APPENDIX G

I-BEAM SUMMARIES—0.6-IN. STRAND

BEAM NAME: ***IA-6-6-1***
END: ***NORTH***
DATE: 10/10/2005

TEST PARAMETERS	
Concrete Compressive Strength	**8990 psi**
Embedment Length(L_e)	**75 in.**
Span	**156 in.**
Failure Mode	**Shear failure at opposite end**
Maximum Load	**98.9 kips**
Maximum Shear	**49.5 kips**
Maximum Moment	**3267 kip-in**
Maximum Deflection attained	**1.65 in.**
Rebound after complete unloading	**0.5 in.**
Average NASP P.O value for strand "A"	**18.29 kips**

	Transfer lengths (in.) for beam # IA-6-6-1		
		At Release	At the time of testing
North	Top	22.84	NA
	Middle	-	NA
	Bottom East	18.36	NA
	Bottom Central	20.15	NA
	Bottom West	29.83	NA

TEST SUMMARY

The bottom surface of concrete at the North end was damaged during transportation and the strands were exposed. As a result, the support point was moved to 9 in. from the end instead of 6 in.

The development length test was conducted on the South end of Beam IA-6-6-1 before the development length test on the North end. Cracking and other damage that occurred to the beam when testing on the South end affected the test that was performed on the North end. Steel plates were attached to the beam after the test on the South end was completed in an attempt to prevent failures in the South shear span. Even so, the test on the North end of the beam ended with a shear failure in the South shear span of the beam. The results from the test on the North end are not useful for assessment of development length testing.

Photo showing the damage at the Bottom surface of North end of beam IA-6-6-1

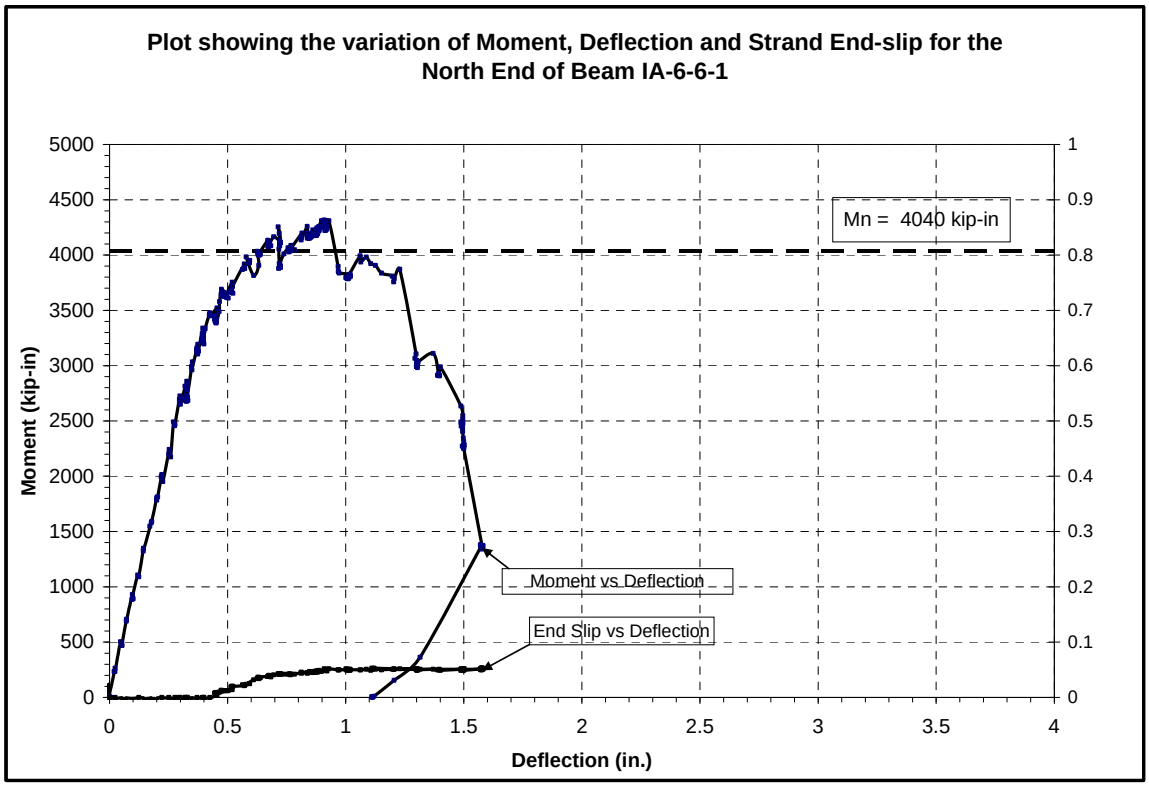
Before starting the test, the web was reinforced with externally connected steel plates on both sides of the beam in the South shear span. Dimensions of the steel plates were 6in. x x1/4 in. and they extended from the South support up to the first loading point from the South end. Holes were drilled through the web to allow the plates to be bolted to the web. The plates were also glued to the surface of the concrete web.

Load was applied in approximately 5.0 kips increments till first flexural cracking. Beyond this point the deflection was increased in each loading by 0.025 in. increments until the total deflection reached 1.0 in. Additional deflection increments were applied in 0.05 in. steps. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 39 in. from the end being tested (30 in. from the North support).

First web shear cracking was observed at the load of 66.3 kips (Shear = 33.15 k; Δ = 0.33 in.). These cracks occurred in the form of two diagonal cracks in the shear zone. No flexural cracks were observed at this point. The first flexural crack was observed at the load of 73.3 kips (Shear = 36.7 kips; Δ = 0.38 in.). The flexural crack appeared as a single crack at Station 80.

First end slip of 0.01 in. was observed at the load of 82.1 kips (Shear = 41.05 kips; Δ = 0.48 in.). The maximum value of end slip was 0.05 at failure.

As the load reached 98.9 kips (Shear = 49.5 kips; Δ = 1.0 in.), an audible crack was heard with the value of load suddenly dropping to 87 kips. A large crack was observed in the South shear span. The load value did not attain its maximum at any increment beyond this point. Finally as the deflection increased to 1.65 in. shear failure was observed at the southern shear span in spite of attaching external steel reinforcement. End slip reading at the South end remained 0.00 throughout the loading and unloading cycles.


Plot showing the variation of Moment, Deflection and Strand End-slip for the North End of Beam IA-6-6-1
Moment (kip-in)
Deflection (in.)
Mn = 4040 kip-in
Moment vs Deflection
End Slip vs Deflection
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
3.5
4

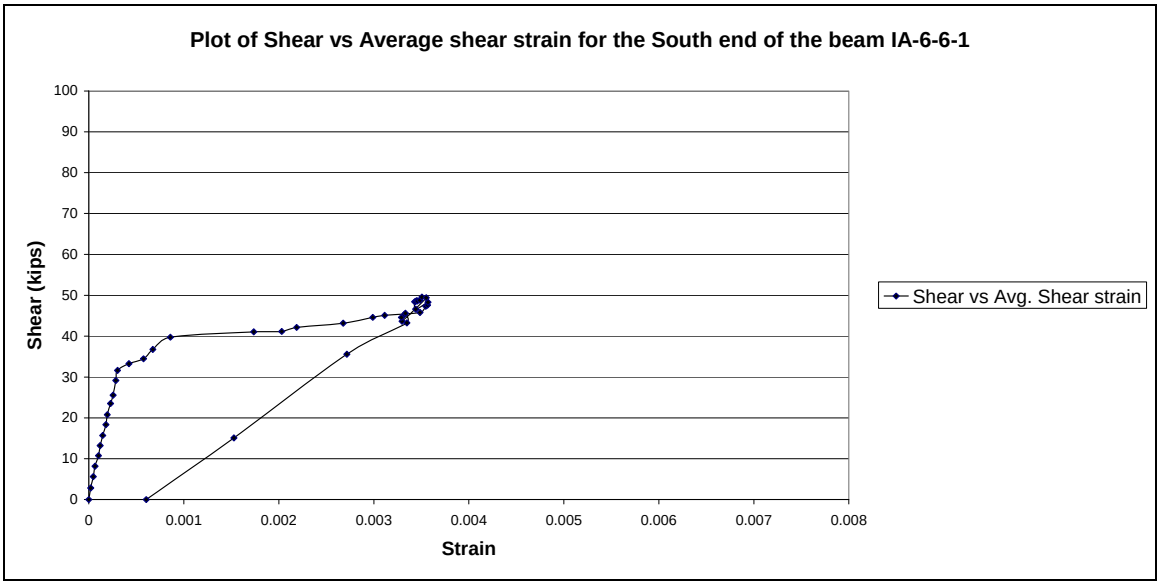

Plot of Shear vs Average shear strain for the South end of the beam IA-6-6-1
Shear (kips)
Strain
Shear vs Avg. Shear strain
100
90
80
70
60
50
40
30
20
10
0
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008

Photo showing the external steel plate attached on the web for compensating the horizontal reinforcement at the North end.

(In all the photographs presented below, cracks marked in black represent the ones originated as flexural cracks while those marked in blue represent the web shear cracks. Red color was used only for marking the grid lines and station points. Number written in red should not be confused with the load values.)

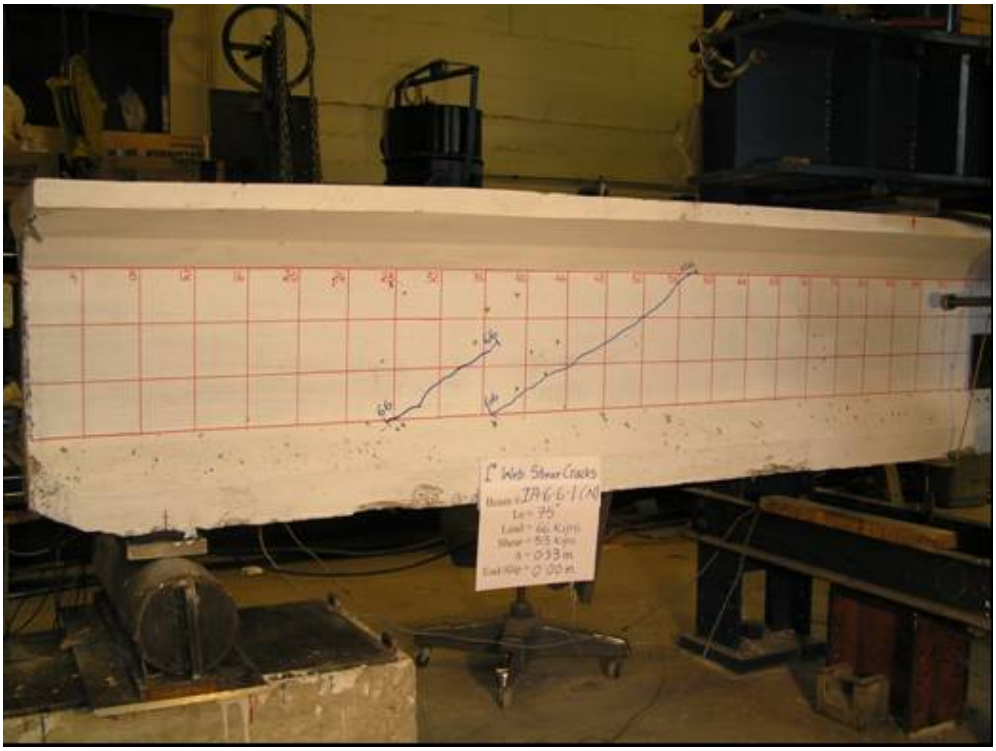


Photo of the North end of the beam IA-6-6-1 showing the first web shear cracking

Photo of South end of beam IA-6-6-1 showing the cracking pattern at the maximum load

