Testing of Trelleborg Structural Plastics

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Figure 1: 3-Point Loading Test of a SCL Wale

Introduction:

For the purpose of product evaluation for use in waterway fender systems the company Trelleborg provided the FDOT Structures Research Center with six fiberglass structurally reinforced composite piles (CP) and six fiberglass structurally reinforced composite lumber (SCL) specimens. All twelve specimens were reinforced with fiberglass reinforcing bars. Out of both specimen groups (CP & SCL) three of each had reinforcing bars of 1.0 inch diameter and the other three had 1.5 inch diameter reinforcing bars. The size of the reinforcing bars inside the structural plastics categorizes them for use in light, medium or heavy duty fender systems. CPs for use in heavy duty fender systems should meet different strength, weight and elasticity requirements than those used in medium duty fender systems and the same can be said for SCLs for use in heavy and medium duty fender systems versus light duty fender systems. Figure 2 shows the ideal cross-sections of all four types of specimens tested. The actual width and height/diameter dimensions of the specimens provided by Trelleborg varied by up to ½" in either direction. In Figure 2 at the top left is the cross-section for SCL for light duty fender systems, SCL for medium and heavy duty is at top right, CP for medium duty is at lower left and CP for heavy duty is at the lower right. All tests were done using the simply supported three point bending setup shown in Figure 4 and were performed on March 25th-29th 2010. Supports for the CP specimens had to be cut from steel plate using the Lab's TorchMate Table and then welded together. Figure 3 shows the dimensions of those supports. These supports were welded to base plates and placed on top of neoprene bearing pads that rested on rotating clevis supports simulating a simply supported condition.

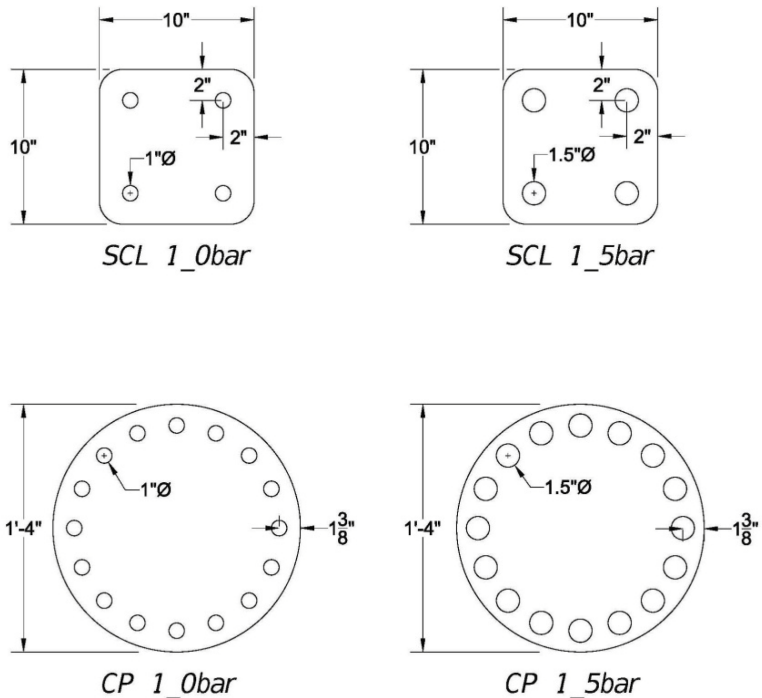


Figure 2: X-Sections of the Tested Specimens

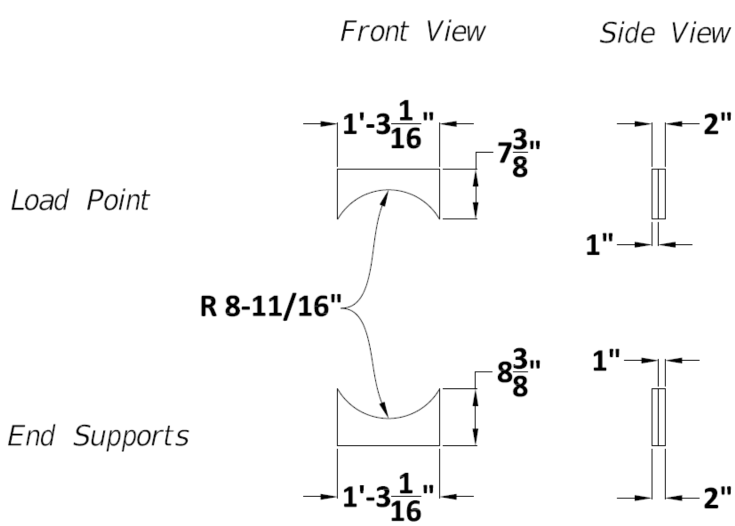
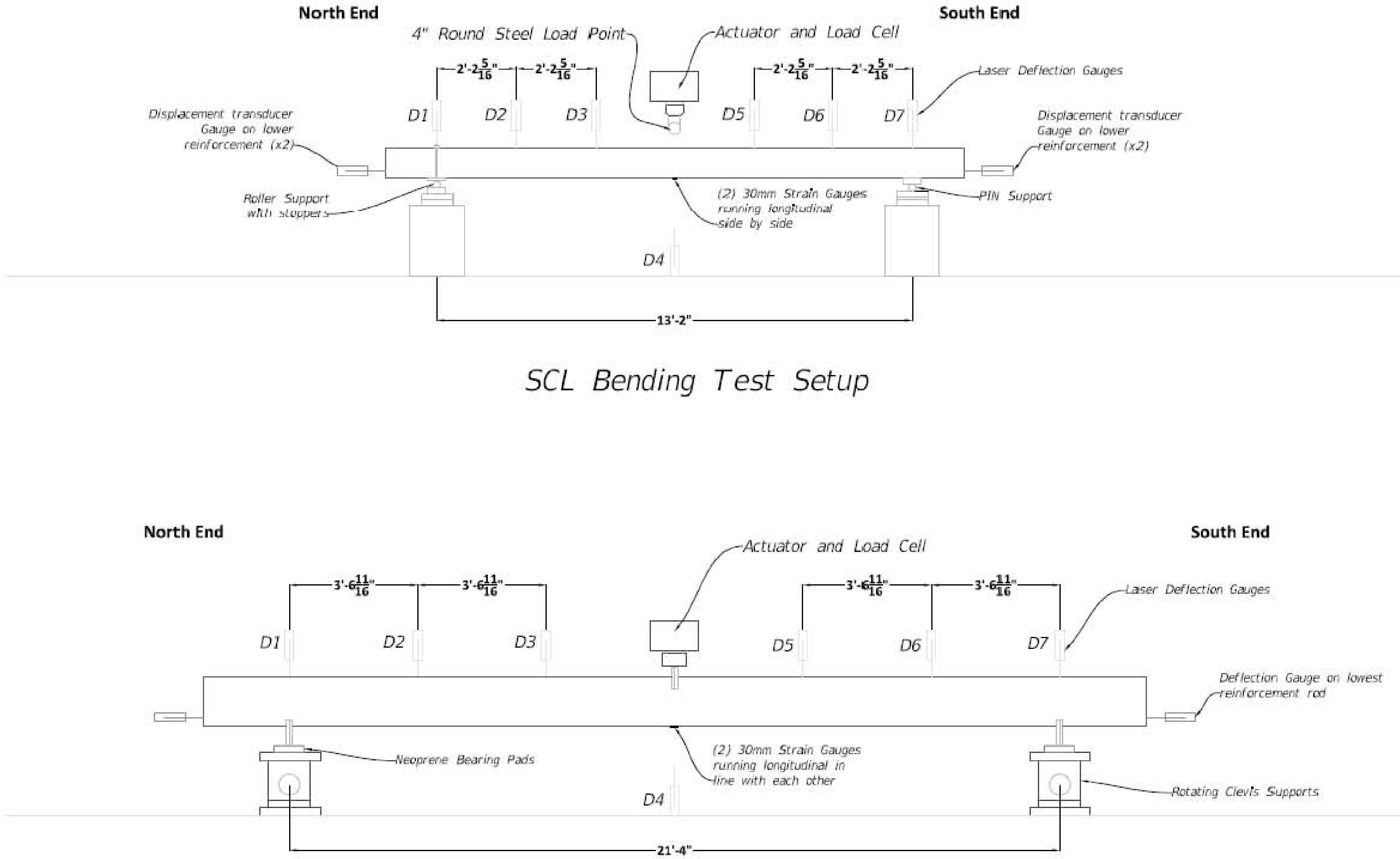


