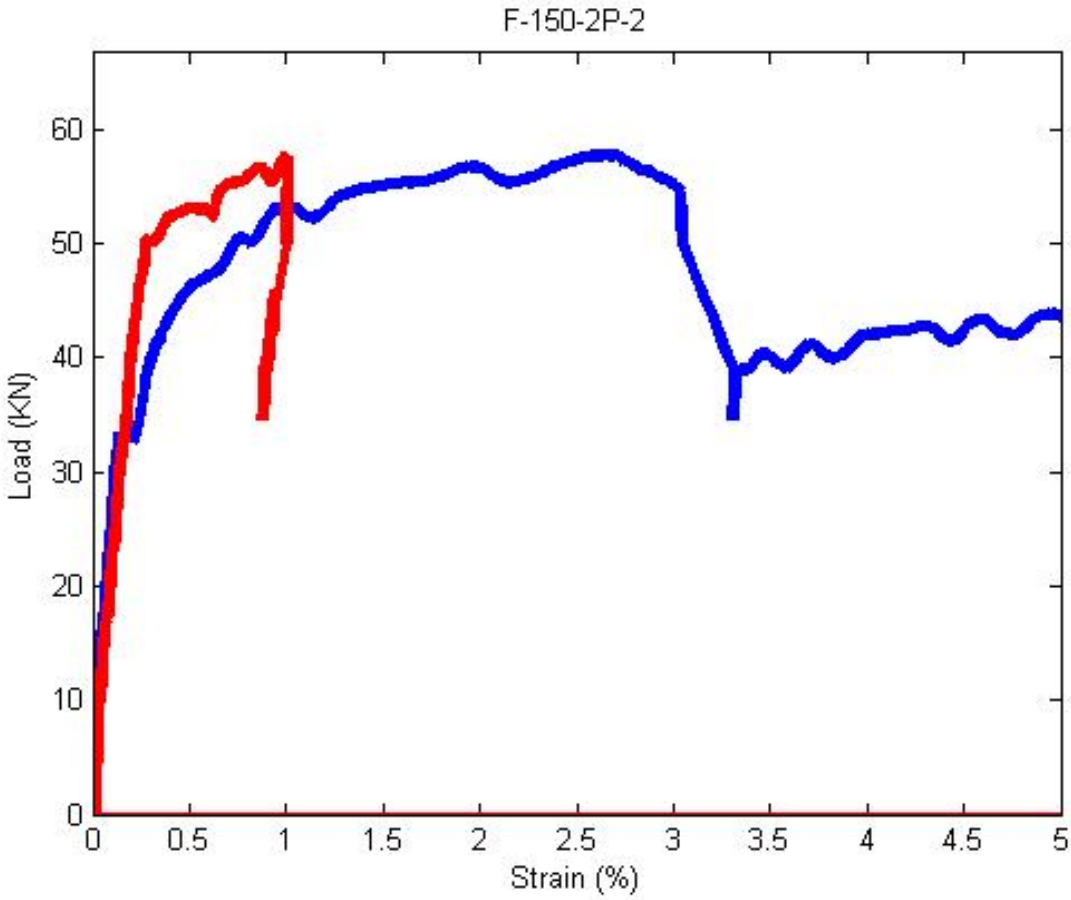
Prior to Load

At Peak Load

Strain Field (DIC)



Strain (%) in Bars vs. Load (KN)