BEAM NAME: ***IA-6-6-1***
END: ***SOUTH***
DATE: 10/10/2005

TEST PARAMETERS	
Concrete Compressive Strength	**8990 psi**
Embedment Length(L_e)	**91 in.**
Span	**188 in.**
Failure Mode	**Flexure**
Maximum Load	**107 kips**
Maximum Shear	**53.5 kips**
Maximum Moment	**4387 kip-in**
Maximum Deflection attained	**2.8 in.**
Average NASP P.O value for strand "A"	**18.29 kips**

	Transfer lengths (in.) for beam # IA-6-6-1		
		At Release	At the time of testing
South	Top	9.36	30.7
	Middle	-	
	Bottom East	16.33	36.72
	Bottom Central	20.15	
	Bottom West	22.21	

TEST SUMMARY

The bottom corner of concrete beam at the South end was damaged during handling at the prestressing plant. The strands were exposed as seen in the photo below. Because of the damage, the support point was located 9 in. from the South end of the beam instead of 6 in. The test on the South end of Beam IA-6-6-1 was tested before the North end. Cracking and other damage that occurred to the beam when testing on the South end affected the test that was performed on the North end.

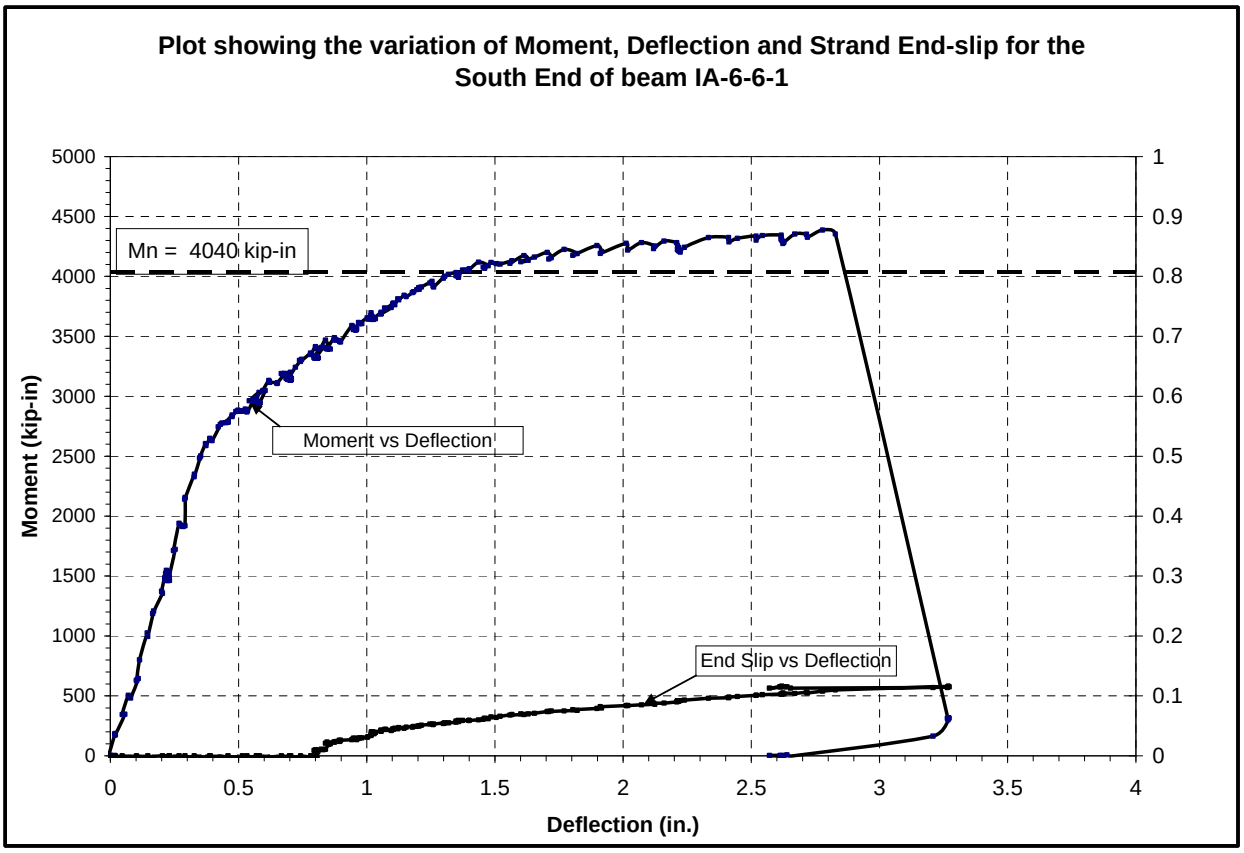
Photo showing the damage at South end caused during handling

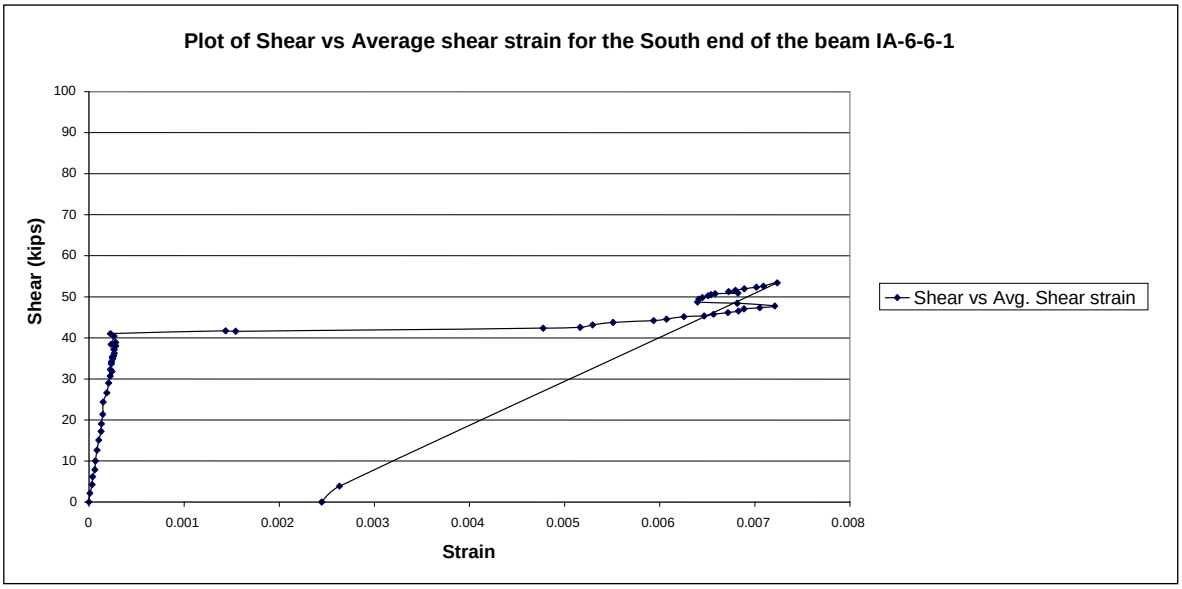
Load was applied in approximate 4.0 kips increments until first flexural cracking. After cracking, beam loadings were done so that the deflection increased in increments of 0.025 in. After the total deflection reached 1.2 in., loading was applied to increase deflection 0.05 in. for each load increment. Finally after the total deflection reached 1.7 in., deflection was increased 0.1 in. in each load increment. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 39 in. from the end being tested (30 in. from the South support).

First flexural cracks were observed at a load of 64.6 kips (Shear = 32.2 kips; Δ= 0.4 in.). The flexural cracks occurred within the maximum moment region at Stations 88, 104 and 112. Initial web shear cracks were observed at the load of 79 kips (Shear = 39.5 kips; Δ = 0.7 in.). Load dropped to 76.8 kips immediately after the web shear cracks formed. DEMEC readings were taken at the reduced value of load.

First end slip of 0.01 in. was observed at the load of 83.5 kips (Shear = 41.6 kips; Δ = 0.8 in.) The value of end slip continued to increases with load till the point of flexural failure at the load of 107 kips (Shear = 53.5 kips ; Δ = 2.8 in.). Maximum end slip value recorded was 0.12 in. End slip readings at the North end remained 0.00 throughout the loading and unloading cycles. The beam failed in flexure at a maximum moment of 4387 k-in., which exceeds the nominal flexural capacity of 4040 k-in.

The beam exhibited a flexural failure in that it was able to achieve its nominal flexural capacity and sustain that load through large deformations (ductility). The fact that strand slip occurred demonstrates that the strand is able to develop tension sufficient to support the flexural loads even while slipping.





(In all the photographs presented below, cracks marked in black represent the ones originated as flexural cracks while those marked in blue represent the web shear cracks. Red color was used only for marking the grid lines and station points. Number written in red should not be confused with the load values.)