Figure 3: End Supports for CP Test Setup



SCL Bending Test Setup

CP Bending Test Setup

Figure 4: Test Setup for SCL (top) and CP (bottom)

Results:

All testing was performed at the Marcus H. Ansley Structures Research Center under the guidance of ASTM D6109 with two main differences being the rate of loading the specimens and that the tests run at our lab were set up for 3-point vs. 4-point bending. The Enerpac actuators the Structures Center has at its disposal were not able to achieve the speed suggested in ASTM D6109 and were instead run as quickly as possible which resulted in a load rate of approximately 1¼ inches per minute for all specimens. Testing was setup in pairs so that a SCL and a CP specimen could be tested one right after the other with preparation of the next pair in between tests. Because of this the data files for the first pair of test specimens SCL #1 with 1.0" reinforcement (SCL_1.0-1) and CP #1 with 1.5" reinforcement (CP_1.5-1) were not viewed until after both tests were performed. It was not until then that an error was found in the data acquisition programming that prevented the test data from being recorded. Therefore no data was obtained for the SCL_1.0-1 and CP_1.5-1 tests. The error was then fixed and the data for the remaining tests are shown in Figures 6, 8, 10, 12, 14, 15, 17 and 19 and the results are presented in Tables 1 & 2. The Flexural Strength listed in Tables 1 & 2 was taken as the maximum stress in the outer fiber at midspan at the maximum load or at first breakage/slip of the fiberglass reinforcement. The Modulus of Elasticity listed in Tables 1 & 2 is the secant modulus taken as the slope between the origin and the stress at 1% strain. The stiffness reported in Tables 1 & 2 was simply calculated by multiplying the secant modulus by the gross moment of inertia (I_g) of the given specimen. The I_g was calculated to be 791.15 in^4 for the SCL specimens and 3217 in^4 for the CP specimens.

Table 1: Test Results of SCL Specimens

Sample #	Flexural Strength (ksi)	Deflection at Flexural Strength (in)	Modulus of Elasticity (ksi)	Stiffness, EI ($kip\text{-}in^2$)
SCL_1.0-2	4.407	7.893	291.23	2.304×10^5
SCL_1.0-3	4.815	8.807	264.76	2.095×10^5
SCL_1.5-1	8.926	9.052	483.64	3.826×10^5
SCL_1.5-2	7.626	8.269	437.12	3.458×10^5
SCL_1.5-3	9.157	10.092	447.15	3.538×10^5

Figure 5: North Roller Support (left) and South Rocker Support (Right) for SCL Test Setup

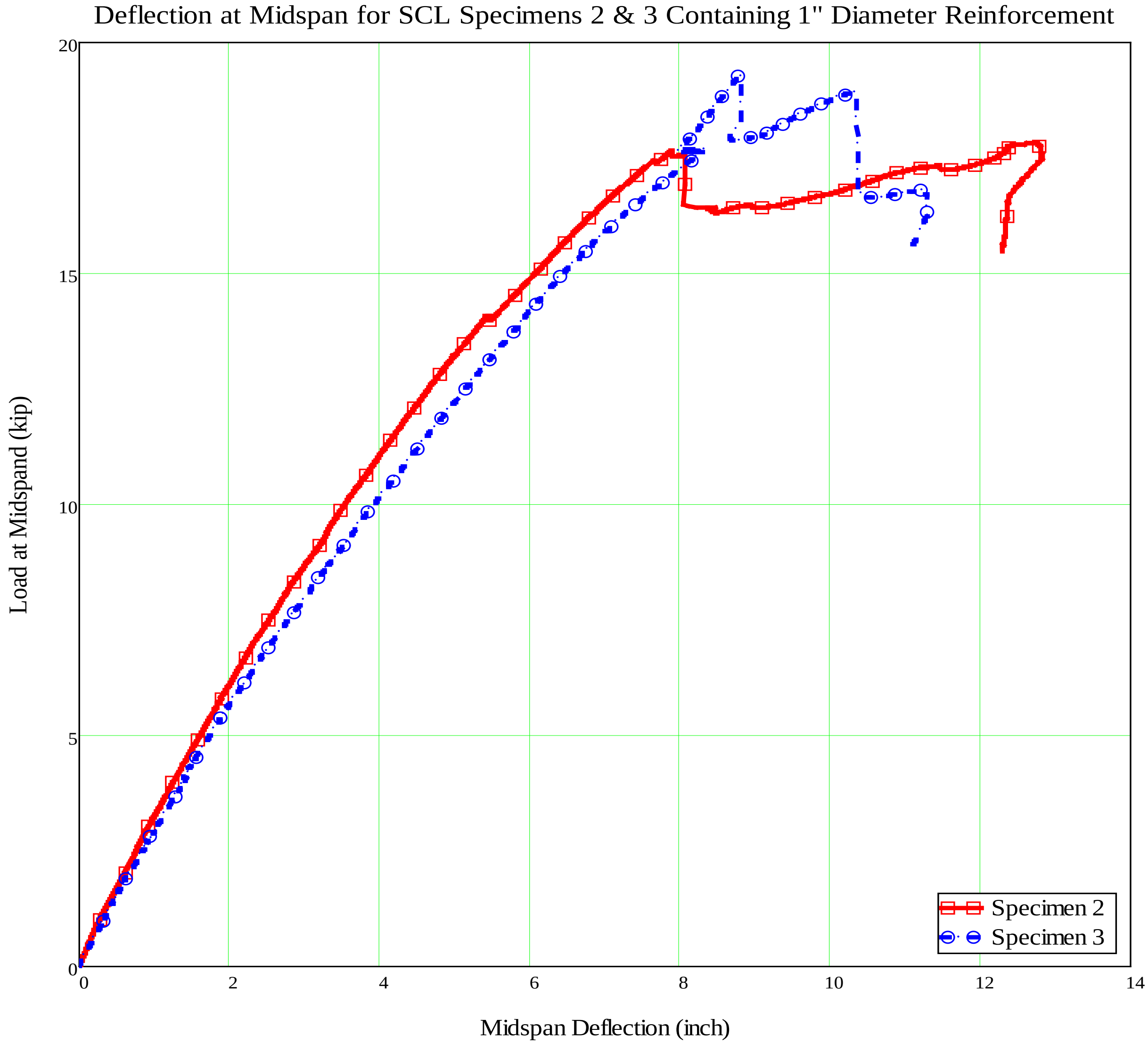


Figure 6: Deflection Curves for SCL Specimens with 1” Diameter Fiberglass Reinforcement