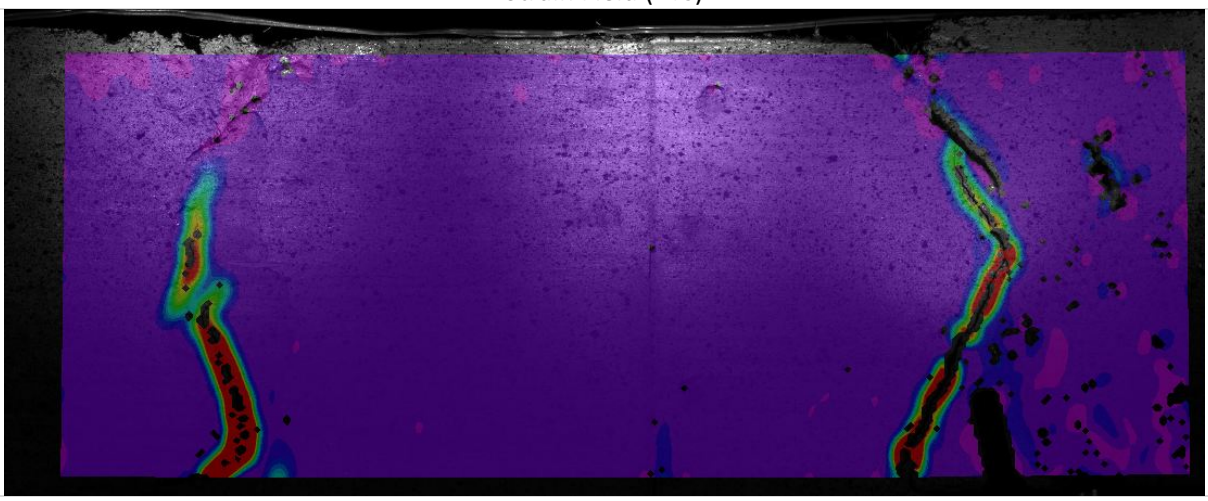


F-200-2P-1	
Joint Width:	8 inches (200 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Pure Flexure

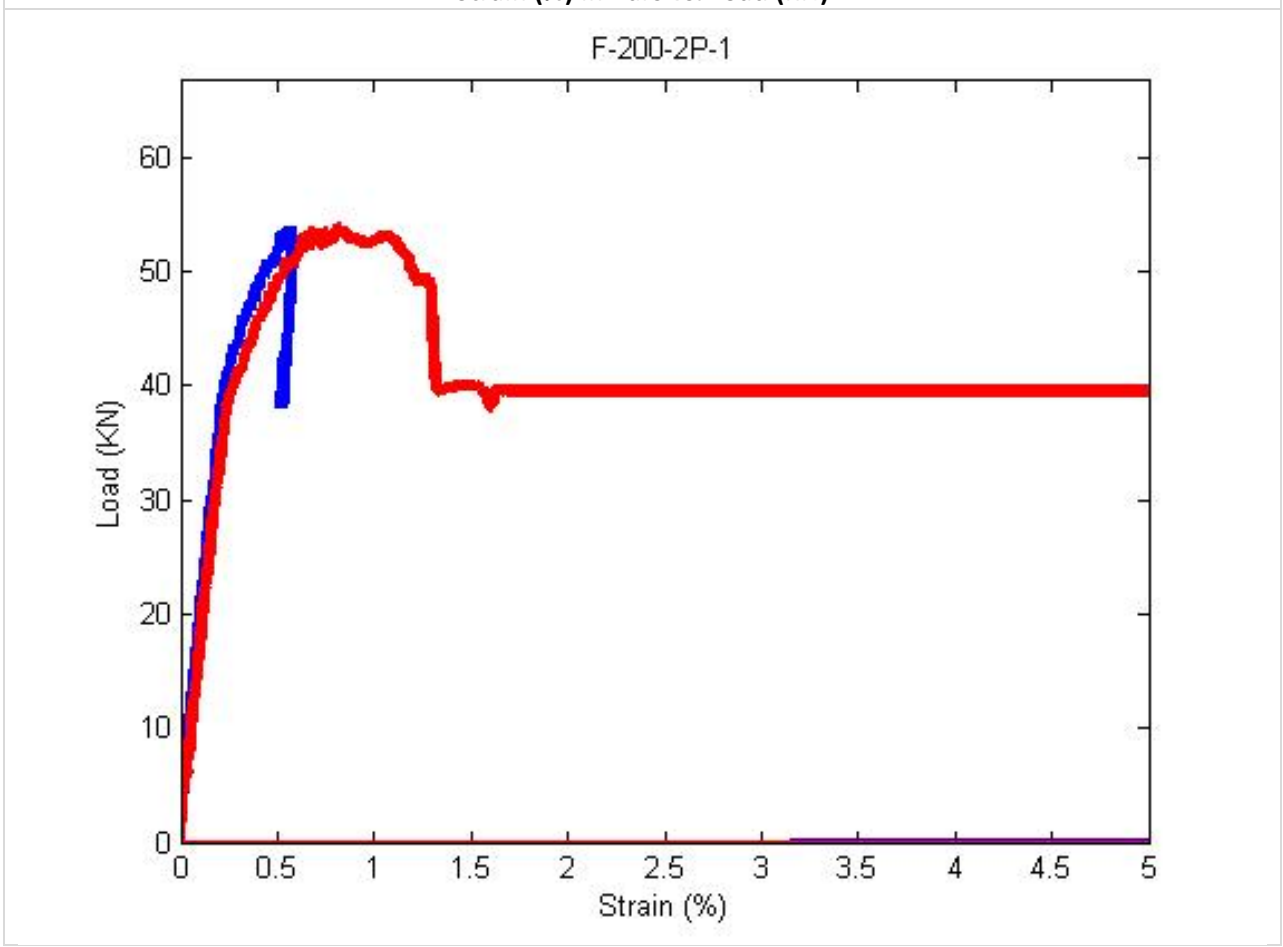
Prior to Load

At Peak Load

Strain Field (DIC)