Photo of the South end of the beam IA-6-6-1 showing the first web shear cracking

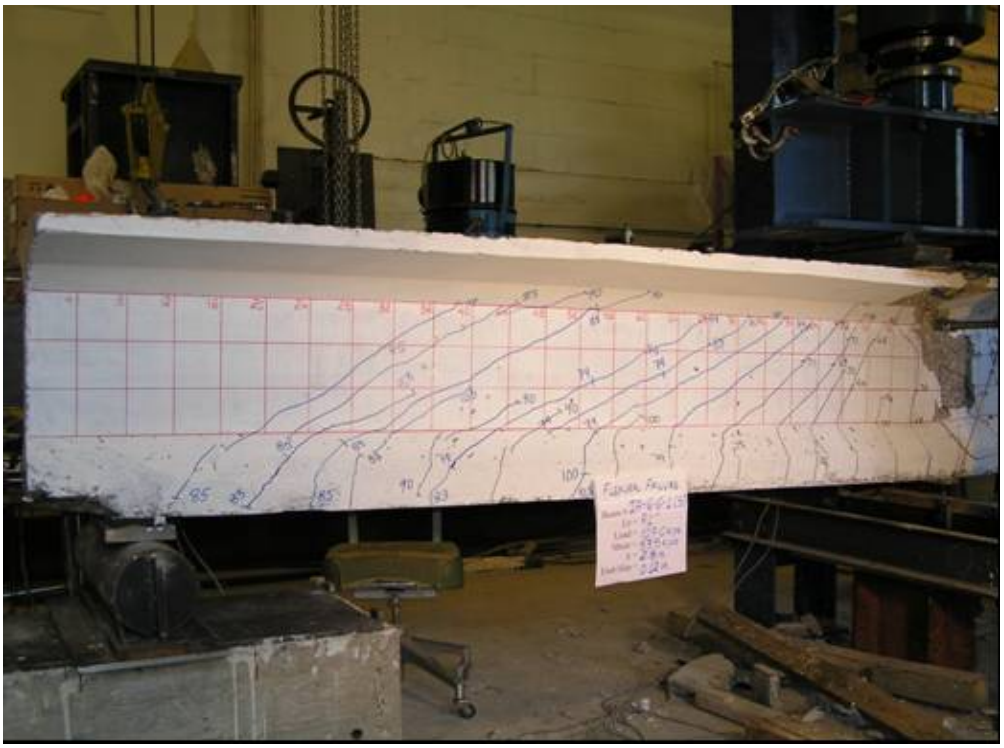


Photo of South end of beam IA-6-6-1 showing the cracking pattern at Flexural failure

BEAM NAME: ***IA-6-6-2***
END: ***NORTH***
DATE: 10/13/2005

TEST PARAMETERS	
Concrete Compressive Strength	**8990 psi**
Embedment Length(L_e)	**88 in.**
Span	**270 in.**
Failure Mode	**Shear**
Maximum Load	**75.5 kips**
Maximum Shear	**50.3 kips**
Maximum Moment	**4125 kip-in**
Maximum Deflection attained	**3.2 in.**
Average NASP P.O value for strand "A"	**18.29 kips**

	Transfer lengths (in.) for beam # IA-6-6-2		
		At Release	At the time of testing
North	Top	20.22	NA
	Middle	-	-
	Bottom East	9.62	27.1
	Bottom Central	22.58	35.72
	Bottom West	15.48	29.95
South	Top	21.84	NA
	Middle	-	-
	Bottom East	14.18	28.62
	Bottom Central	14.92	24.49
	Bottom West	19.47	37.69

TEST SUMMARY

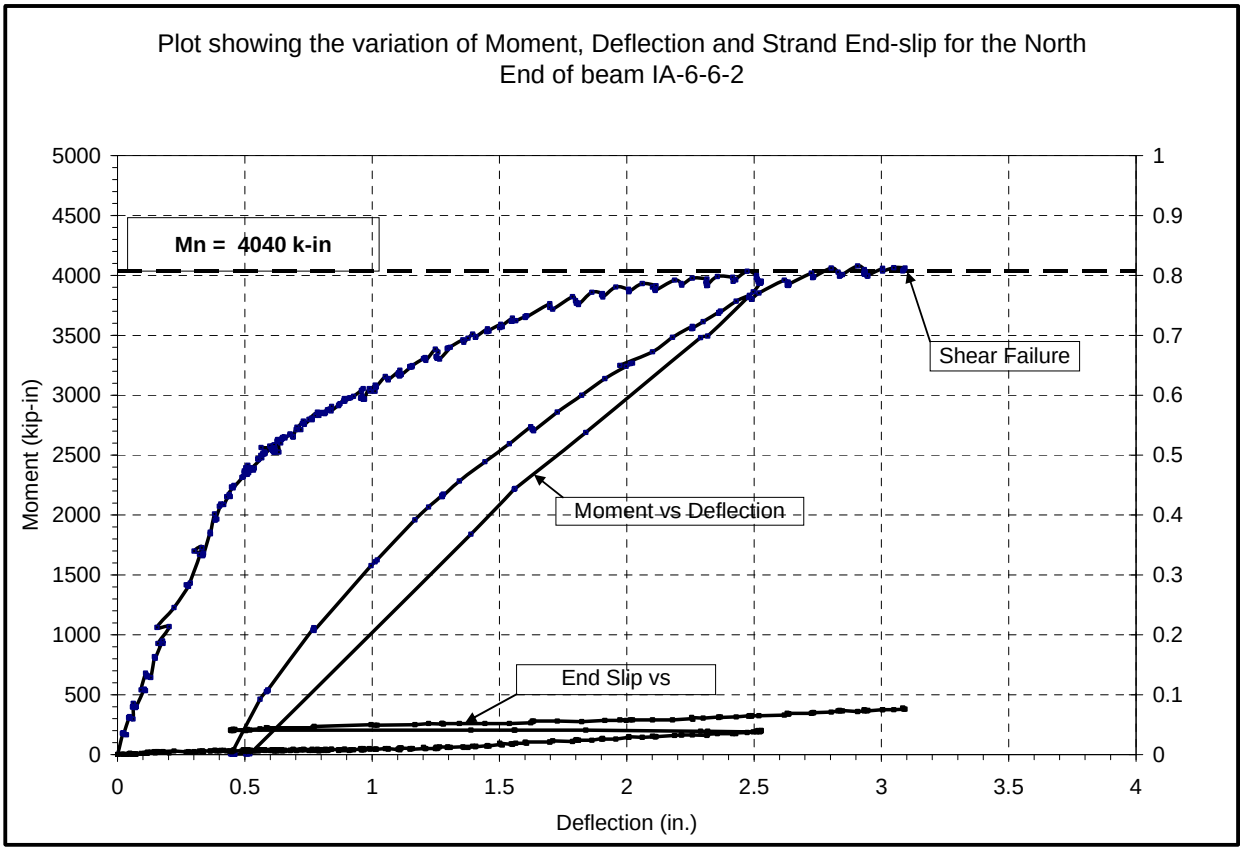
The initial condition of the beam was recorded on photographs. There were several initial cracks present on the beam with a significantly long crack at the junction of flange and web. These cracks were caused during handling of the beam in the prestressing plant.

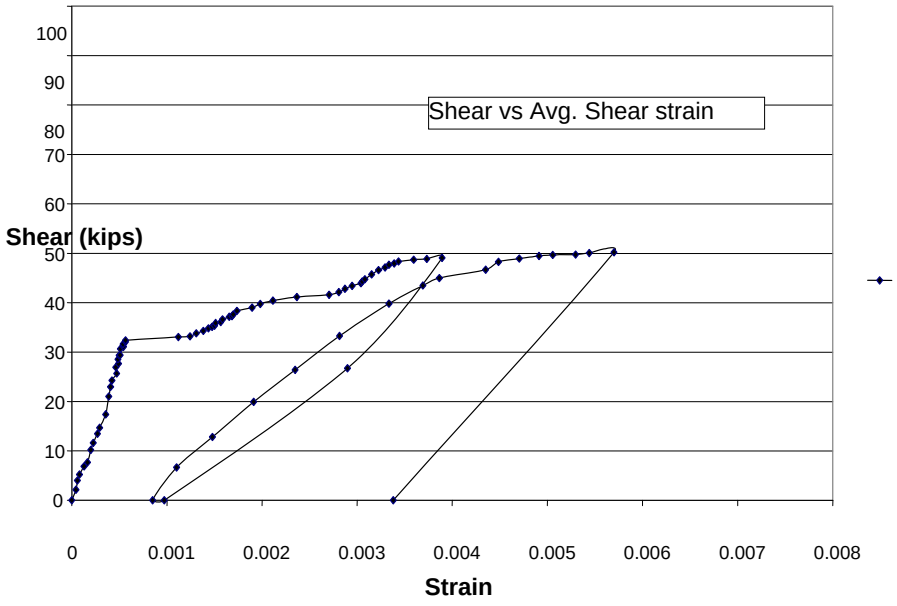
Photo showing the cracks present on the beam IA-6-6-2 before starting the test.

The beam was loaded in two cycles on 13th and 14th October 2005 respectively. For the first loading cycle, load was applied in approximately 3.0 kip increments until first flexural cracking. Beyond this point the deflection was increased in 025 in. increments until the total deflection reached 1.0 in. Then deflection was increased in 0.05 in. increments. For the second cycle, load was increased in 10 kips increment up to 60 kips. Beyond 60 k, load was increased at increments of 2.5 k. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 36 in from the end being tested.

First flexural cracks occurred nearly simultaneously with the first web shear cracks at the load of 44 kips (Shear = 29.3 kips) and deflection of 0.5 in. First flexural cracks occurred as a pair of cracks located at Stations 96 and 100. First web shear cracks occurred in the form of three cracks almost parallel to each other in the shear zone.

The first end slip of 0.01 in. was observed along with an audible shear crack at 58.5 kips (Shear = 39 kips; Δ= 1.1 in.). The value of end slip continued to increase very gradually till at Shear failure the maximum value of end slip was 0.13 in. No significant changes were noticed during further load increments. The maximum value of load attained was 75.3 kips (Shear = 50.2 kips; Δ = 2.9 in.) when the shear cracks were seen to grow wide with concrete spalling from the sides of the web. As the deflection increased to 3.1 in., the load dropped to 73.8 kips and a sudden shear failure occurred with diagonal crushing of the concrete in the web. The end slip reading at the South end remained at 0.00 in throughout the loading and unloading cycles.





Plot of Shear vs Average shear strain for the North end of the beam IA-6-6-2

(In all the photographs presented below, cracks marked in black represent the ones originated as flexural cracks while those marked in blue represent the web shear cracks. Red color was used only for marking the grid lines and station points. Number written in red should not be confused with the load values.)

