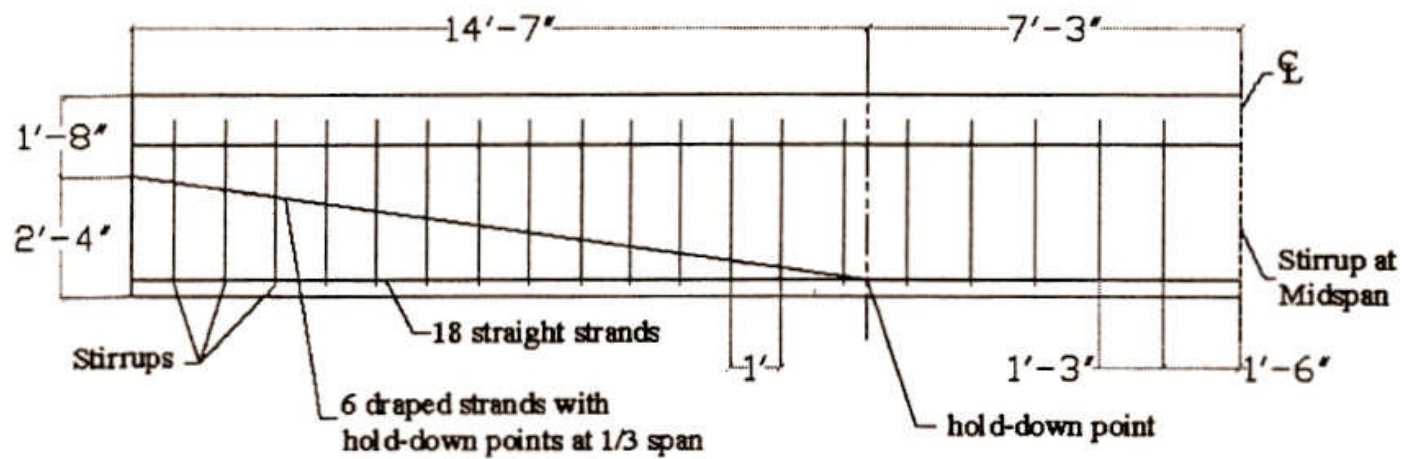


# Full Scale Testing of FRP Repaired Prestressed Beams

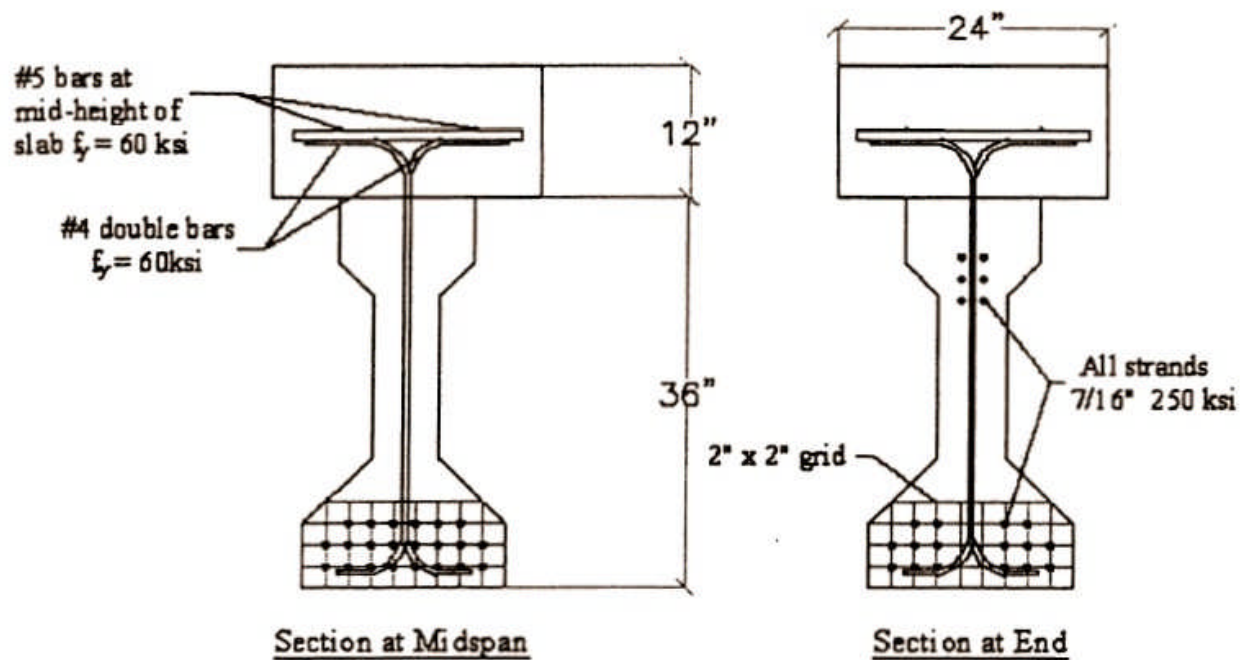


# The Ghost Girders





a) Typical Profile of Test