Strain (%) In Bars vs. Load (KN)

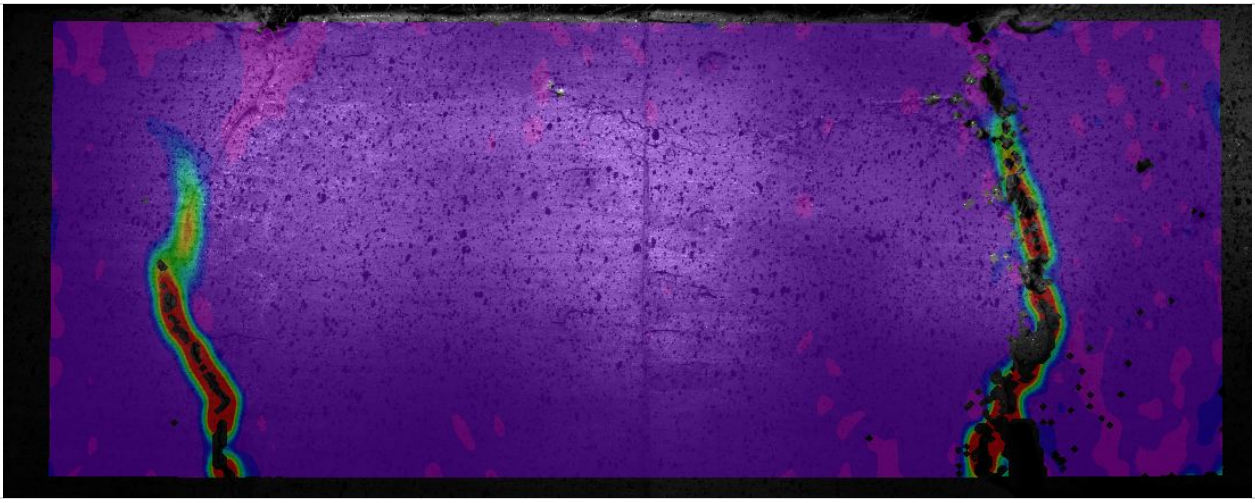


F-200-2P-2	
Joint Width:	8 inches (200 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Pure Flexure