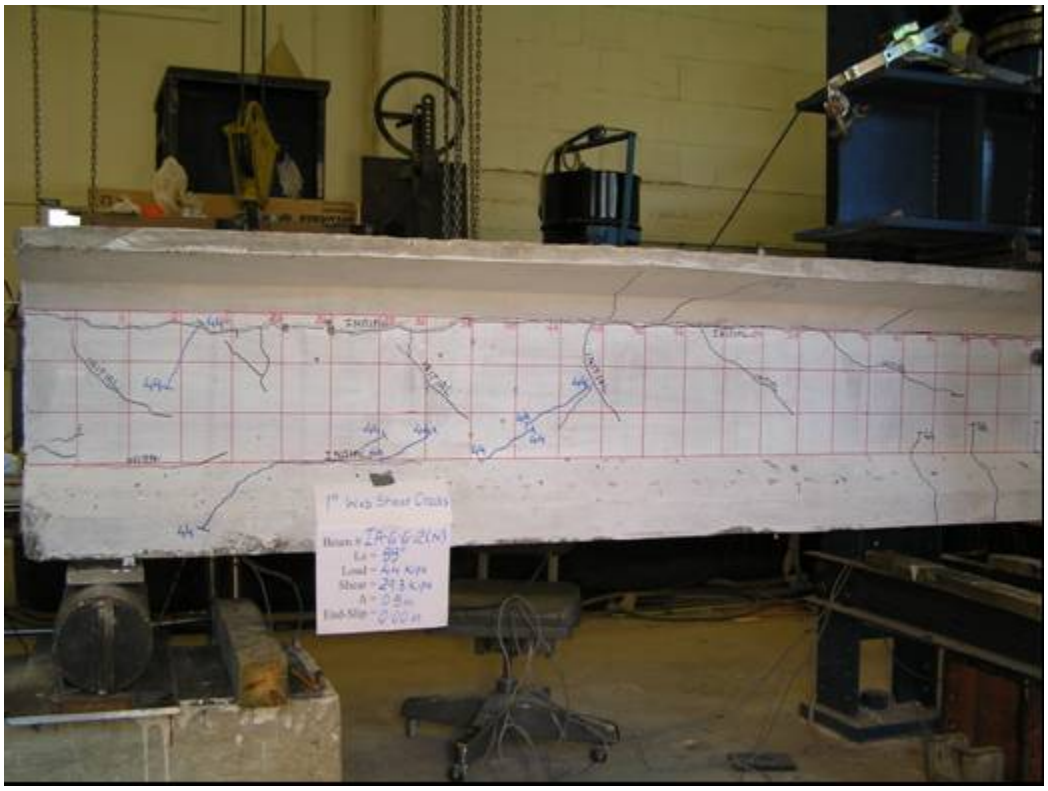


Photo of the North end of the beam IA-6-6-2 showing the first web shear cracking (incidentally the point of first flexural cracking as well)

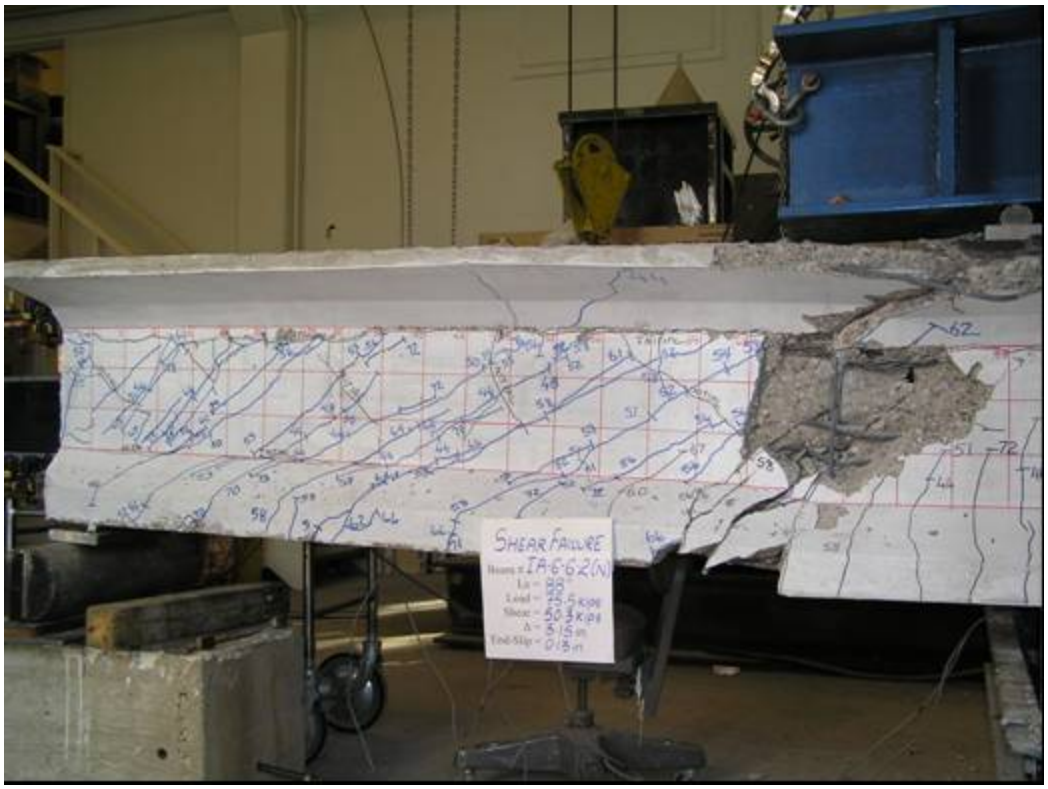


Photo of North end of beam IA-6-6-2 showing the cracking pattern at failure

BEAM NAME: ***IA-10-6-1***
END: ***NORTH***
DATE: 11/02/2005

TEST PARAMETERS	
Concrete Compressive Strength	**14990 psi**
Embedment Length(L_e)	**58 in.**
Span	**166 in.**
Failure Mode	**Shear failure at the opposite end**
Maximum Load	**127 kips**
Maximum Shear	**81.6 kips**
Maximum Moment	**4243.2 kip-in**
Maximum Deflection attained	**1.2 in.**
Average Transfer Length (L_t) @ release	**-**
@ time of testing	**-**
Average NASP P.O value for strand "A"	**18.29 kips**

TEST SUMMARY

The development length test was conducted on the South end of Beam IA-10-6-1 prior to this test. The test on the South end concluded with a flexural failure along with a tension failure of a strand in the region of maximum moment. For this reason, the loading span for this test, the test on the North end was shorter than planned. The shorter span resulted in higher shears in the south end opposite the "test" end. The high shear force resulted in a shear failure at the South shear span of the test, intended to test the NORTH end of the beam. Still, the load resisted by the beam matched and even exceeded the nominal flexural capacity calculated for the cross section, so in a sense the strand was able to develop adequate tension even though the beam the test did not test the ductility of the flexural failure.

Before starting the test the strands on the South end were fixed with chucks for preventing any end slip from that end as the South end was already tested.

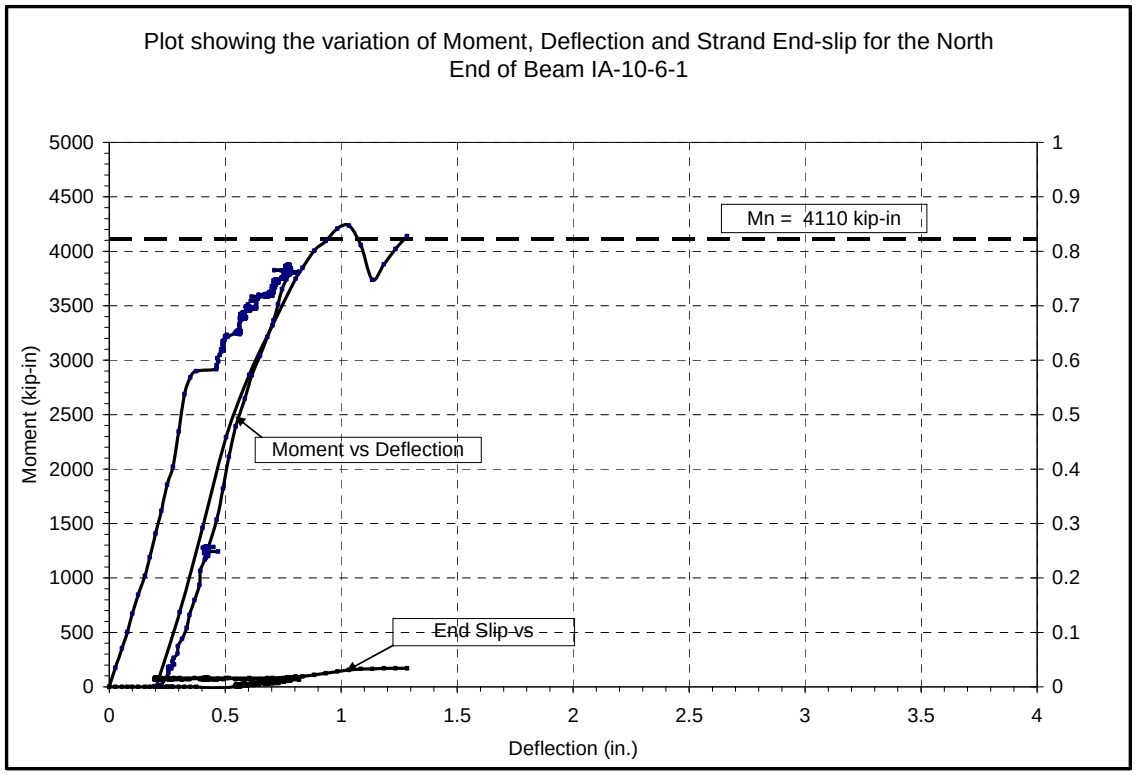
Photo showing chuck assembly at South end to prevent strands

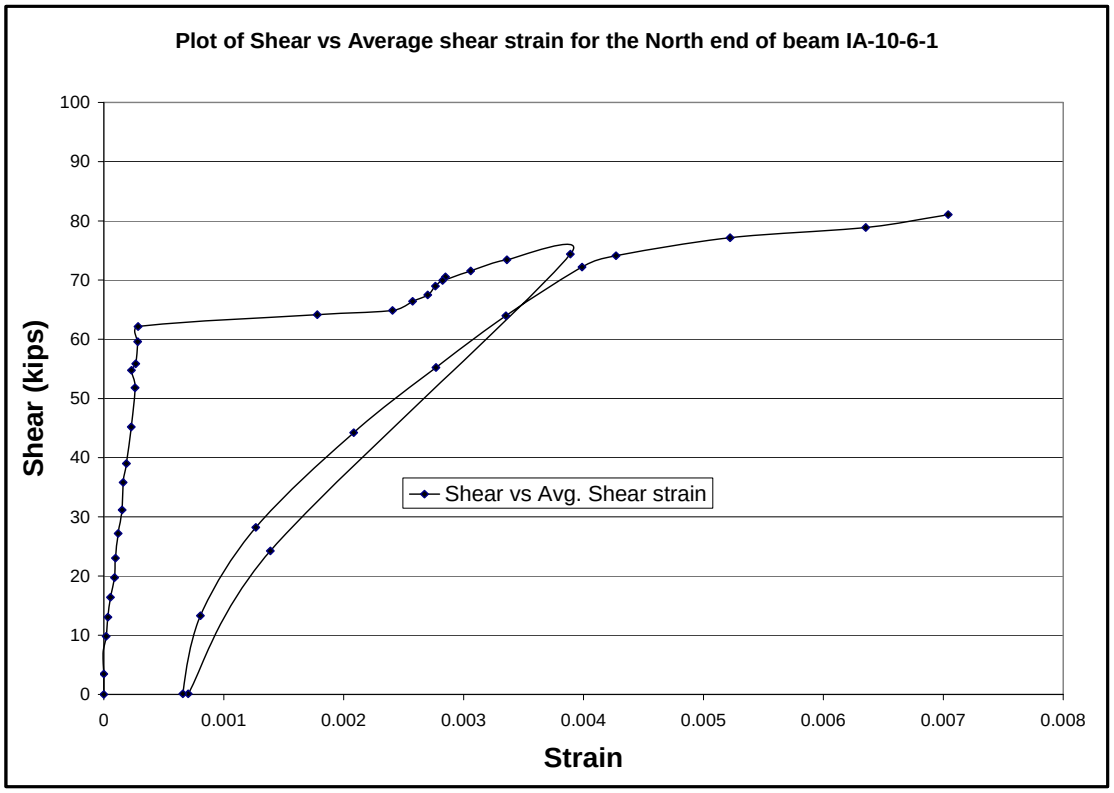
The beam was loaded in two loading cycles. For the first loading cycle, load was applied in approximately 5.0 kips increments till the total defection reached 0.7 in. The beam was unloaded completely at this stage. For the second loading cycle, deflection was incremented by approximately 0.1 in. till earlier value was attained. Beyond this, the deflection increments were set to 0.05 in. till the end of the test. New cracks which occurred during the second loading were marked with a bar on top of the load values at which they occurred. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 36 in from the end being tested.