Specimens in Undamaged State

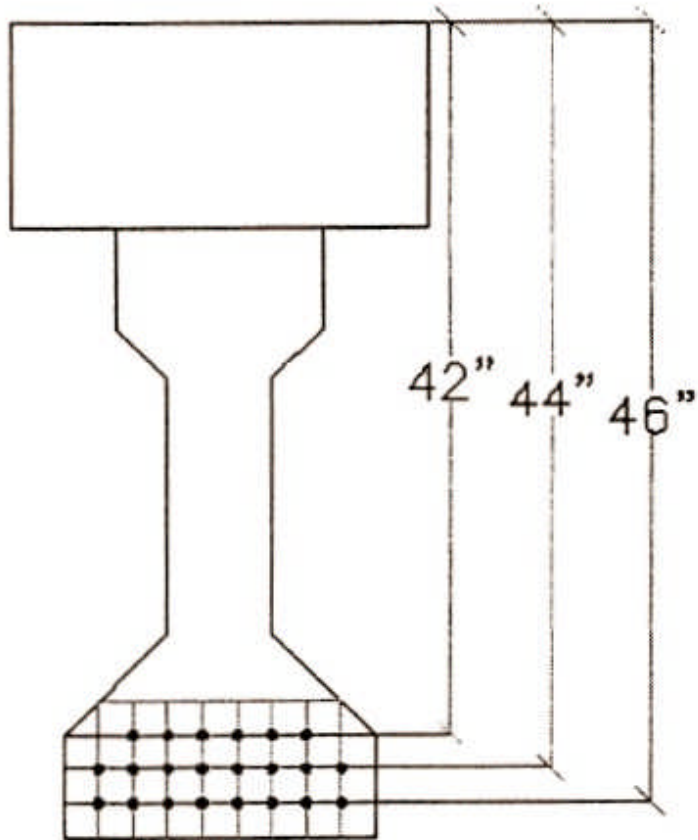


Beams were artificially damaged to simulate what happens in the field due to impact with over height vehicles



(a)