Figure 7: North Roller Support and South Rocker Support during Testing

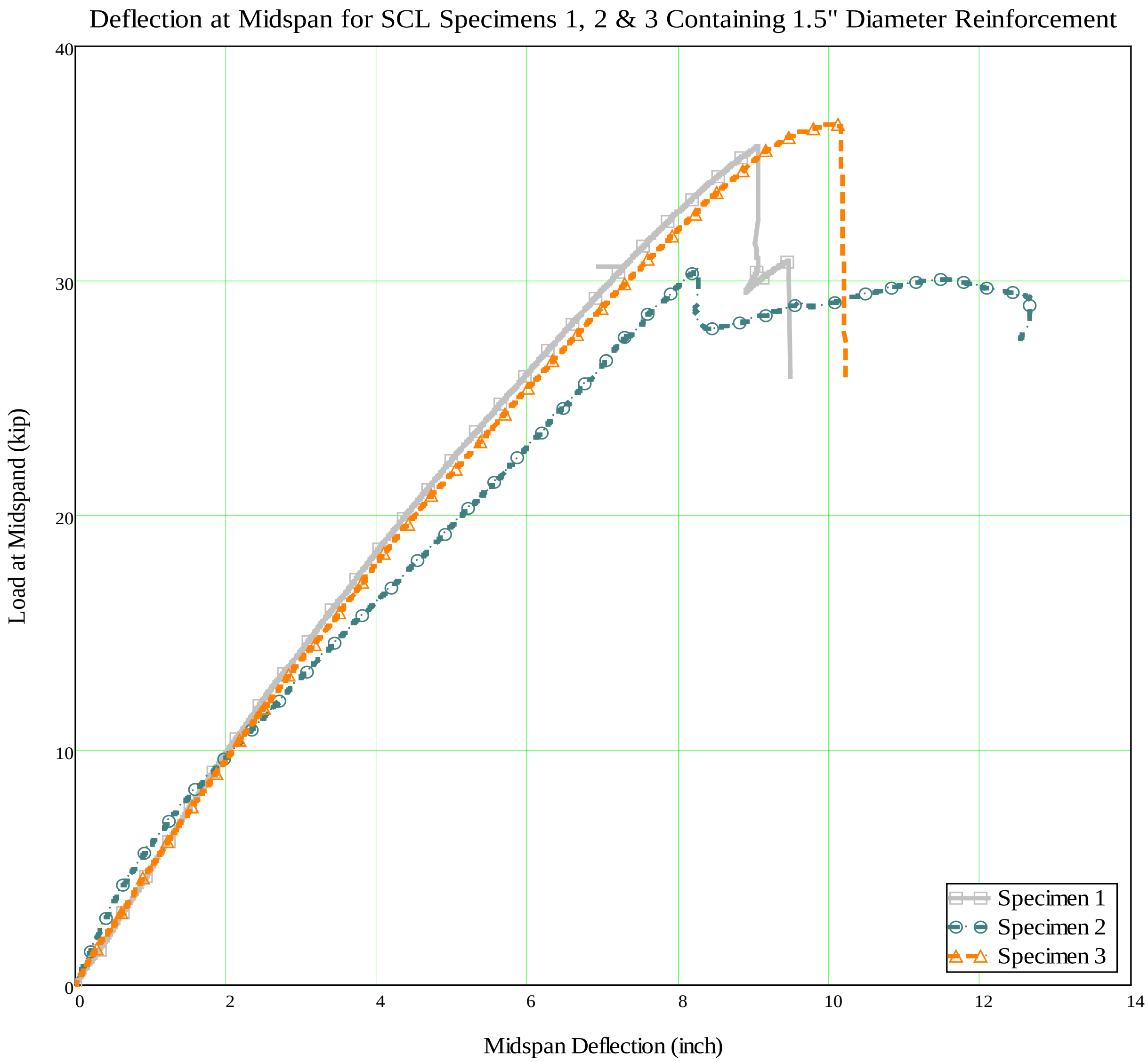


Figure 8: Deflection Curves for SCL Specimens with 1.5" Diameter Fiberglass Reinforcement

Figure 9: Loading a SCL Specimen, a Bulge can be Seen Under the Load Point

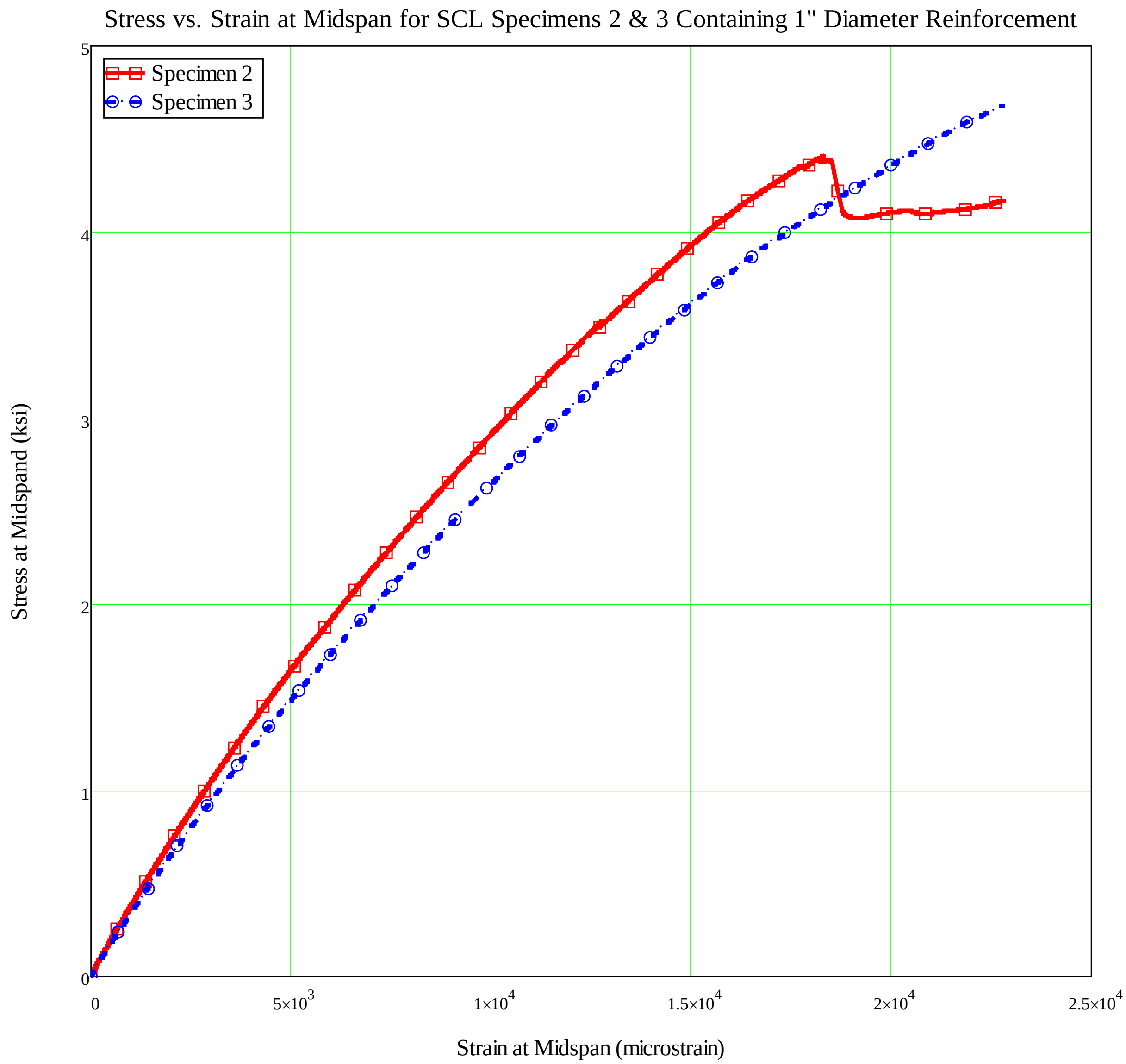


Figure 10: Strain Curves for SCL Specimens with 1” Diameter Fiberglass Reinforcement