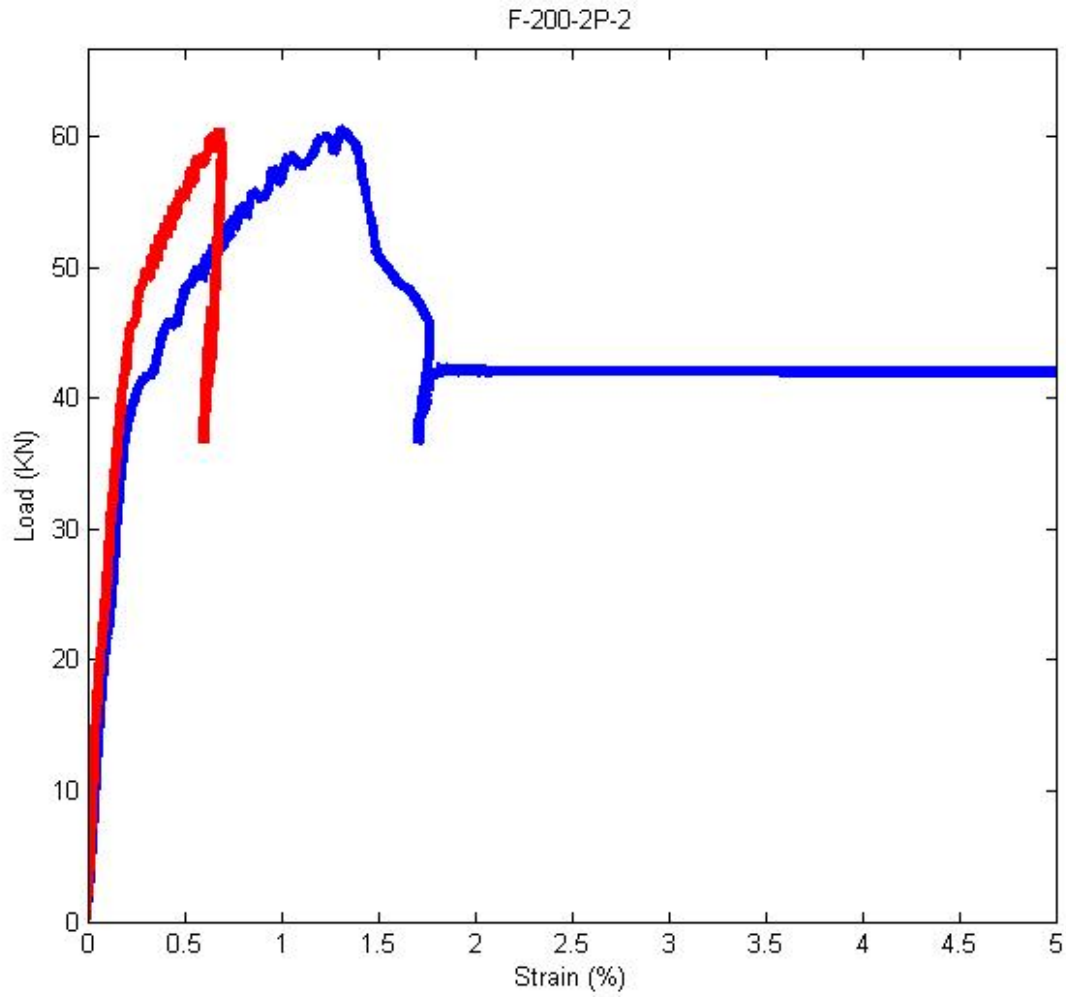
Prior to Load

At Peak Load

Strain Field (DIC)



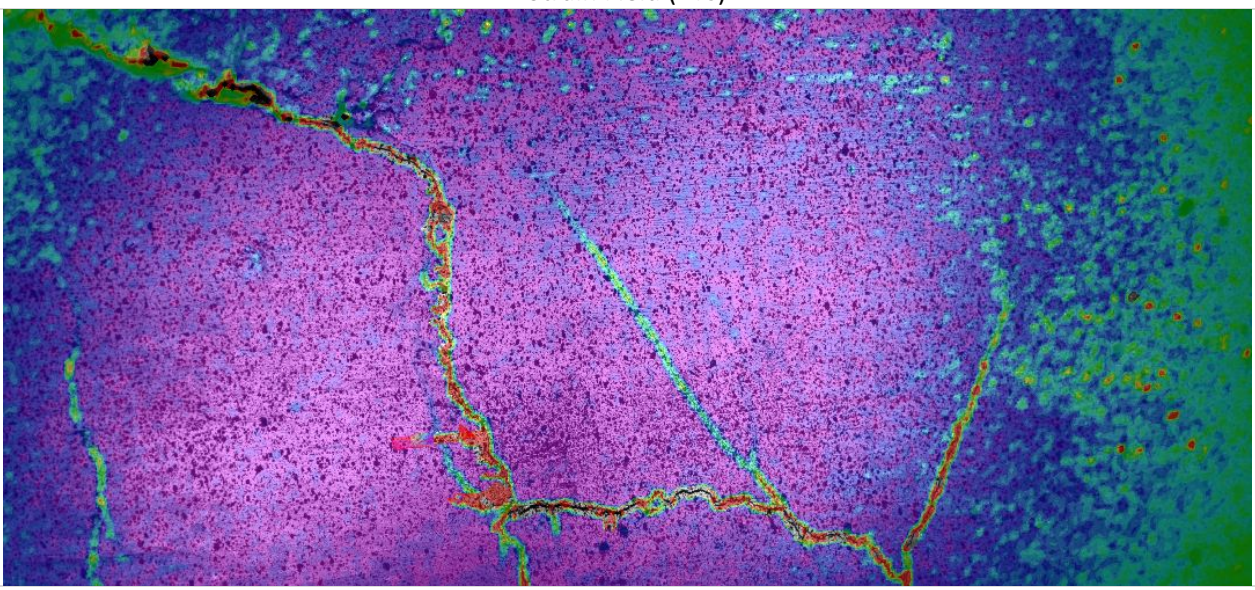
Strain (%) in Bars vs. Load (KN)



SF-100-1P-1	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	1%
Loading Scheme:	Combined Shear and Flexure