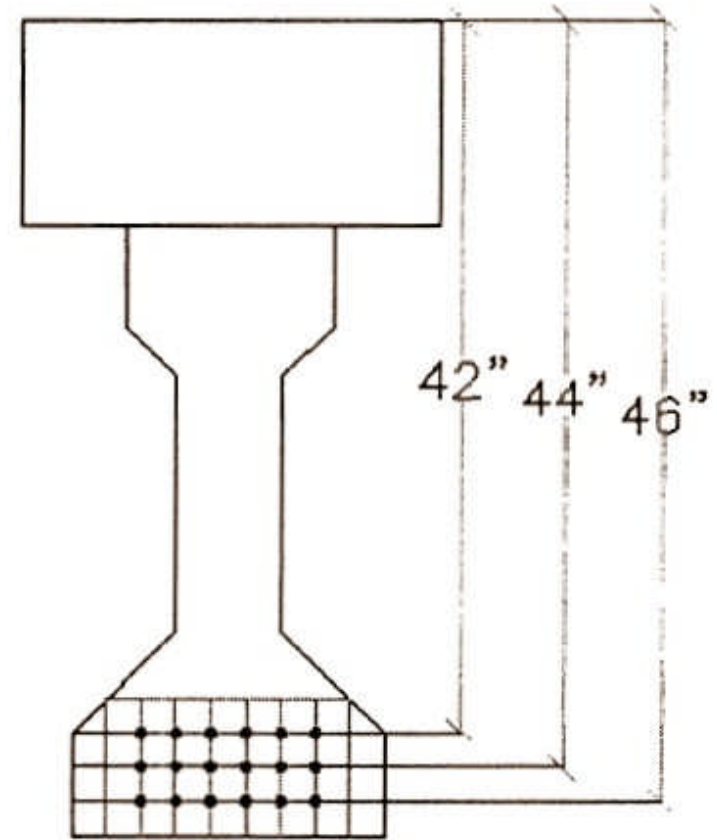
Undamaged



$$\begin{aligned} A_{p_1} &= 0.648 \text{ in}^2 \\ A_{p_2} &= 0.864 \text{ in}^2 \\ A_{p_3} &= 0.864 \text{ in}^2 \end{aligned}$$

(b)

Damaged



$$\begin{aligned} A_{p_1} &= 0.648 \text{ in}^2 \\ A_{p_2} &= 0.648 \text{ in}^2 \\ A_{p_3} &= 0.648 \text{ in}^2 \end{aligned}$$









# 6 beams, 6 Tests


- ▶ 1) Control Beam Undamaged
- ▶ 2) Control Beam Damaged
- ▶ 3) Damaged Repaired with CFRP
- ▶ 4) Damaged Repaired with GFRP Spray up
- ▶ 5) Damaged Repaired with CFRP
- ▶ 6) Damaged Repaired with CFRP

Test Specimen	3	4	5	6
Fiber Material and Description	Carbon Uni-directional with Aramid Cross Fibers	Carbon Uni-directional with Cross Fibers	E-Glass Multi-directional Fibers	Carbon Uni-directional Fibers
Resin Material	Epoxy	Polyurethane	Vinyl Ester	Epoxy
Elongation at Failure	1.21%	1.05%	1.43%	1.50%
Tensile Modulus (ksi)	10500	11000	1522	10100
Ultimate Tensile Strength (ksi)	127	115	15.08	150
Total Laminate Thickness from Data Sheets (in.)	0.160	0.124	0.500	0.069
Total Average Laminate Thickness Measured (in.)	0.276	0.236	0.138 to 0.386	0.169
Number of Laminates	4	4	1	3
Total Length of Laminates (ft.)	20 20 20 20	40 32 24 16	20	20 20 20
Width of Laminates (in.)	16	12	18	18
Vertical FRP Anchorage Description	None	2 Plies CFRP Oriented at 0 and 90 Degrees, 12 ft from Midspan	Sprayed GFRP ~ 1/2" Thick 2 ft Wide up to Bottom Flange	2 Plies CFRP at 0 Degrees up to Bottom Flange

## AASHTO Girder Tests 2002

Girder Type: Type II AASHTO  
Strand Pattern: See attached

### Legend

 P1200-5-X Crack Gauge



SDP2000 or SDP200R LVDT



Load Cell (400 kip)

### Theoretical Capacity

(not including self wt.): 2007 kip-ft.  
Max. Theoretical Applied Load: 133.8 kip