Figure 11: Deflection Gauge Setup for Detecting Slip of Reinforcement for SCL Specimens

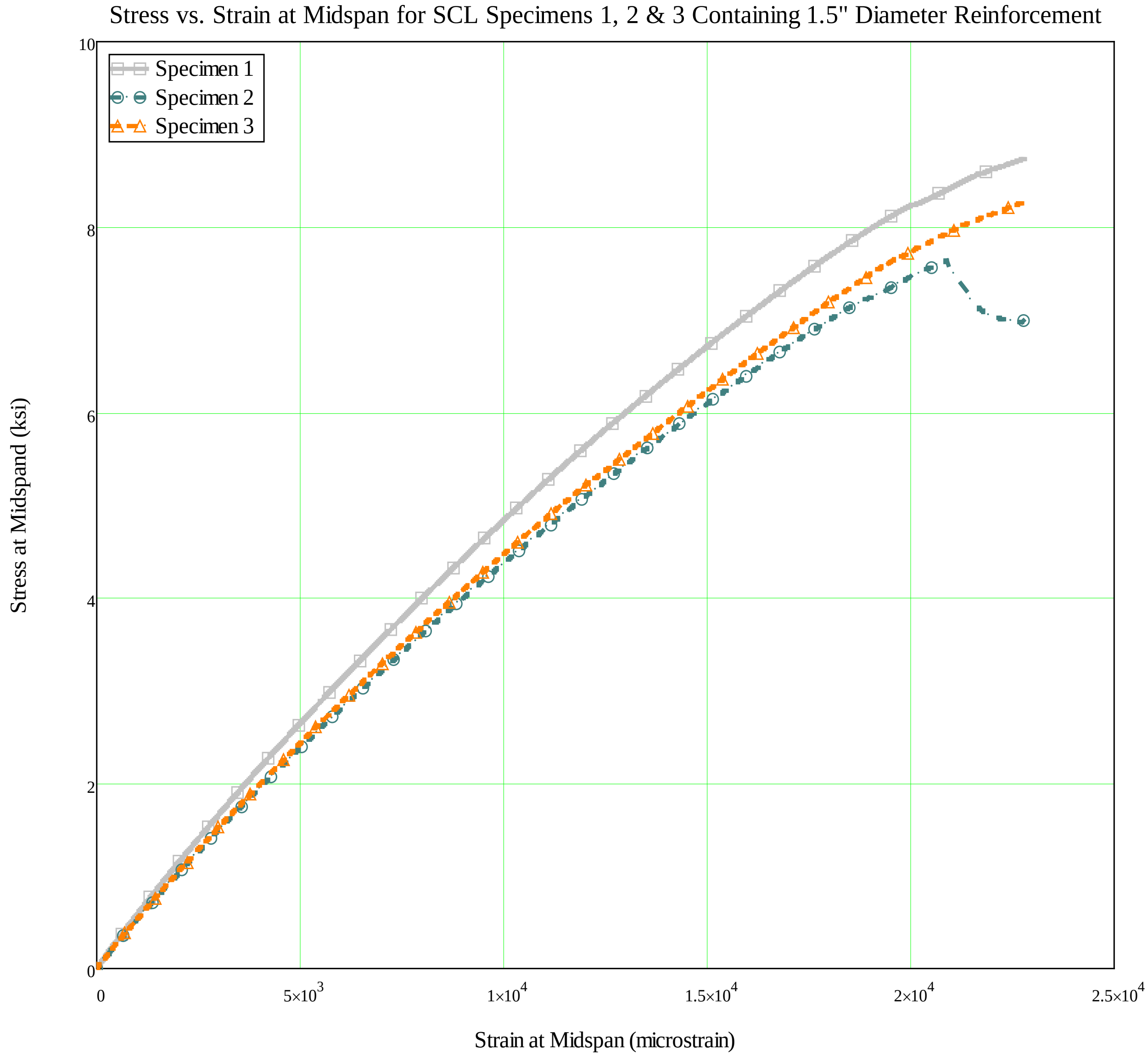


Figure 12: Strain Curves for SCL Specimens with 1.5" Diameter Fiberglass Reinforcement

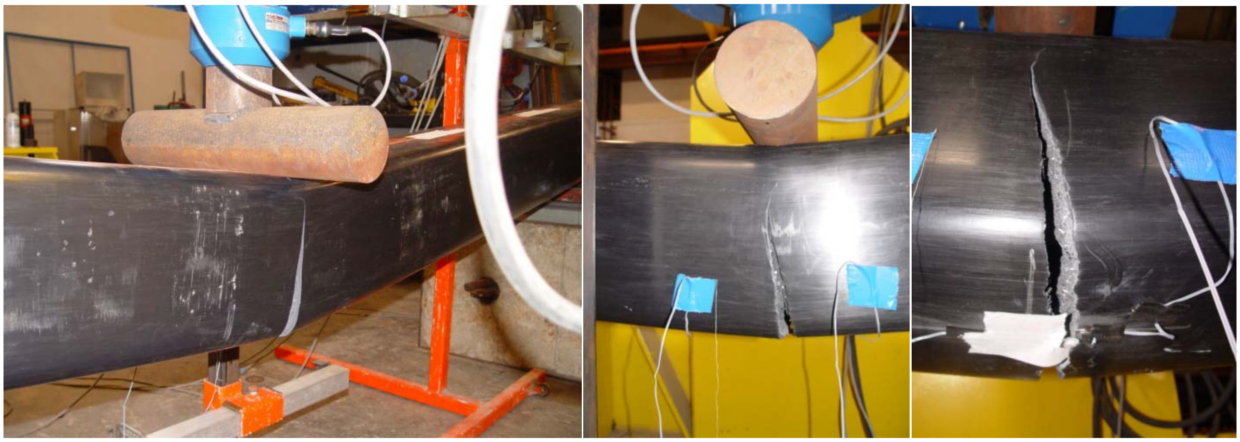


Figure 13: Rupture of a SCL Specimen

Table 2: Test Results of CP Specimens

Sample #	Flexural Strength (ksi)	Deflection at Flexural Strength (in)	Modulus of Elasticity (ksi)	Stiffness, EI (kip-in^2)
CP_1.0-1	6.53	12.209	392.61	1.263 x 10^6
CP_1.0-2	6.40	12.148	412.15	1.326 x 10^6
CP_1.0-3	7.32	13.140	427.98	1.377 x 10^6
CP_1.5-2	12.17	10.899	836.56	2.691 x 10^6
CP_1.5-3	12.18	11.187	823.08	2.648 x 10^6