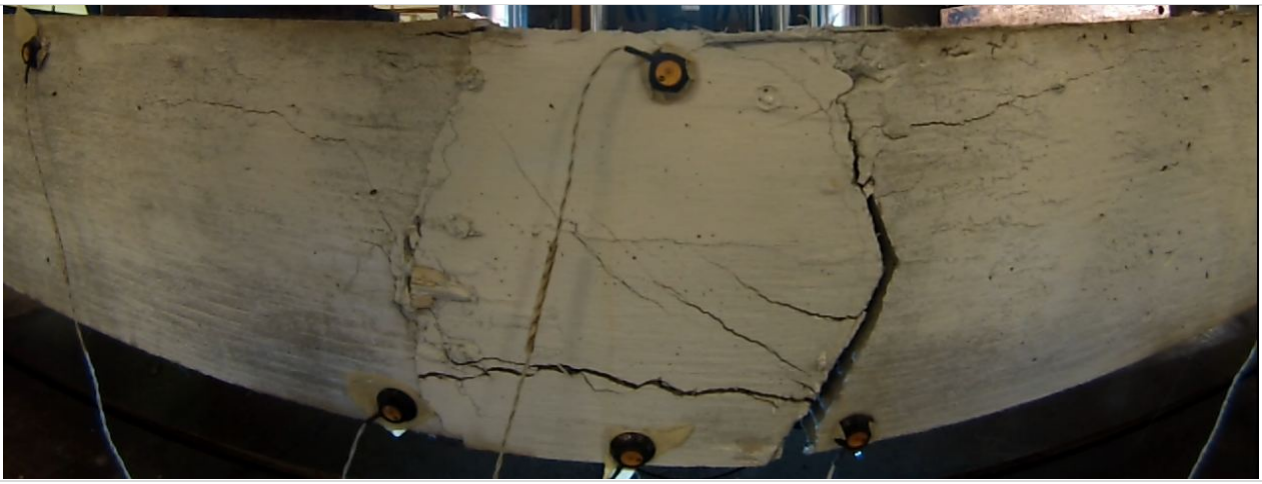
At Peak Load

Strain Field (DIC)

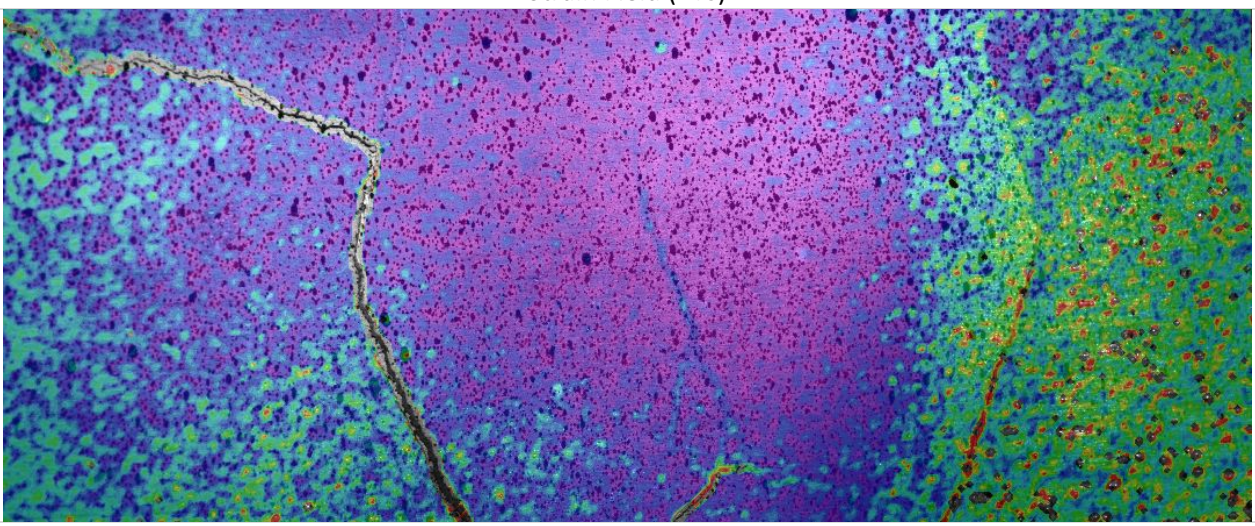


SF-100-1P-2	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	1%
Loading Scheme:	Combined Shear and Flexure