### Test Results:

Capacity = 2012 kip-ft  
Max. Applied Load = 134.1 kip

### Material properties:

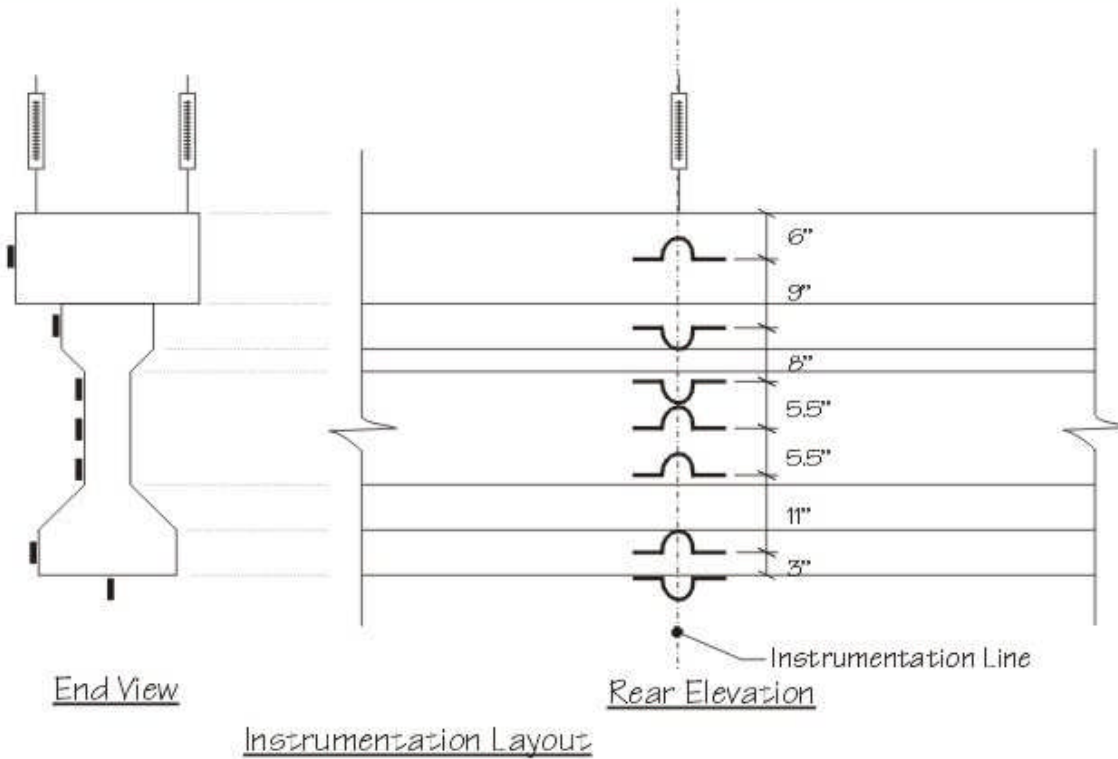
$f'_{concr} = 6300$  psi  
 $f'_{girder} = 4500$  psi  
250 ksi 7/16" dia. Strands