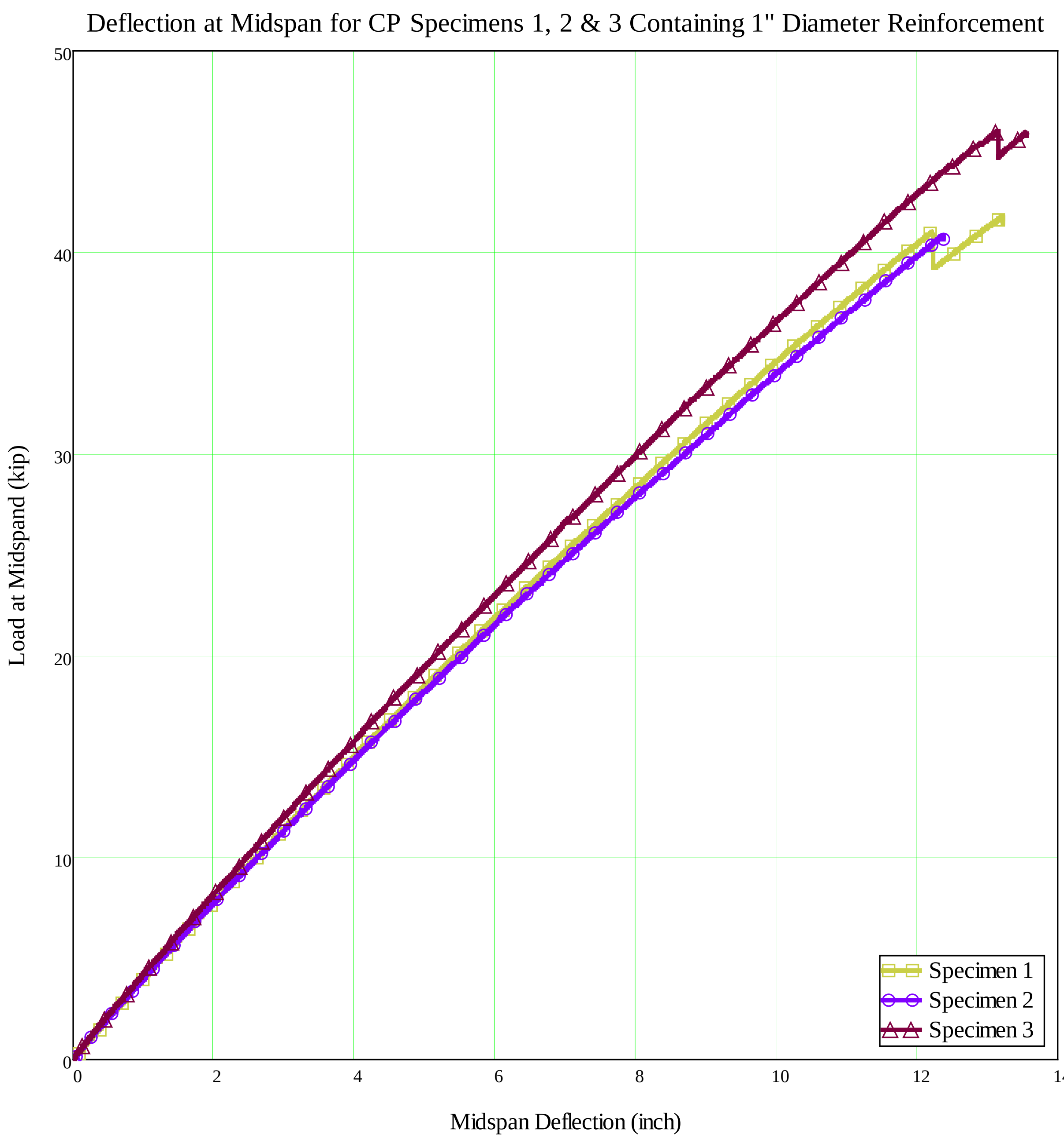


Figure 14: Deflection Curves for CP Specimens with 1" Diameter Fiberglass Reinforcement

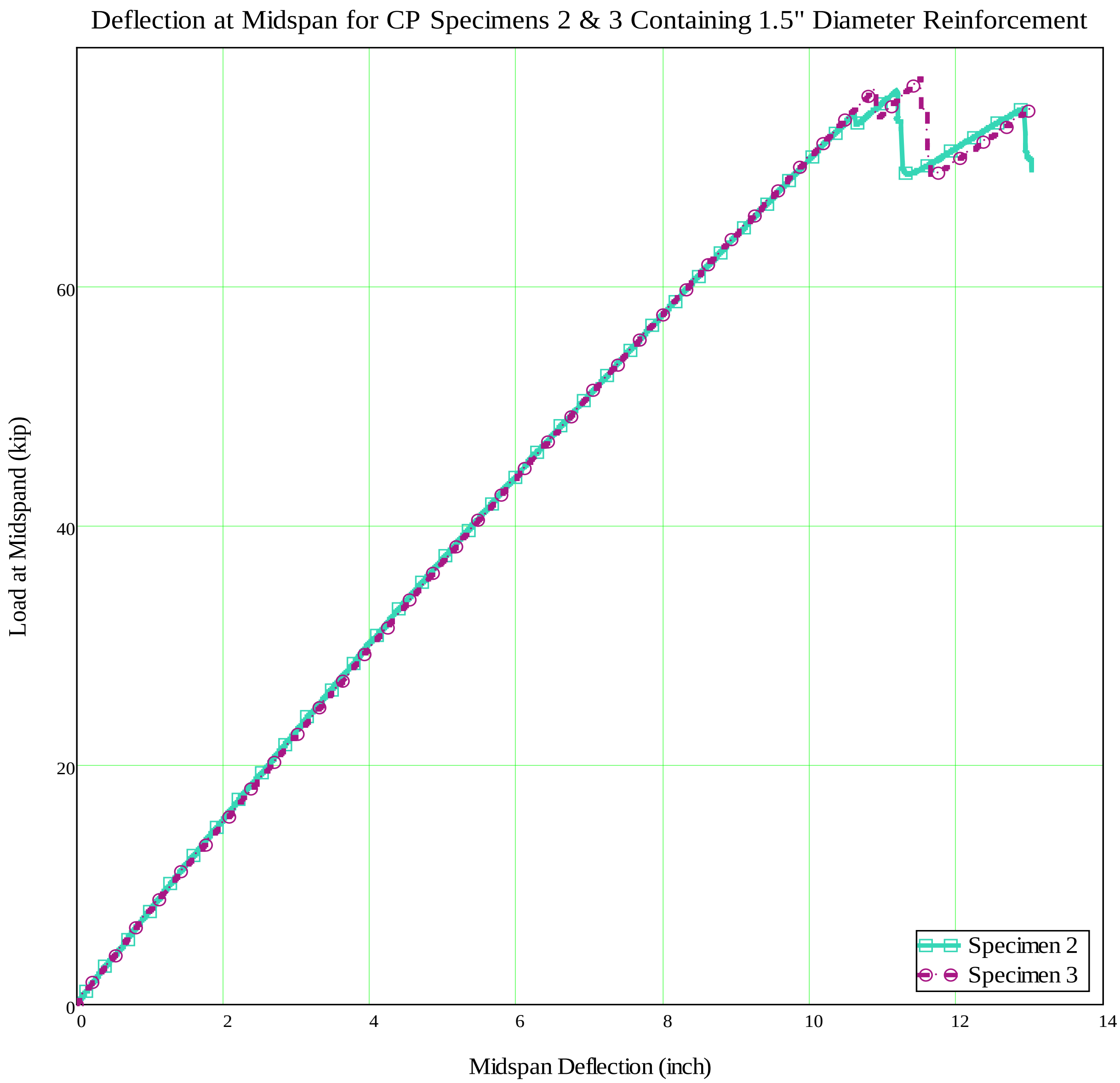


Figure 15: Deflection Curves for CP Specimens with 1.5” Diameter Fiberglass Reinforcement