First flexural crack was observed simultaneously with the first web shear cracking at the load of 85.2 kips (Shear = 54.8 kips; deflection = 0.35 in.) No significant drop in load was noticed.

First end slip of 0.01 in was observed at the load of 100.9 kips (Shear = 64.9 kips; deflection = 0.45 in.) End slip reading went on increasing very slowly till at failure, the maximum noted end slip reading was 0.05 in.

It was noticed that the shear cracks were growing wider in the South side shear zone. Finally the beam gave off violently at the maximum load of 127 kips (Shear = 81.6 kips; deflection = 1.2 in.) The shear failure of beam at the opposite side was extremely violent with the beam literally breaking into two halves. Unloading data for the beam could not be noted due to the nature of beam failure.


Plot showing the variation of Moment, Deflection and Strand End-slip for the North End of Beam IA-10-6-1
Moment (kip-in)
Deflection (in.)
Mn = 4110 kip-in
Moment vs Deflection
End Slip vs
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.5
1
1.5
2
2.5
3
3.5
4


Plot of Shear vs Average shear strain for the North end of beam IA-10-6-1
Shear (kips)
Strain
Shear vs Avg. Shear strain
100
90
80
70
60
50
40
30
20
10
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008

(In all the photographs presented below, cracks marked in black represent the ones originated as flexural cracks while those marked in blue represent the web shear cracks. Red color was used only for marking the grid lines and station points. Number written in red should not be confused with the load values.)

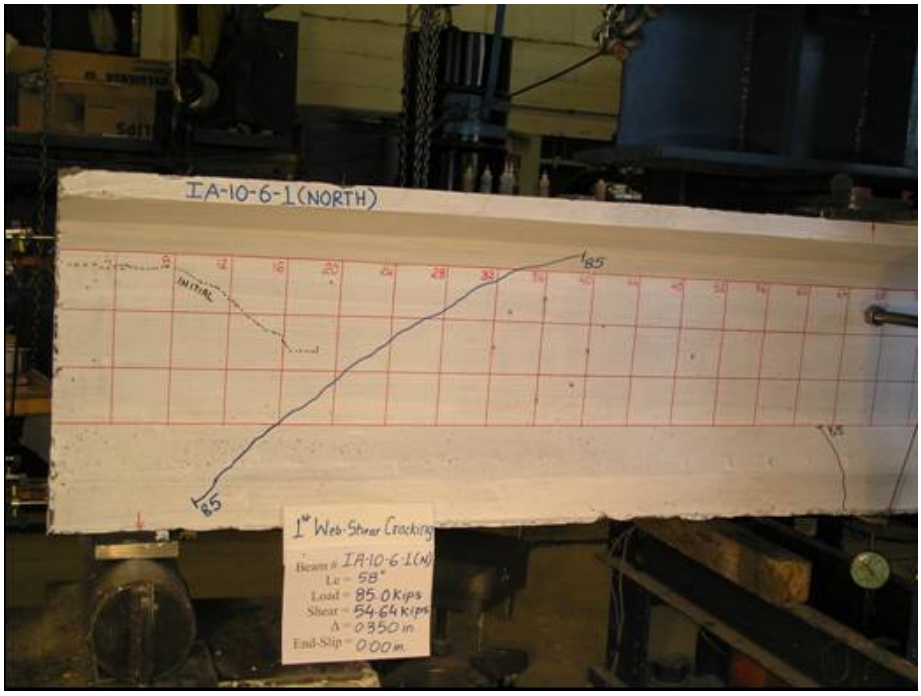


Photo showing first web shear cracking for IA-10-6-1-N

Photo showing shear failure at the opposite end for IA-10-6-1-N

BEAM NAME: ***IA-10-6-1***
END: ***SOUTH***
DATE: 10/26/2005

TEST PARAMETERS	
Concrete Compressive Strength	**14990 psi**
Embedment Length(L_e)	**72 in.**
Span	**222 in.**
Failure Mode	**Strand Fracture**
Maximum Load	**105 kips**
Maximum Shear	**70 kips**
Maximum Moment	**4620 kip-in.**
Maximum Deflection attained	**2.5 in.**
Average Transfer Length (L_t) @ release	**-**
@ time of testing	**-**
Average NASP P.O value for strand "A"	**18.29 kips**

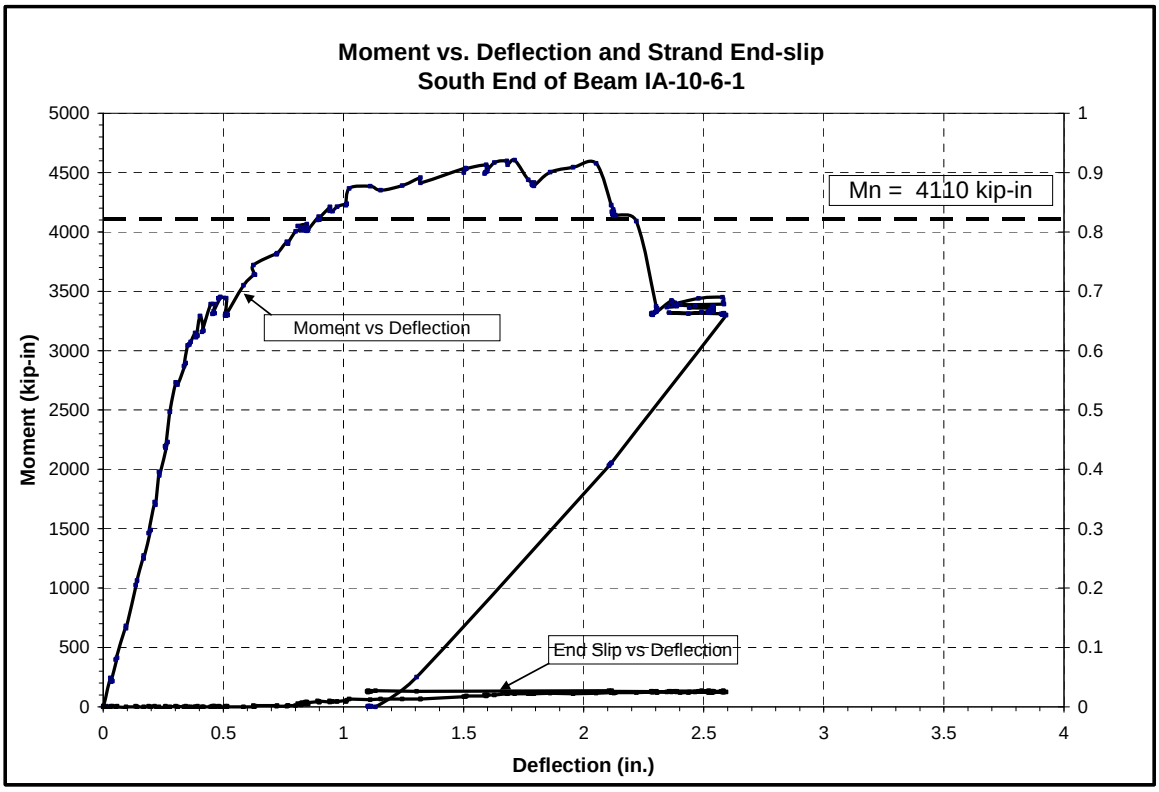
TEST SUMMARY

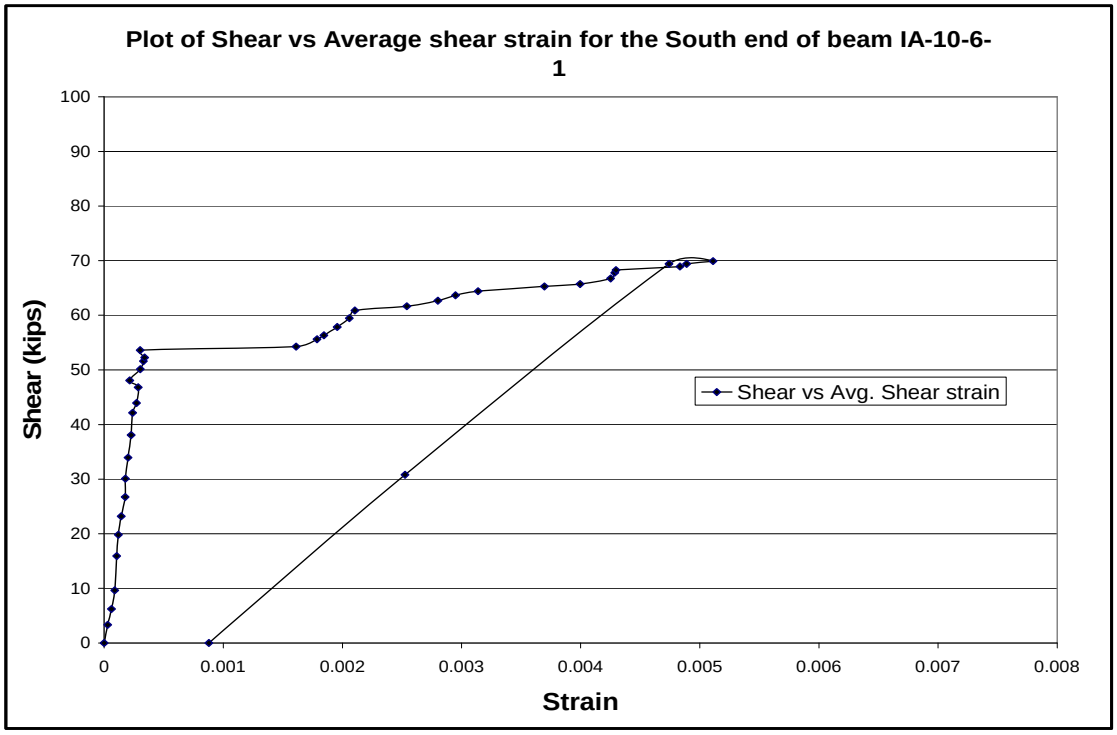
Load was applied in 5.0 k increments to a total deflection of 0.4 in. Then load was applied to increase deflection in increments of 0.05 in. up to 1.15 in. total deflection. Then load was applied to increase deflection in increments of 0.10 in. until the beam failed. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 36 in from the end being tested.