Girder manufacture date: ~1967

Test date: 6/19/2002

## Control Girder

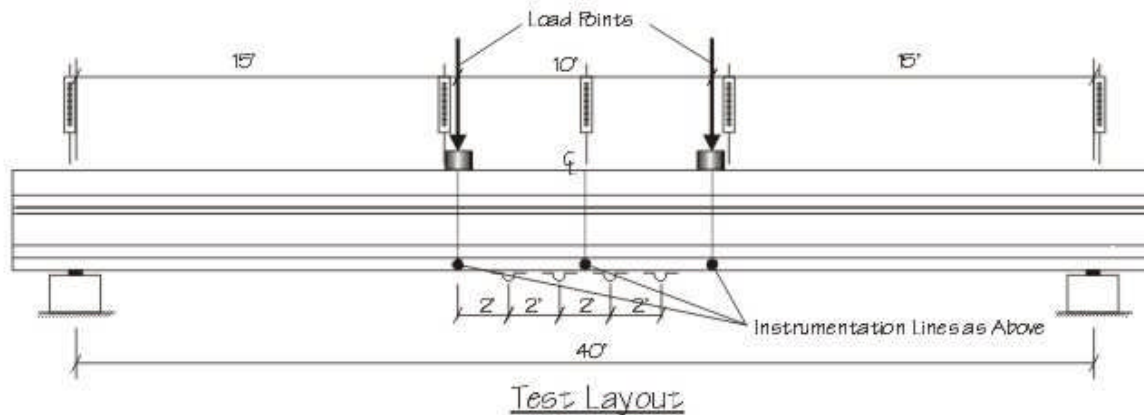