At Peak Load



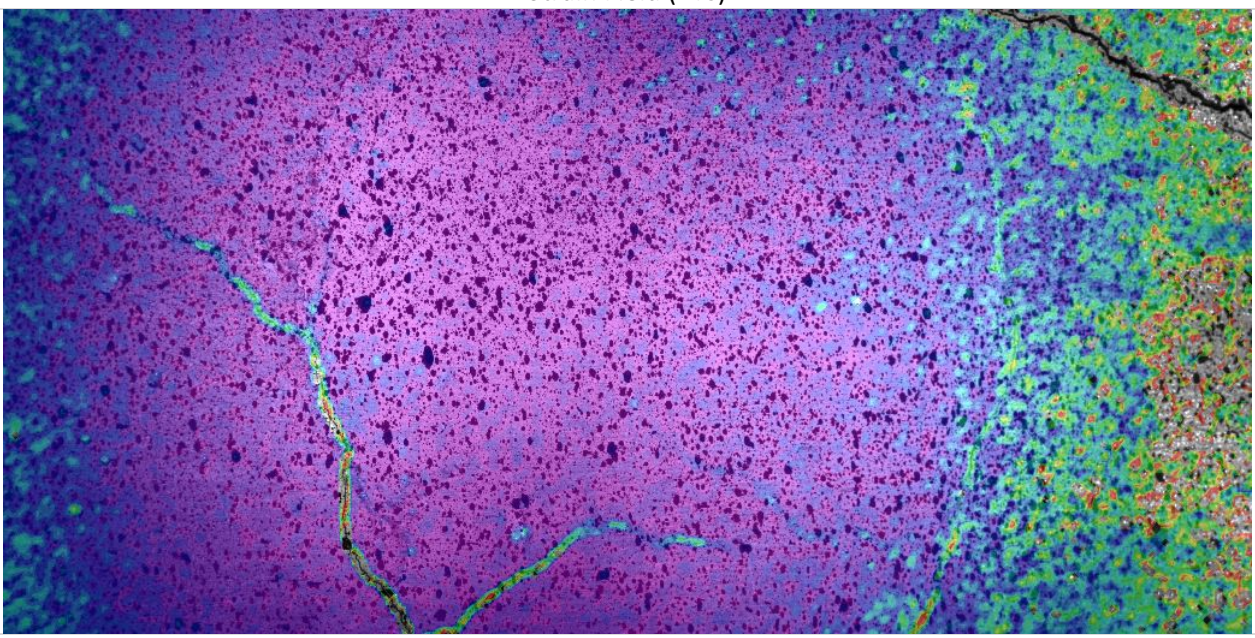
Strain Field (DIC)



SF-100-2P-1	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Combined Shear and Flexure

At Peak Load

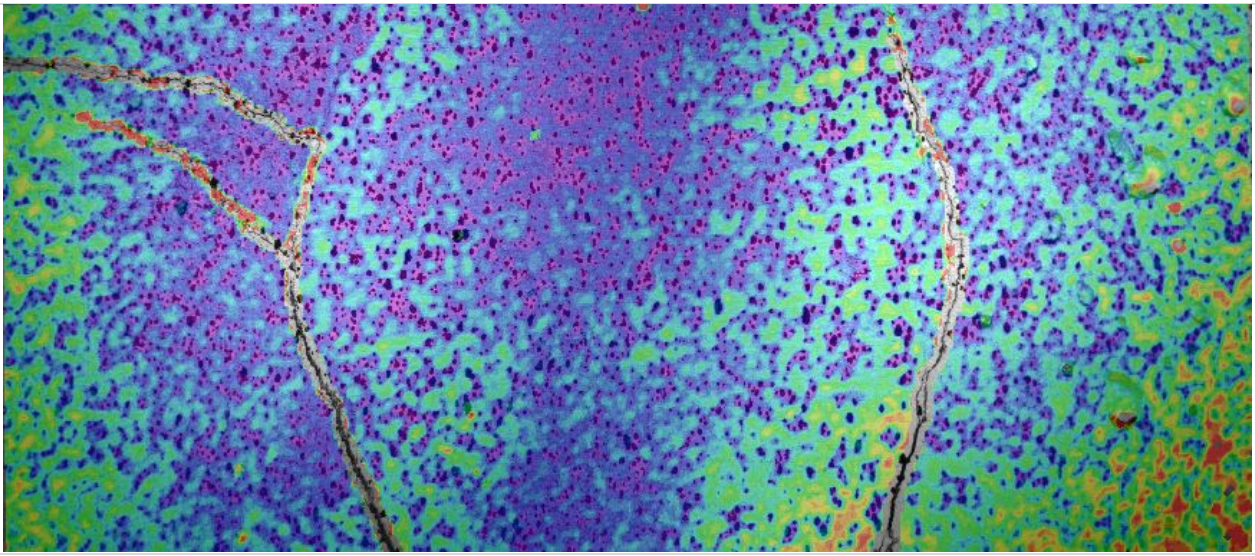
Strain Field (DIC)