The first flexural crack was observed at a load of 65.7 kips (Shear = 43.8 k; Δ= 0.33 in.). The first secondary crack was observed at a load of 77.6 kips (Shear = 51.7 k; Δ= 0.45 in.). At the load of 80.6 kips (Shear = 53.7 k; Δ= 0.5 in.) an inclined flexure-shear crack was observed near the first loading point from the South end. Initial web shear cracks were observed at the load of 81.6 kips (Shear = 54.4 kips; Δ= 0.58 in.). The value of load dropped to 77.2 kips after the web shear cracks formed. Web shear cracks formed one succession, one after another starting from the loading point nearest to South support and moving towards South support.

End slip of 0.01 in. was observed at the load of 92.7 kips (Shear = 61.8 kips; Δ= 0.9in.). End slips increased gradually with each load increment until beam failure. Beam failure was caused by a strand fracture. At that time the maximum value of end slip was 0.03in. A sudden violent noise was heard at the load of 105 kips (Shear = 70 kips; Δ= 2.5 in.). Load value dropped to 94 kips. After careful observation of the widest crack where concrete spalling took place, it was noticed that one of the strands (Bottom East) had fractured.

This beam failed in flexure, and the bond of the strand was adequate to develop strand tension necessary to support the flexural capacity.


Moment vs. Deflection and Strand End-slip
South End of Beam IA-10-6-1
Mn = 4110 kip-in
Moment vs Deflection
End Slip vs Deflection
Moment (kip-in)
Deflection (in.)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
3.5
4


Plot of Shear vs Average shear strain for the South end of beam IA-10-6-1
Shear vs Avg. Shear strain
Shear (kips)
Strain
100
90
80
70
60
50
40
30
20
10
0
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008

(In all the photographs presented below, cracks marked in black represent the ones originated as flexural cracks while those marked in blue represent the web shear cracks. Red color was used only for marking the grid lines and station points. Number written in red should not be confused with the load values.)

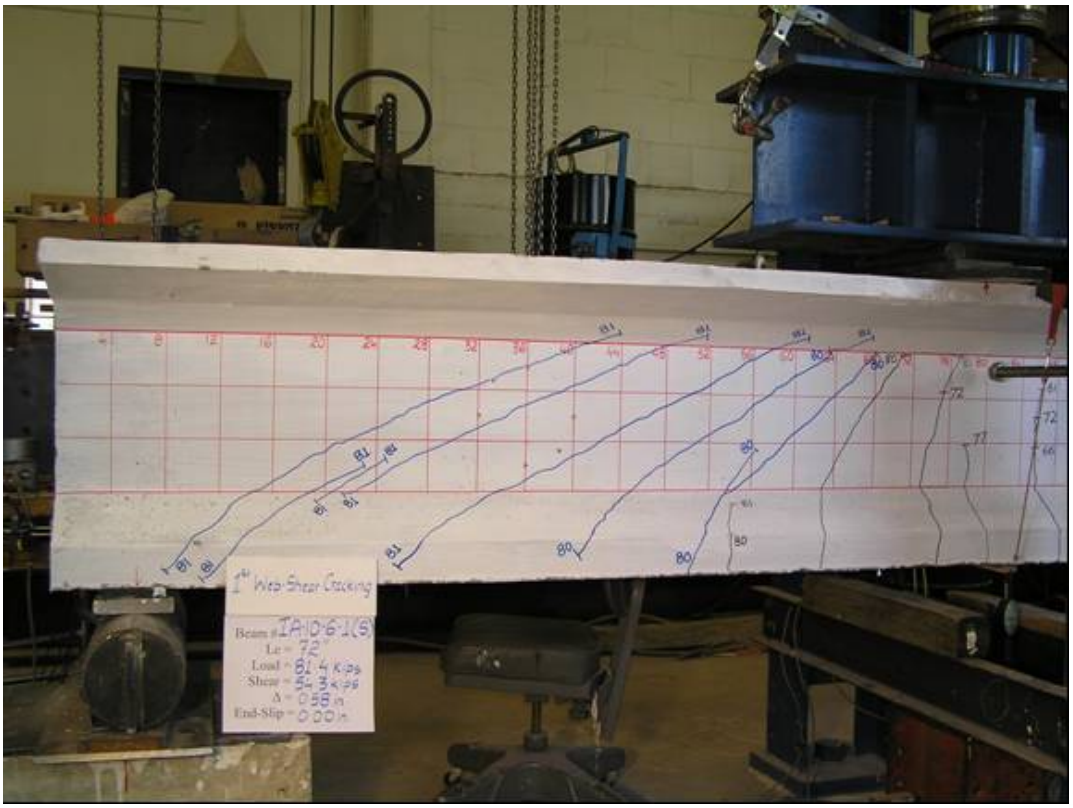


Photo of the South end of the beam IA-10-6-1 showing the first web shear cracking

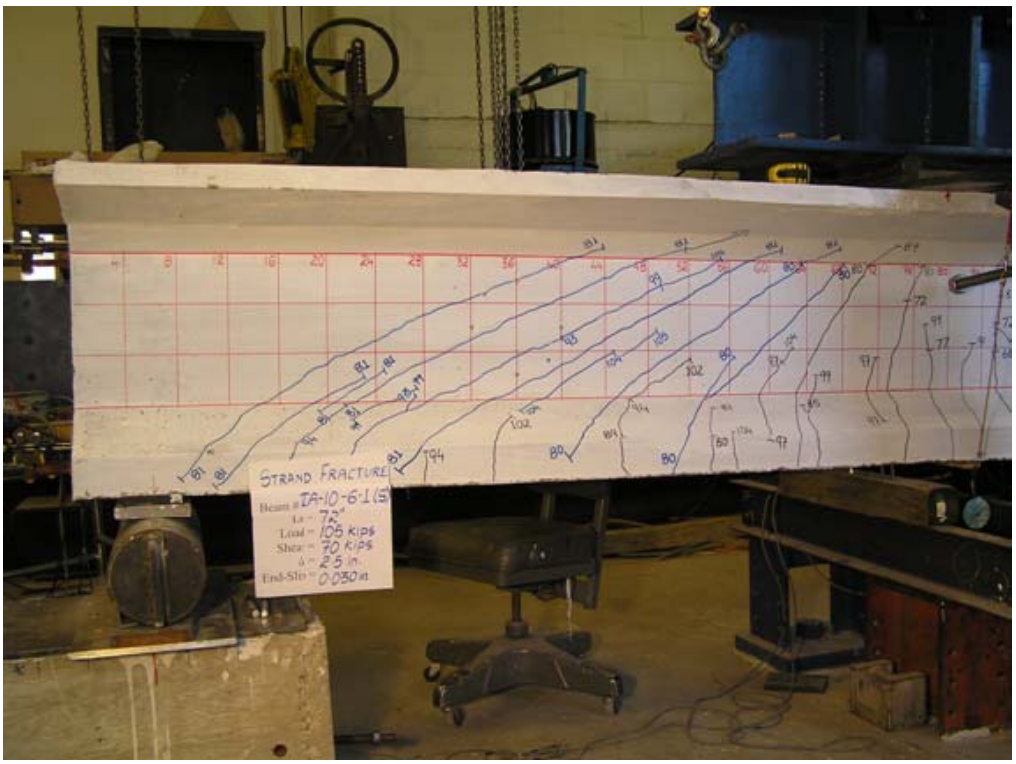


Photo of South end of beam IA-10-6-1 showing the cracking pattern at strand fracture

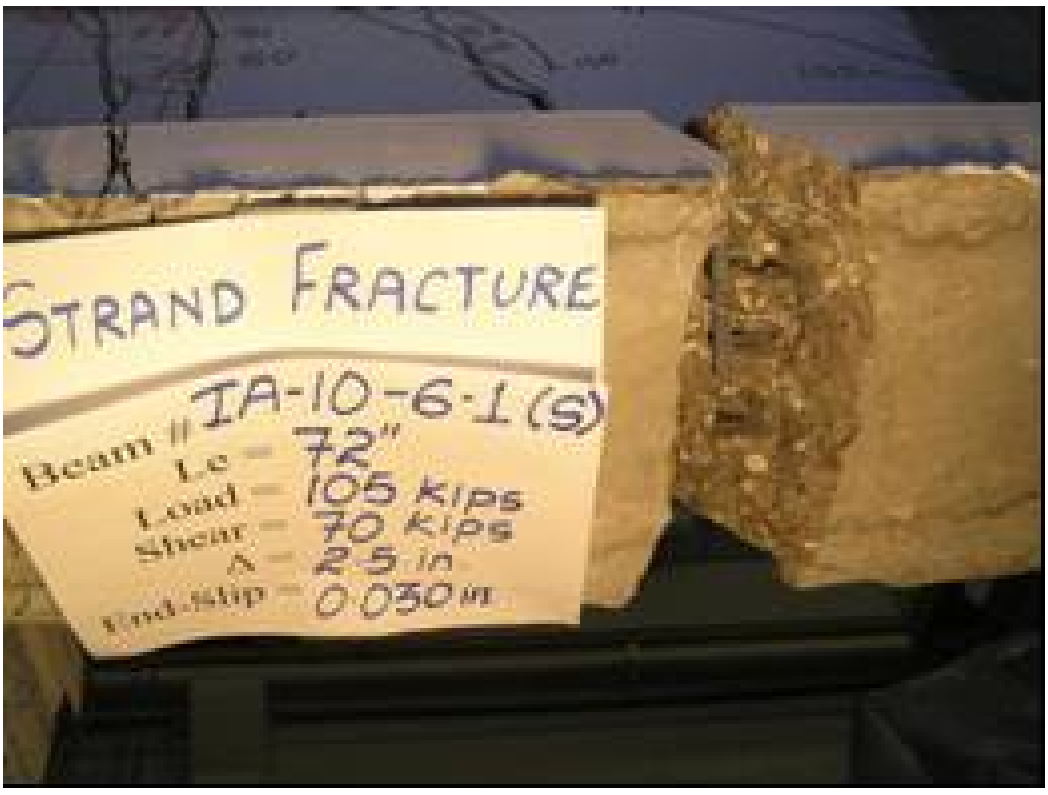


Photo showing the fractured strand (Test IA-10-6-1-S)

BEAM NAME: ***IA-10-6-2***
END: ***NORTH***
DATE: 10/2/2005

TEST PARAMETERS	
Concrete Compressive Strength	**14930 psi**
Embedment Length(L_e)	**72 in.**
Span	**222 in.**
Failure Mode	**Shear failure at opposite side**
Maximum Load	**67.8 kips**
Maximum Shear	**45.2 kips**
Maximum Moment	**2983.2 kip-in**
Maximum Deflection attained	**0.9 in.**
Rebound after complete unloading	**0.4 in.**
Average NASP P.O value for strand "A"	**18.29 kips**

	Transfer lengths (in.) for beam # IA-10-6-2		
		At Release	At the time of testing
North	Top	21.43	23.43
	Middle	16	-
	Bottom East	16.12	22.51
	Bottom Central	10.93	50.43
	Bottom West	17.82	20.53

TEST SUMMARY

The development length test was conducted on the South end of Beam IA-10-6-1 prior to this test. The test on the South end concluded with a flexural failure along with a tension failure of a strand in the region of maximum moment. For this reason, the loading span for this test, the test on the North end was shorter than planned. The shorter span resulted in higher shears in the south end opposite the "test" end. The high shear force resulted in a shear failure at the South shear span of the test, intended to test the NORTH end of the beam. Still, the load resisted by the beam matched and even exceeded the nominal flexural capacity calculated for the cross section, so in a sense the strand was able to develop adequate tension even though the beam the test did not test the ductility of the flexural failure.