Sheet 1 of 2



End View

Rear Elevation

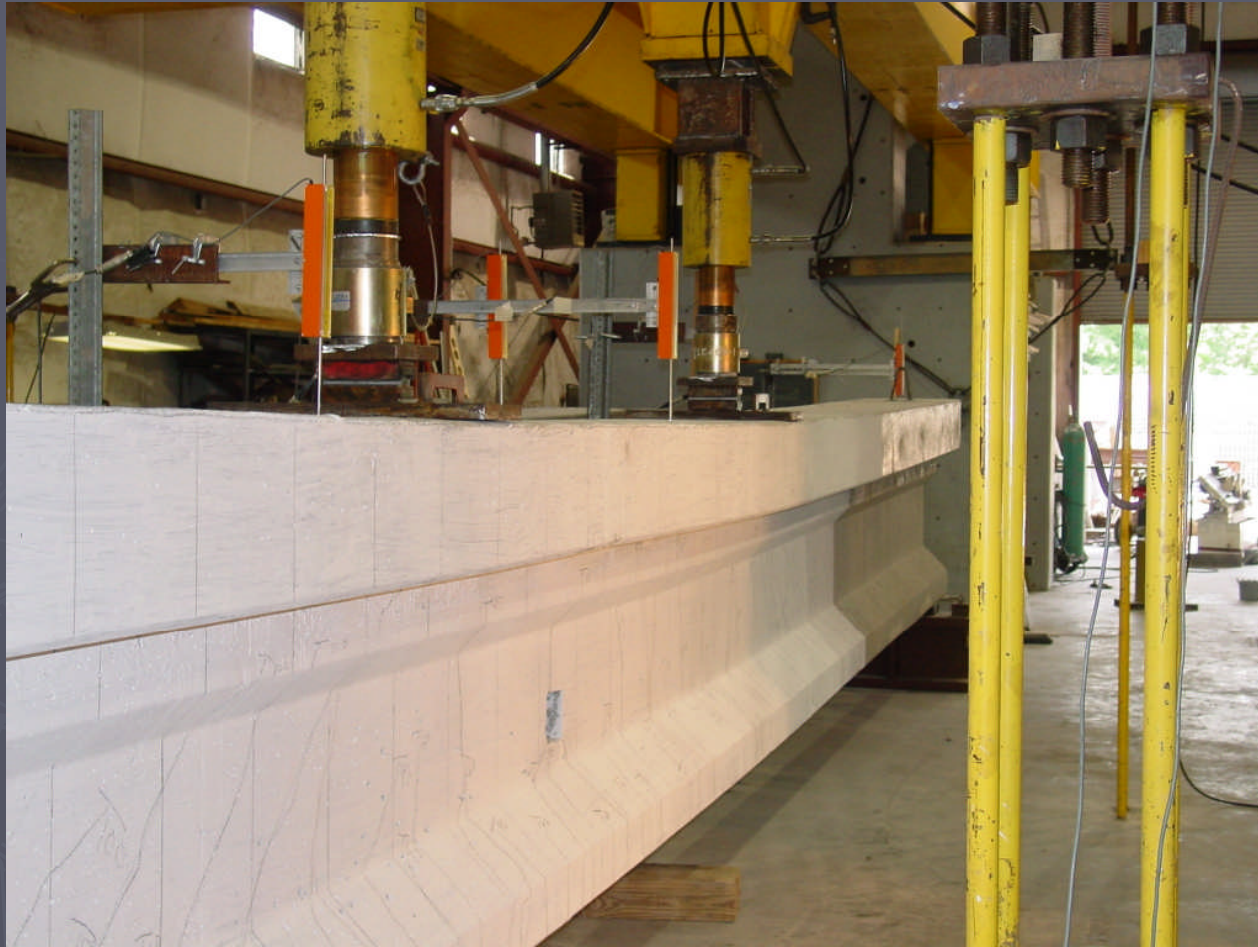
Instrumentation Layout