Figure 16: Testing a CP Specimen

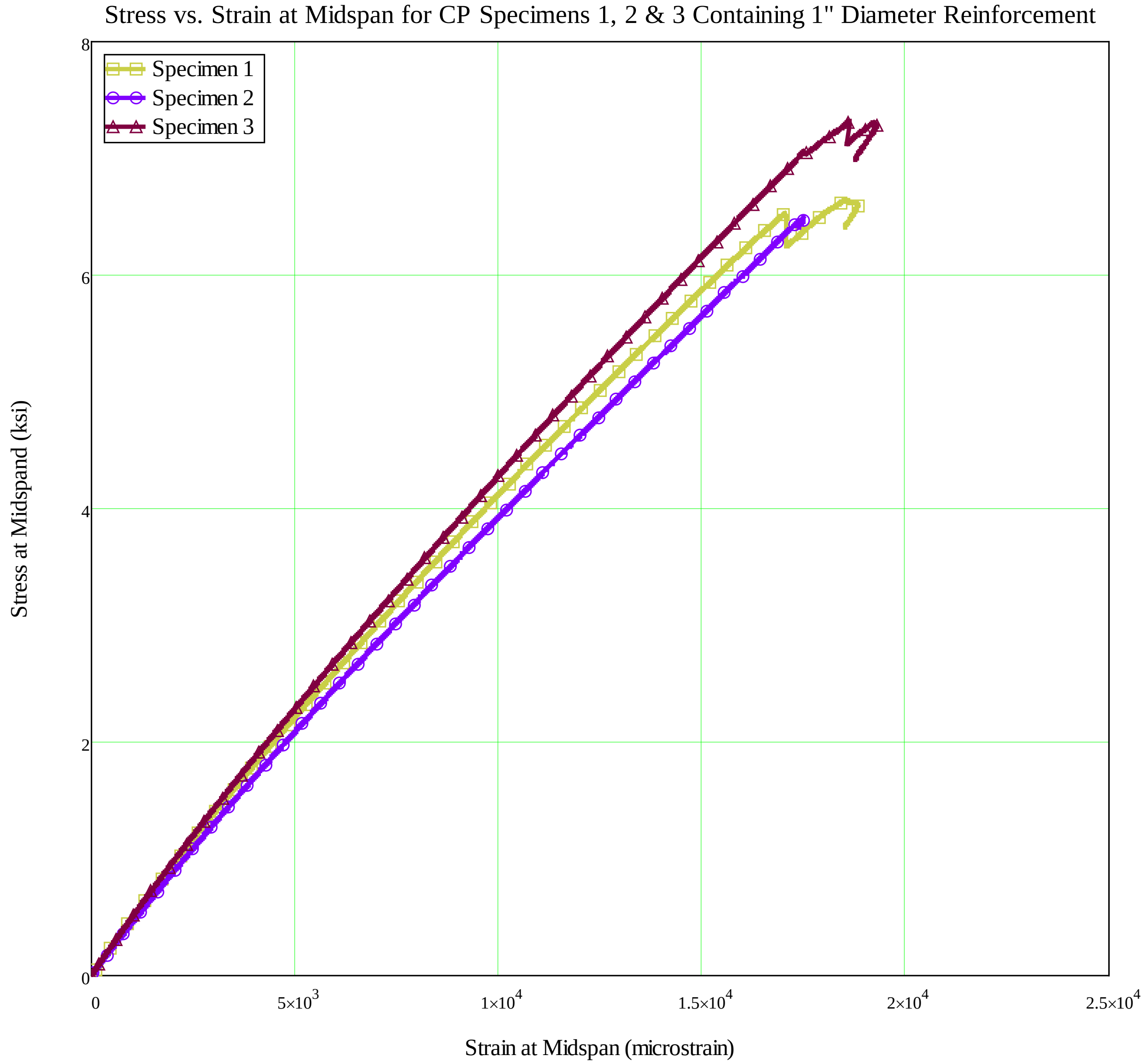


Figure 17: Strain Curves for CP Specimens with 1" Diameter Fiberglass Reinforcement

Figure 18: End Support for CP Specimens (Left) and Load Point (Right)

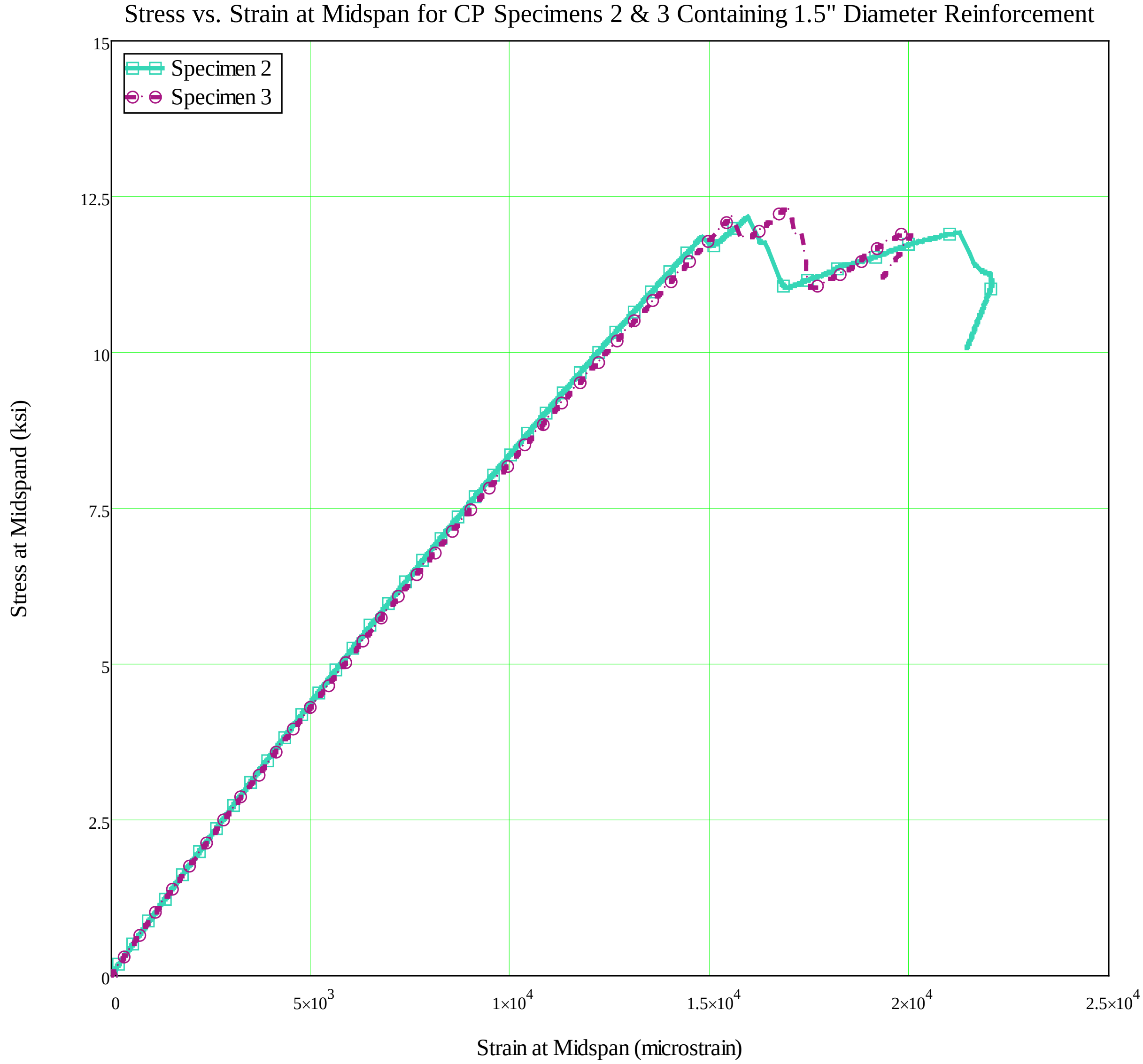


Figure 19: Strain Curves for CP Specimens with 1.5" Diameter Fiberglass Reinforcement