Before starting the test, strands at the South end were prevented from slipping with an arrangement of chucks as shown in the photo below.

Load was applied in approximately 3.0 kips increments till first flexural cracking. Beyond this point the deflection was incremented by 0.025 in. till the end of the test. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 36 in from the end being tested.

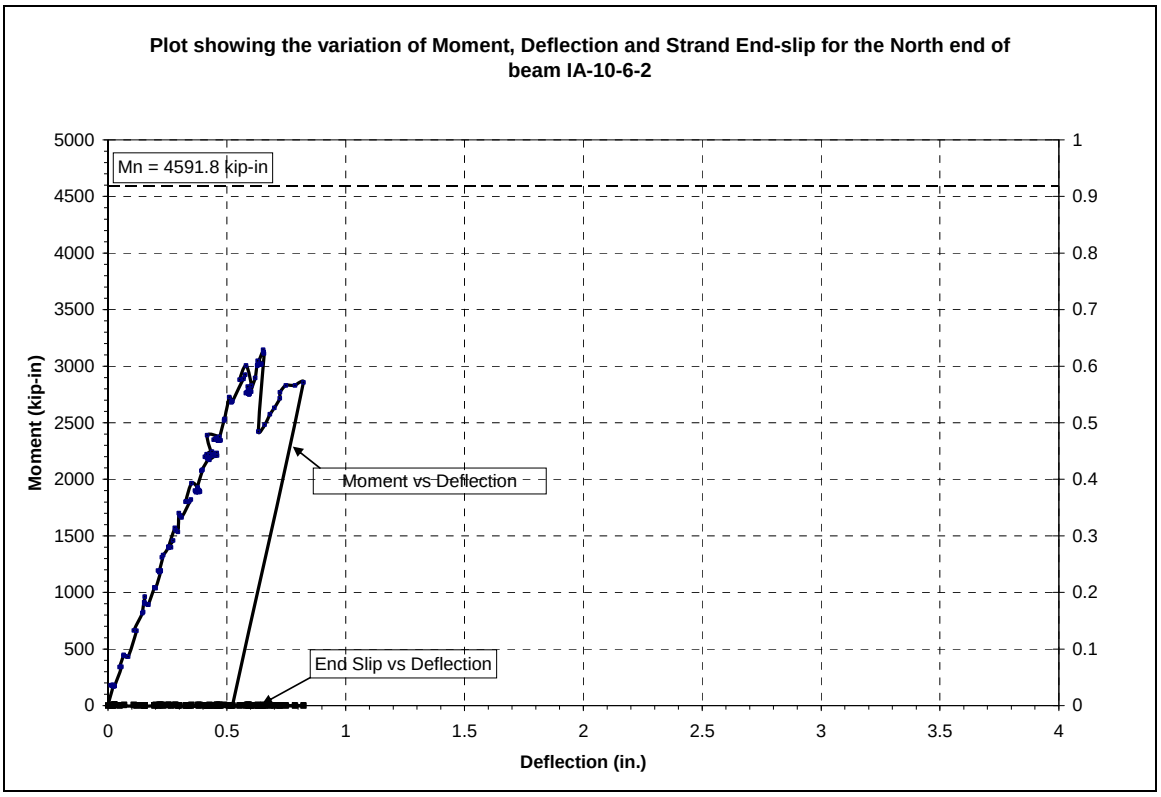
Even before the first flexural cracks were formed, an inclined crack originating from the initially existing cracks on the other side was noticed. The load at this point was 18 kips (Shear = 12 kips ; deflection = 0.18 in.). More and more audible cracks continued to form near the South end support along with spalling of concrete.

At 55.7 kips (Shear = 37.1 kips; deflection = 0.63 in.) a prolonged cracking sound was heard near the south support with load value dropping to 50.7 kips.

First flexural crack was observed at the load of 64.9 kips (Shear = 43.3 kips; deflection = 0.8 in.) A single crack was noticed at Stn. 86 at this stage. No significant drop in load was recorded.

For this particular test, there was no web shear crack noticed in the North side shear zone. The loading was stopped when the beam was observed to have failed in shear near the South support. The maximum load reached was 67.8 kips (Shear = 45.2 kips; deflection = 0.9 in.)

End-slip value remained 0.00 throughout the loading cycle.


Plot showing the variation of Moment, Deflection and Strand End-slip for the North end of beam IA-10-6-2
Mn = 4591.8 kip-in
Moment vs Deflection
End Slip vs Deflection
Moment (kip-in)
Deflection (in.)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
3.5
4

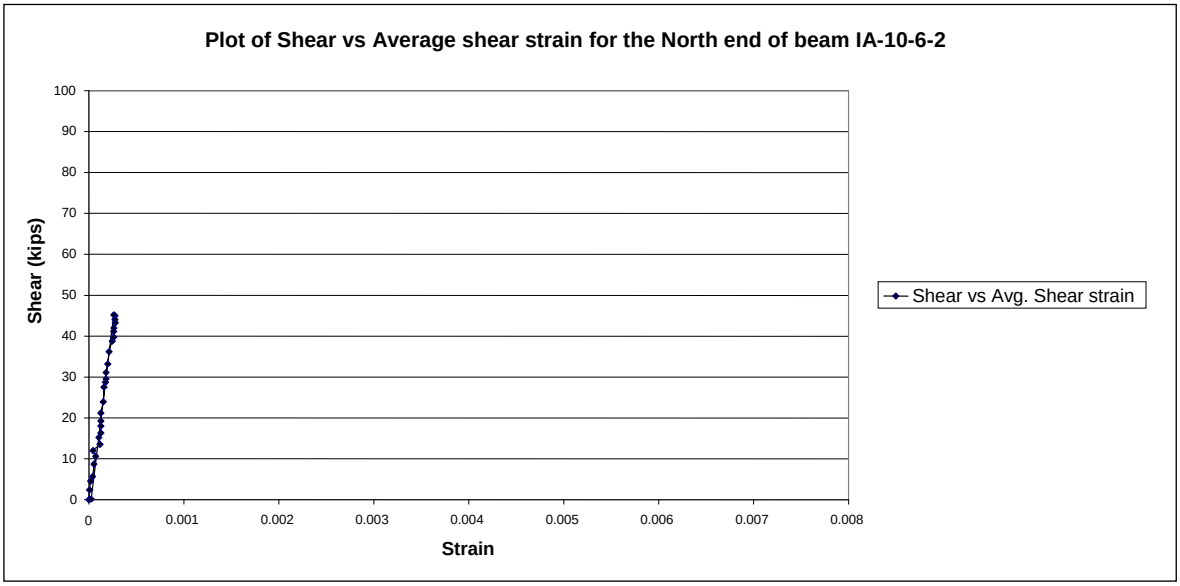

Plot of Shear vs Average shear strain for the North end of beam IA-10-6-2
Shear vs Avg. Shear strain
Shear (kips)
Strain
100
90
80
70
60
50
40
30
20
10
0
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008

Photo of the North end of the beam IA-10-6-2 showing shear failure in the South side shear zone.

BEAM NAME: IA-10-6-2
END: SOUTH
DATE: 10/20/2005

TEST PARAMETERS	
Concrete Compressive Strength	**14930 psi**
Embedment Length(L_e)	**88 in.**
Span	**270 in.**
Failure Mode	**Flexure**
Maximum Load	**83.4 kips**
Maximum Shear	**55.6 kips**
Maximum Moment	**4559.2 kip-in**
Maximum Deflection attained	**5.7 in.**
Rebound after complete unloading	**3.4 in.**
Average NASP P.O value for strand "A"	**18.29 kips**

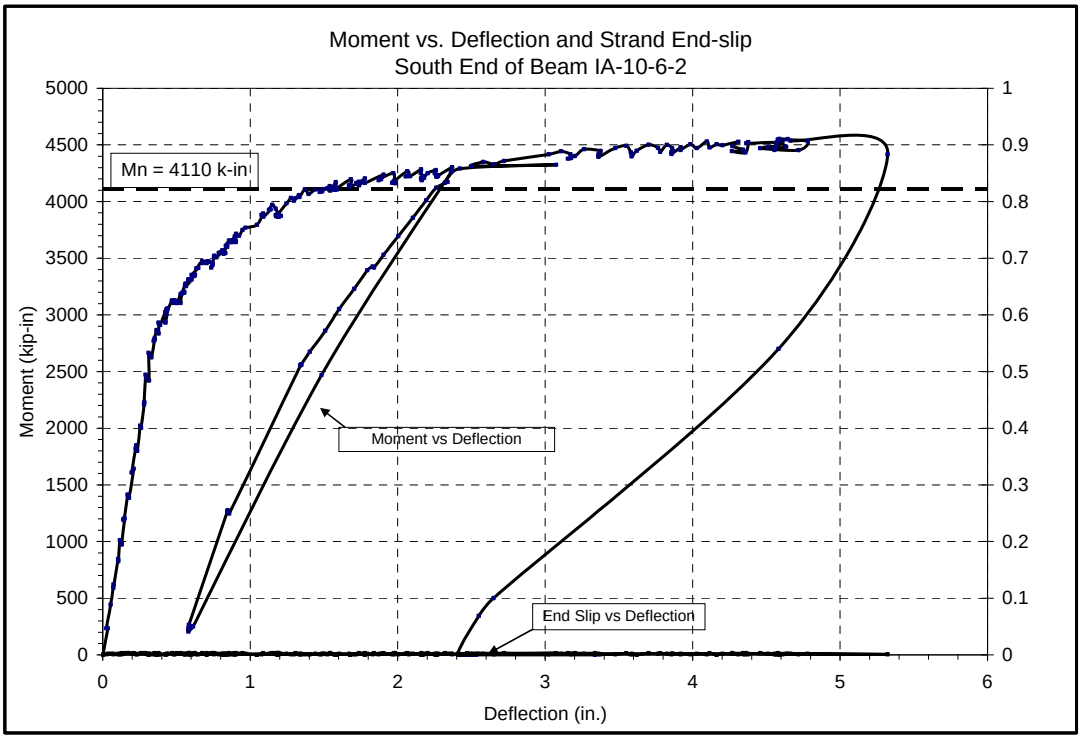
	Transfer lengths (in.) for beam # IA-10-6-2		
		At Release	At the time of testing
South	Top	6.16	19.36
	Middle	6.48	-
	Bottom East	6.42	10.64
	Bottom Central	9.45	NA
	Bottom West	2.90	NA