SF-100-2P-2	
Joint Width:	4 inches (100 mm)
Fiber Content (% vol.)	2%
Loading Scheme:	Combined Shear and Flexure

At Peak Load

Strain Field (DIC)



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13. APPENDIX E – SPECIAL PROVISIONS

Special provisions were developed for one of the proposed UHPC blends. The provisions are necessary for MDOT to bid future UHPC projects. The approved provisions are listed in this Appendix.

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
MICHIGAN ULTRA HIGH PERFORMANCE CONCRETE (MI –UHPC) FOR FIELD CAST JOINTS

a. Description. This work consists of using Michigan Ultra High Performance Concrete (Mi-UHPC) for field casting of closure pours between precast components. The concrete mixture described in this special provision must be used at locations specified on the plans. All work must be in accordance with the standard specifications, except as modified herein.

b. Materials. The concrete mixture must contain the following materials per cubic yard:

Material	Weight [lb/yd^3]
Cement Blend	
Portland Type I	653
Slag Cement	653
Silica Sand	
Fine Sand[1]	407
Coarse Sand[2]	1629
Silica Fume	327
Water	277
High Range Water Reducer[3,4]	17.6[5]
Steel Fibers[5]	265

[1]US Silica F75
[2]US Silica F12
[3]AdvaCast 575
[4]High range water reducer is applied at the rate of 21.6 oz/cwt
[5]The steel fibers are 2% by volume.

Steel fibers – Steel fibers must be straight with a smooth surface and conform to ASTM A820, Type I fibers. They must have a diameter of 0.008 in and length of 0.75 in, both with a ±5% tolerance, and a minimum tensile strength of 285 ksi.

High Range Water Reducer – use AdvaCast 575. No substitutions are permitted without written approval of the Engineer.

c. Equipment. High shear paddle mixers with 0.5 cyd minimum capacity must be used. Paddle- or scraper-to-pan wall clearance must be small enough to prevent the material being mixed from adhering to the sidewalls. Pumping Mi-UHPC is not permitted.

d. Submittals. Submit the following to the Engineer, at least 21 days before placing for review and approval:

A. Material certifications and manufacturer's published product literature.

B. A quality control plan that must include, but is not limited to, the following:

(1) Mixing protocol.

(2) Casting procedure.

(3) Sampling and testing procedure.

(4) Curing procedure.

(5) Grinding procedure after field placement.

e. Pre-Pour Meeting. Prior to the initial placement of the Mi-UHPC, the Contractor must arrange for an onsite meeting with the Engineer and Construction Field Services. The objective of the meeting will be to clearly outline the procedures for mixing, transporting, finishing and curing of the Mi-UHPC, and to review the trial batch requirements.

f. Trial Batch. Perform one trial batch, a minimum of 21 days before concrete placement, to verify the mixture meets the requirements of this special provision. The trial batch must be attended by the Engineer and Construction Field Services.. The trial batch must be of sufficient size to complete the trial placement. Perform the trial batch under the same ambient conditions (e.g. time of day, weather, etc.) as anticipated during construction. Include documentation of ambient conditions at the time of the trial batch and anticipated ambient conditions at time of trial placement with the submittal to the Engineer.

Trial Placement: Construct a full scale trial batch mix and placement simulating a field cast closure pour full width between precast beams and of sufficient length to use at least the minimum mix capacity of the equipment, including quantities for sampling and testing. The trial placement must use the equipment and the same forming, casting, and curing procedures that will be used during construction. The trial placement must be witnessed by the Engineer and Construction Field Services.

Provide the results of temperature, slump, density (unit weight), 4-day compressive strength, and 7-day compressive strength testing. Each compressive strength test must be conducted according to subsection g.6 of this special provision. Submit the results of all tests above to the Engineer for review and approval a minimum of 10 calendar days prior to the use of the Mi-UHPC in the field .