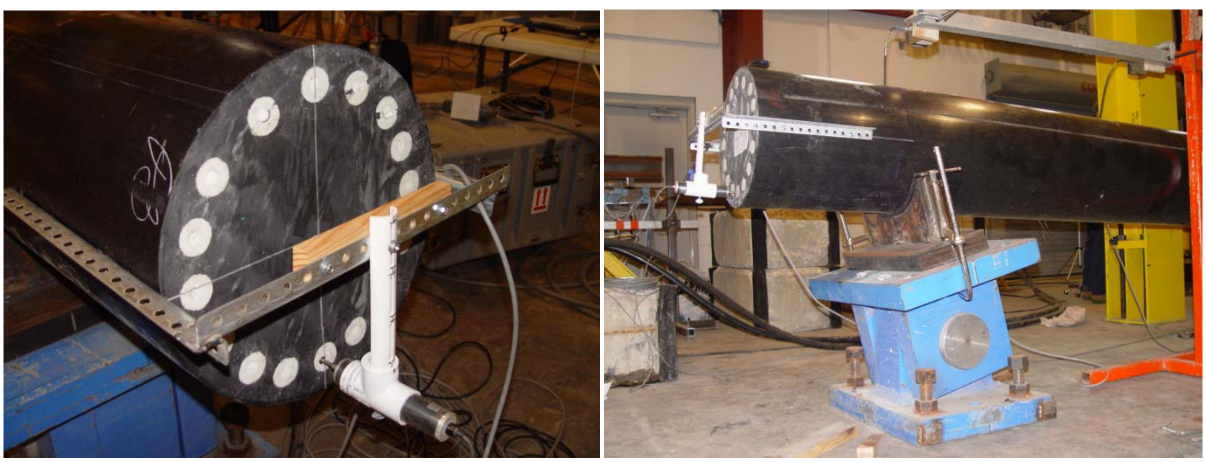


Figure 20: Deflection Gauge Setup for Detecting Slip of Reinforcement for CP Specimens

Discussion:

The data sets collected are accurate but there are a couple issues worth noting with a few of the graphs and photos presented above. The stress vs. strain plots in Figures 10 &12 are not truly complete. The highest strain the data acquisition system was set to read the strain gauges was just above 22,800 microstrain. This is why the graphs in Figures 10 & 12 all terminate at the same point in relation to the x-axis. This was not an issue with the CP specimens because they did not reach that high a level of strain before failure. The absence of a full set of strain data for the SCL specimens is thought to be inconsequential seeing as strain data far beyond 1% strain were recorded and displayed and the stress at 1% strain was used to calculate the modulus of elasticity per ASTM D6109. Also of note is the failure depicted in Figure 13. It should be known that the specimen shown in Figure 13 which is a SCL specimen with 1.5" diameter reinforcing was the only specimen to experience rupture failure. Even though all other specimens experienced breaking or slipping of the fiberglass reinforcement they all rebounded mostly to their original state with only a couple inches of permanent deflection at midspan and a surface dimple where the load was applied. Table 3 lists the averaged structural properties for each specimen type.

Table 3: Averaged Test Results of the Structural Properties of SCL and CP Materials

ID Name	Bar Diameter (inches)	Member Size (inches)	Avg. Modulus of Elasticity (ksi)	Avg. Stiffness, EI (kip-in^2)	Avg. Flexural Strength (ksi)
SCL_1.0	1.0	10 x 10	278	2.20×10^5	4.6
SCL_1.5	1.5	10 x 10	456	3.61×10^5	8.6
CP_1.0	1.0	16 OD	411	1.32×10^6	6.8
CP_1.5	1.5	16 OD	830	2.67×10^6	12.2

During testing popping and cracking sounds could be heard. These sounds are believed to be slipping or breaking of the fiberglass reinforcing bars. Review of the data shows that notable (though small) movements of the reinforcement coincide with failure of the member. Figures 21 & 22 are plots for bar slip of a couple of the more obvious examples. A negative value on the "Bar Slip" axis marks the reinforcement is moving inside of the member, away from the deflection gauge and a positive value that the bar is moving outside the member. Table 4 gives stress and strain values for when the first sizeable bar movement occurred for the specimens we have a full set of strain data for.

Table 4: Stress and Strain Values at First Notable Reinforcement Slip or Failure

ID Name	Stress (ksi)	Strain (microstrain)
SCL_1.0-2	4.41	18286
SCL_1.5-2	7.63	20900
CP_1.0-1	6.53	17042
CP_1.0-2	6.40	17192
CP_1.0-3	7.32	18616
CP_1.5-2	12.17	15985
CP_1.5-3	12.34	16960