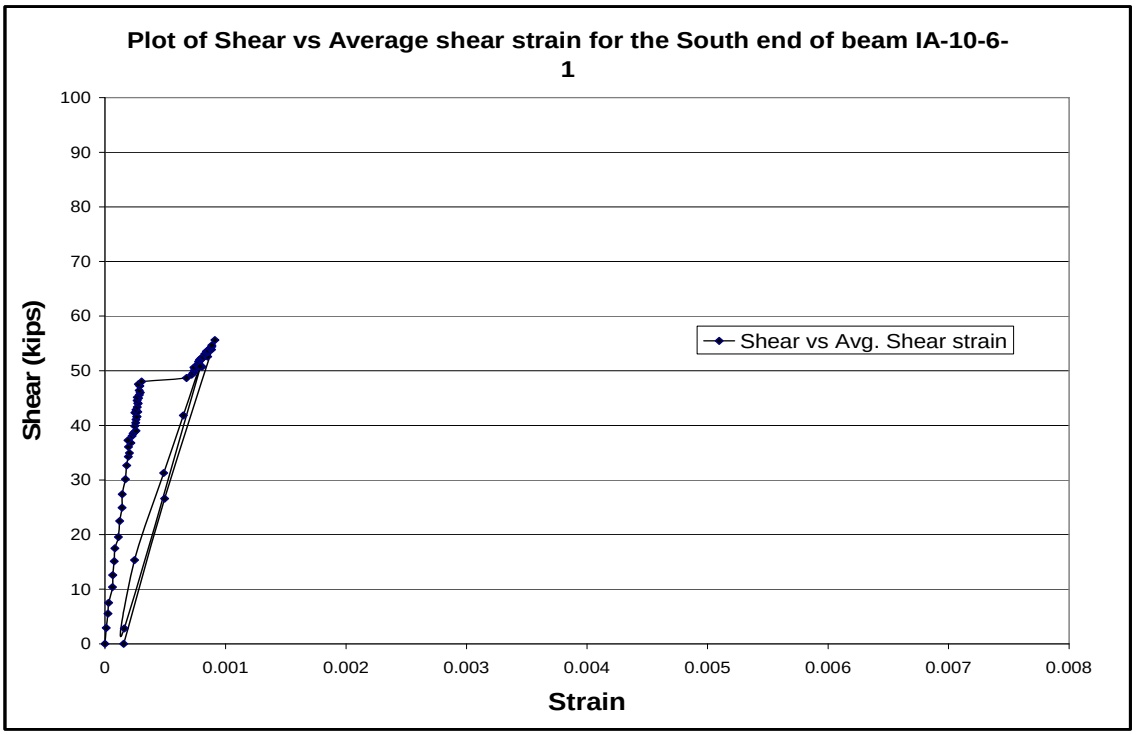
TEST SUMMARY

Load was applied in approximately 4.0 kips increments till first flexural cracking. After cracking the deflection was increased by 0.025 in. increments. After a total deflection of 1.0 in., the beam was loaded in increase deflection in 0.05 in. increments. After the total deflection reached 1.8 in. the deflection increment was set to 0.1 in. DEMEC readings were taken at all load increments at both faces (East and West) with the rectangular rosette pattern at 36 in from the end being tested.

First flexural crack was observed at the load of 51.4 kips (Shear = 34.3 kips; Δ= 0.35 in.) A single crack was noticed at Stn. 96 at this stage. No significant drop in load was recorded. At a load of 63.5 k (Shear = 42.3 kips; Δ= 0.68 in.) an inclined flexural shear crack was observed between Stations 68 and 80. The load value dropped to 63.4 kips after this crack occurred. Initial web shear cracking was observed at the load of 73 kips (Shear = 48.7 kips; Δ= 1.2 in.). At this load, a number of web shear cracks formed nearly parallel to each other in the shear zone.

No significant changes were noticed as the deflection was incremented further. Maximum deflection attained was 5.7 in. and load at this point was 83.4 kips (Shear = 55.6 kips). Crack width of the central crack was noted as 0.5 in. End slip value still remained 0.00in at both ends. Further increments in deflection were not possible as the hydraulic ram had reached its stroke limit. The beam was completely unloaded and the deflection, end slip and DEMEC readings were noted. The beam failed in flexure without significant strand slips.





(In all the photographs presented below, cracks marked in black represent the ones originated as flexural cracks while those marked in blue represent the web shear cracks. Red color was used only for marking the grid lines and station points. Number written in red should not be confused with the load values.)

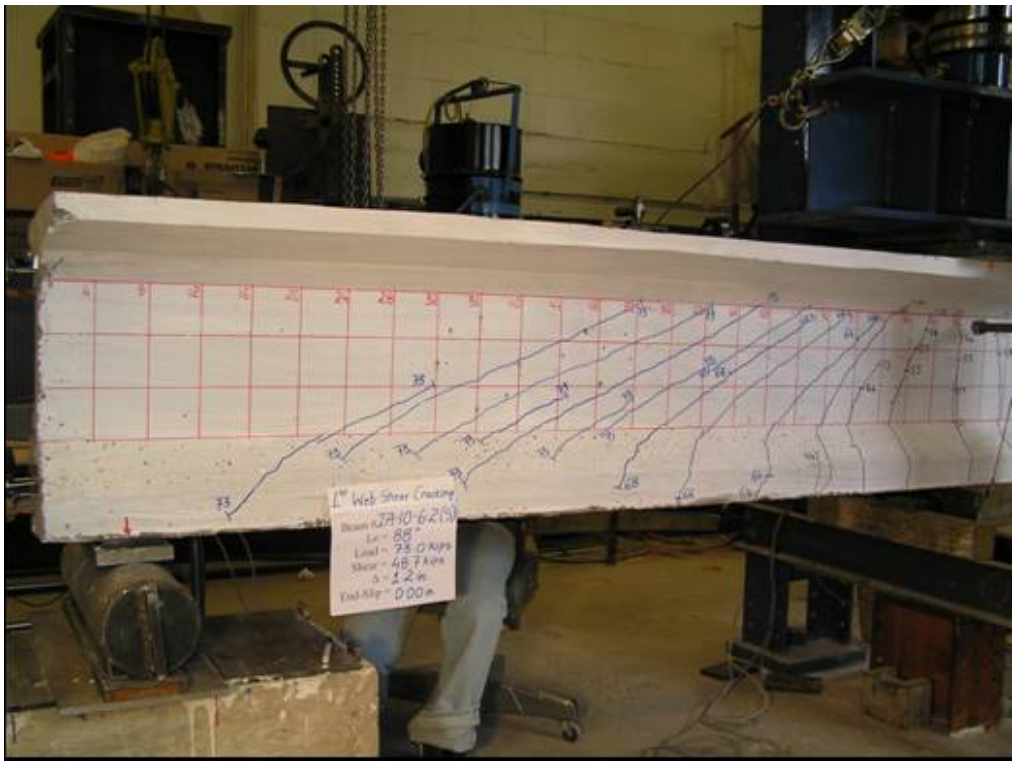


Photo of the South end of the beam IA-10-6-1 showing the first web shear cracking

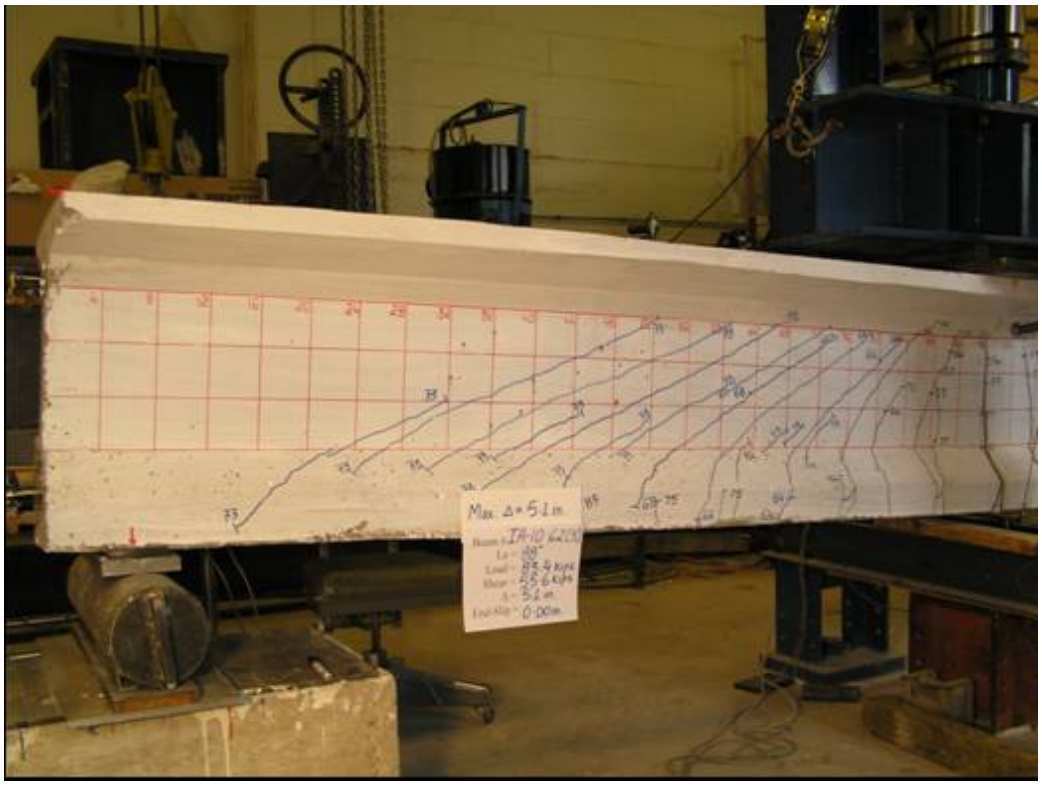


Photo of South end of beam IA-10-6-1 showing the cracking pattern at the maximum load (Deflection value in the photo is mistakenly written as 5.1 in. instead of 5.7 in.)