To be considered a successful trial batch, the compressive strength must meet 12 ksi at 4 days, and 15 ksi at 7 days, and the slump flow must be within the range of 7 to 12 inches.

To be considered a successful trial placement, there must be no segregation of the Mi-UHPC and no visible voids when the forms are removed.

If the trial batch or trial placement does not meet these requirements, discard the material and repeat the trial batch and trial placement at no additional cost to the Department.

g. Construction.

1. Storage. Assure the proper storage of constituent materials, fibers, and additives as required by the manufacturer's specifications in order to protect materials against exposure to moisture and loss of physical and mechanical properties.

2. Temperature Limitations. Do not place concrete at ambient air temperatures below 40 degrees F, nor above 90 degrees F. The top surface of the concrete must be covered with insulating blankets, having a minimum R Value as specified in Table 706-1 of the Standard Specifications for Construction, when the air temperature is below 60 degrees F. Insulating blankets must meet the requirements of subsection 903.07.C of the Standard Specifications for Construction. Leave insulating blankets in place for a minimum 7 calendar days.

3. Mixing Protocol. The following mixing protocol must be followed:

A. Mix silica fume and all sand together for at least 7 minutes.

B. Add cement and mix together for at least another 7 minutes. Do not allow material to cake on the side of the mixer .

C. Add water and HRWR to the mixture and mix for a minimum of 10 minutes.

D. Perform the slump flow test according to subsection e.9 of this special provision. If the slump flow is between 7 and 12 inches, add the steel fibers into the mix. Do not incorporate any Mi-UHPC into the project with slump flow outside the stated range.

E. Mix the steel fibers and cementitious material for at least 5 minutes.

4. Forms: The forms must be water tight and coated to prevent absorption of water. The formwork must be resistant to the hydraulic pressure of the mix.

5. Quality Control. Submit a copy of all quality control records to the Engineer within 24 hours after the date of concrete placement covered by the record.

Use a flow table to measure the slump flow for each batch of Mi-UHPC. Conduct the slump flow test in accordance with ASTM C230/C230M without compacting and without moving or impacting the base plate. Record the slump flow for each batch in the QC records. The slump flow must be within the range of 7 to 12 in. Do not incorporate Mi-UHPC into the project with slump flow outside the stated range.

6. Compression Testing Requirements. Make three sets of compressive strength test samples for each day of placement. Each set consists of three 2x2 inch cubes. All test samples must be cured using the same method of curing as outlined in the quality control plan. The compressive strength tests must be conducted on a minimum of three 2x2 inch cube samples according to ASTM C109.

7. Casting Process: The fresh mix must not be allowed to flow farther than 24 inches during placement. Start the casting process at one end of the joint and proceed to the other end at

a speed comparable to the flow speed of the fresh mix. Once the other end of the joint is reached, reverse the casting process and proceed in the other direction to cast another layer of Mi-UHPC. Continue this process until the full depth of the joint has been cast. Vibrators may not be used.

Fill the joint 0.5 inch higher than the adjacent concrete to allow entrapped air to rise in this zone during curing.

8. Curing. Do not apply curing compound. The concrete surfaces must be continuously cured with wet burlap per subsection 706.03.N.1.b, except that the wet burlap must be applied immediately after casting.

9. Grinding. Grind the Mi-UHPC surface flush with the adjacent concrete surface within ±1/8 inch tolerances. Grinding of the Mi-UHPC surface can be performed after it has attained 12 ksi compressive strength. Suspend grinding operations if significant fiber pullout is observed. Do not resume grinding until approved by the Engineer.

h. Acceptance. The Engineer will sample the Mi-UHPC and test it for 4, 7, and 28 day compressive strength and table slump flow. If the Mi-UHPC achieves a minimum of 12 ksi at 4 days, 15 ksi at 7 days, the table slump flow is within 7 to 12 inches, and Mi-UHPC placement, segregation, and consolidation are acceptable, the Mi-UHPC for each representative placement will be accepted.

i. Measurement and Payment. The completed work, as described, will be measured and paid for at the contract unit price using the following pay item:

Pay Item	**Pay Unit**
Conc, Michigan Ultra High Performance	Cubic Yard

Conc, Michigan Ultra High Performance will be measured in cubic yards based on plan quantities. Payment for **Conc, Michigan Ultra High Performance** includes all labor, equipment, and materials required for the first trial batch, forming, furnishing, testing, placing, finishing, and curing the concrete according to this special provision. No additional compensation will be made for trial batches or trial placements that fail to meet the requirements of this special provision.