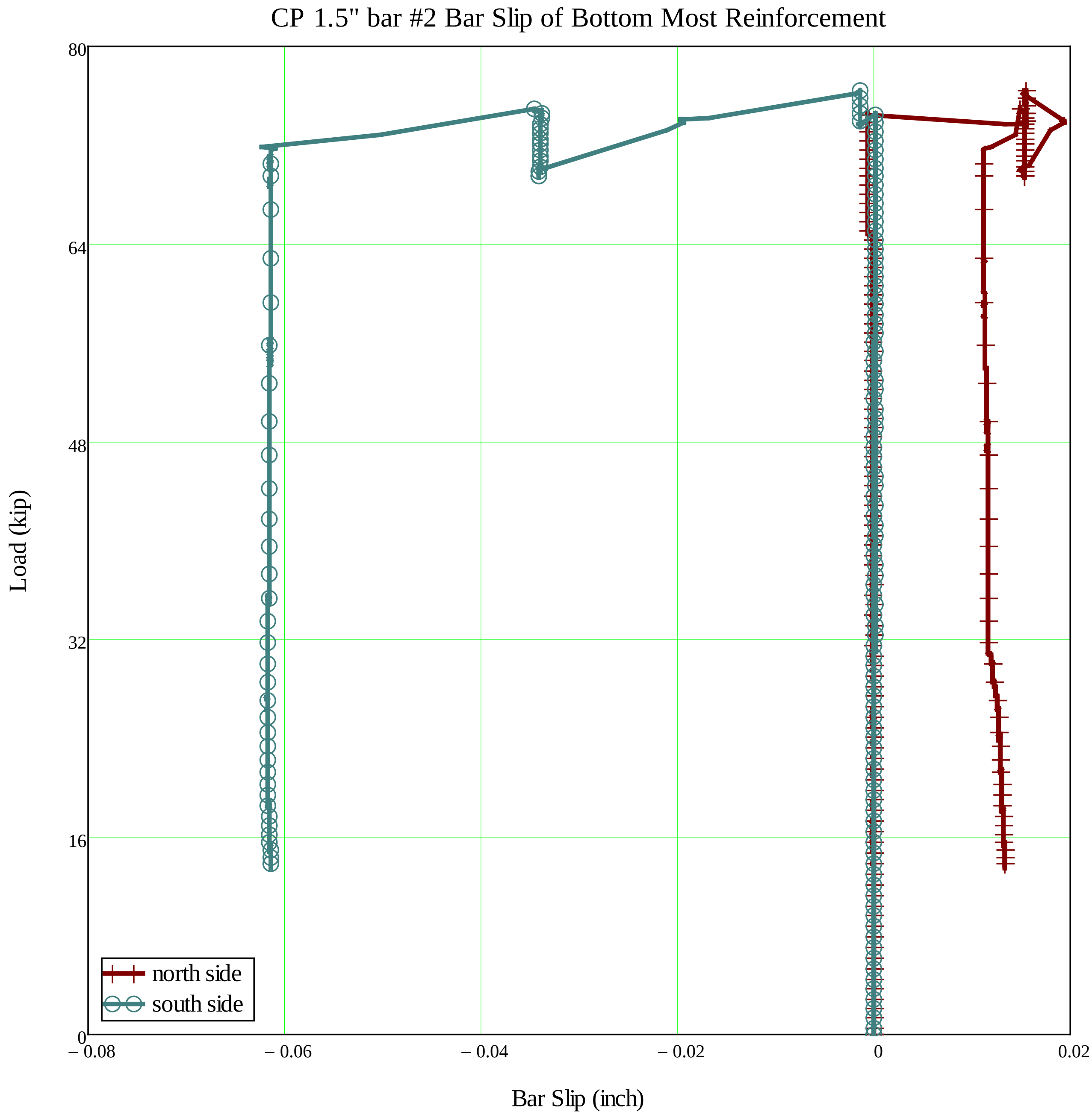


Figure 21: Slip of Reinforcement during CP_1.5-2 Testing

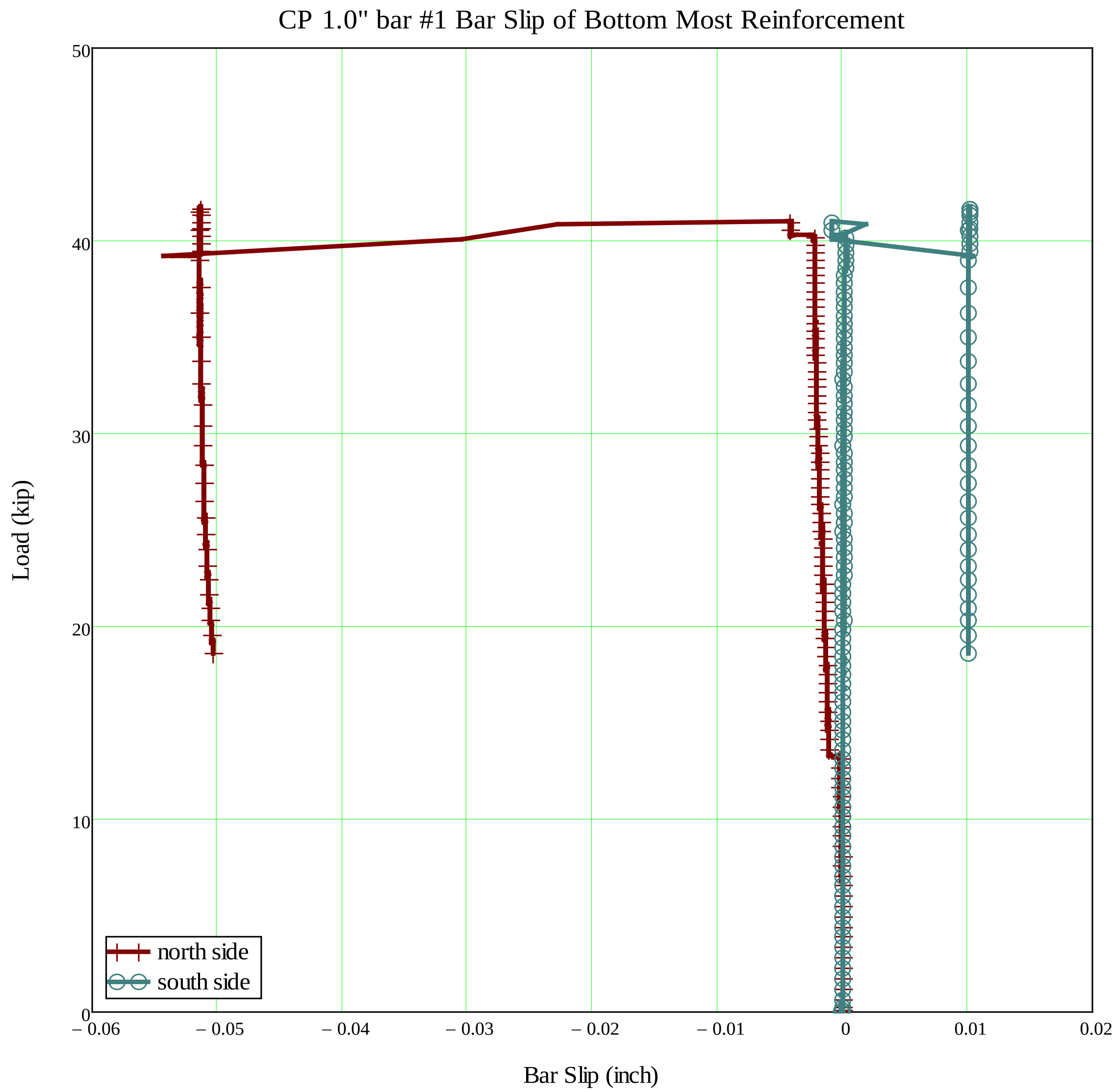


Figure 22: Slip of Reinforcement during CP_1.0-1 Testing

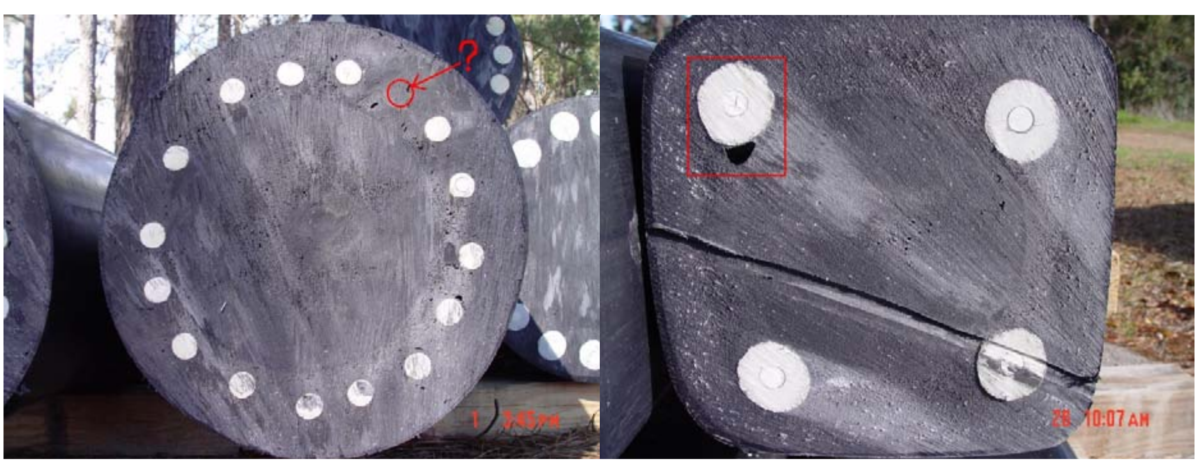


Figure 23: Possible Issues a Structural Plastic Member May be Rejected for

Conclusion:

A final note is that a careful field inspection of the materials provided by the manufacturer should be done to make sure all structural plastics are: 1) free of large voids especially along the edge of the reinforcement 2) not cracked or split, 3) have no voids or cracks in fiberglass reinforcement, 4) the reinforcing bars are properly spaced and 5) the required minimum number of reinforcing bars are present. Figure 23 shows a couple examples of what to look for that were found on two of the specimens provided by Trelleborg. There appears to be a reinforcing bar missing in the CP specimen of the left picture of Figure 23. All sixteen reinforcing bars were present on one side of the specimen but not on the other leaving the consumer to wonder where along the span the missing bar stopped. Perhaps a specification should be written to require that the vendor drill out the end of the pile at the location of a "missing" bar to show that the bar is within a certain distance from the end of the pile. In the right picture of Figure 23 a large void is seen right alongside a 1.5" diameter reinforcing bar. If this is a frequent occurrence the strength of the bond between the reinforcing bars and the plastic member may become a concern.

Overall the specimens provided by Trelleborg behaved well in the fact that only one out of the twelve experienced catastrophic failure. The rest of the specimens bent with an extreme amount of deflection (between 9.5" and 13.5") and were able to rebound close to their original state with only a small dimple and bulge at the load point and a couple inches or less of permanent deflection.