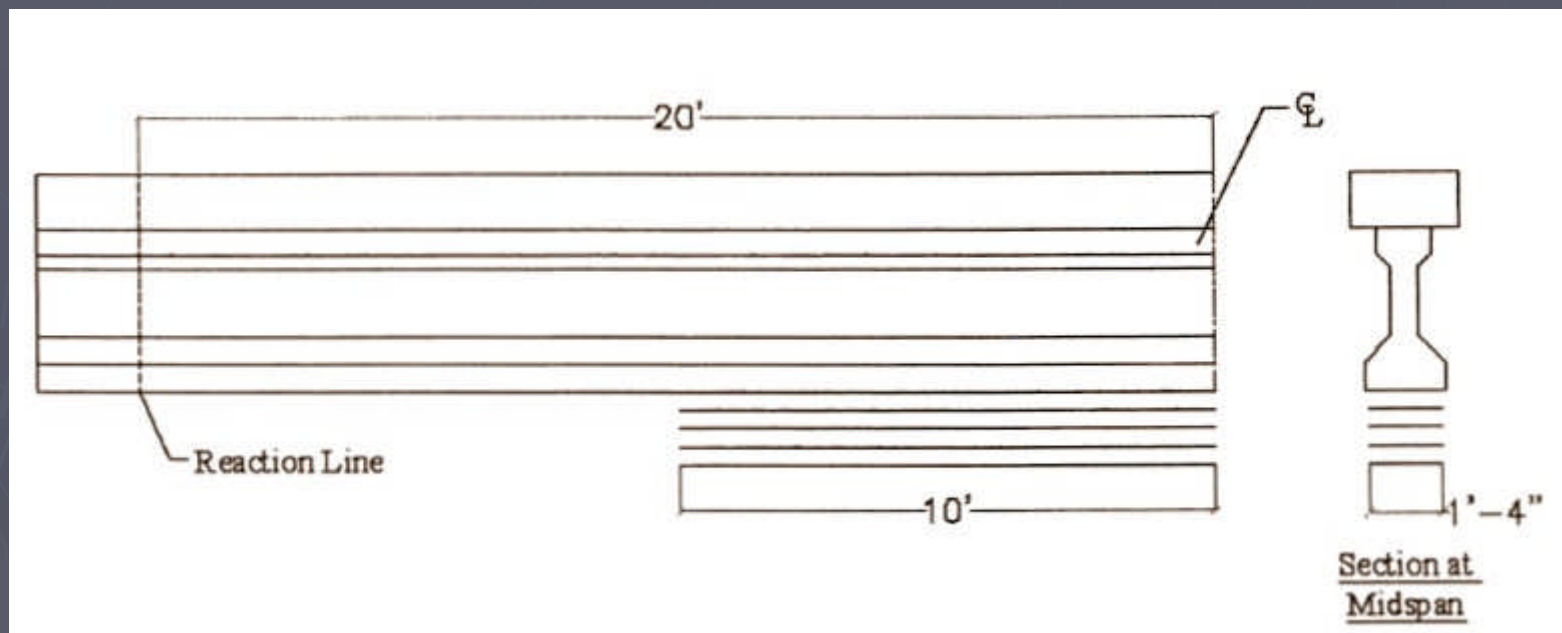
Test Layout



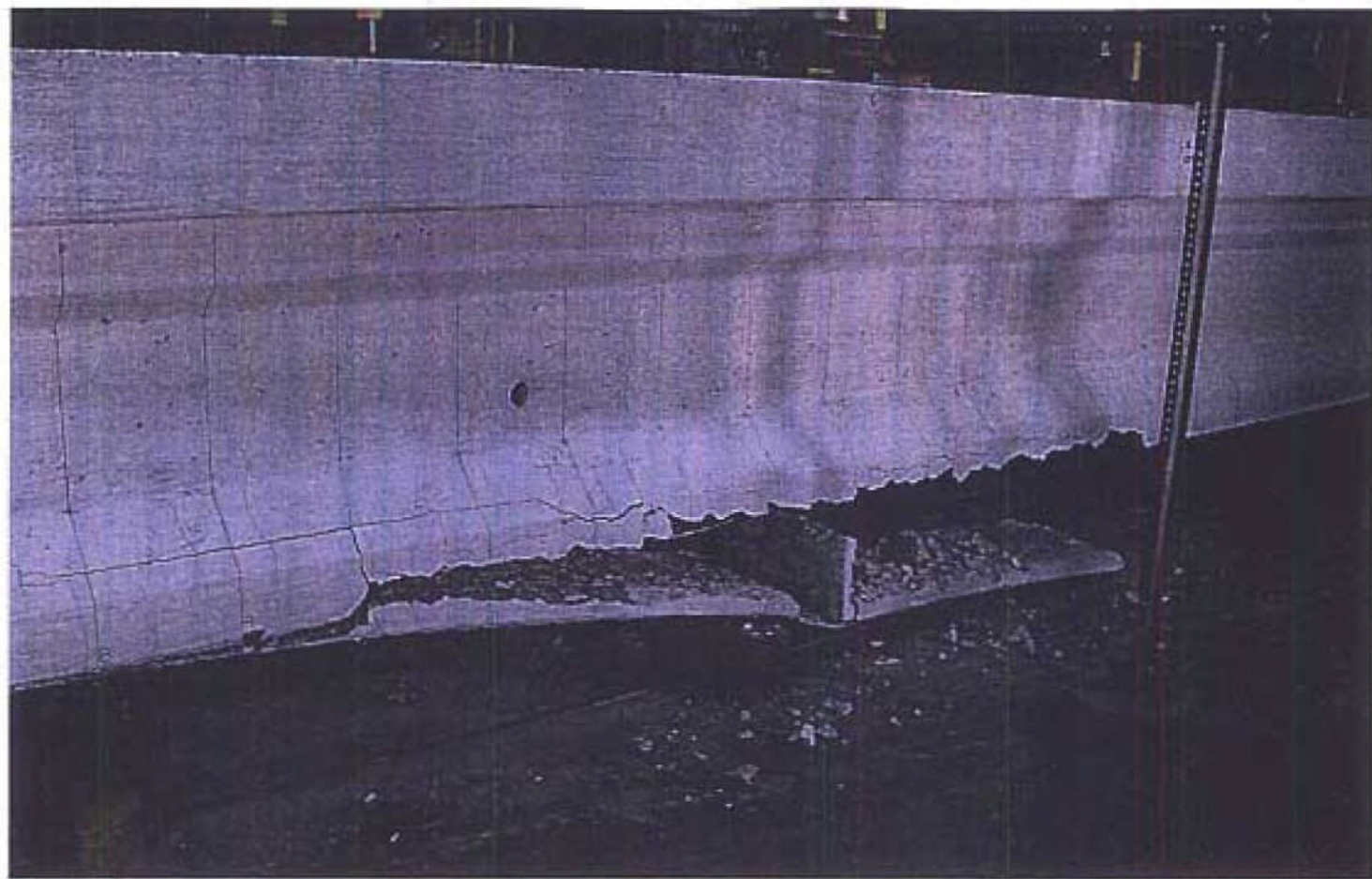
# Beam Being Tested



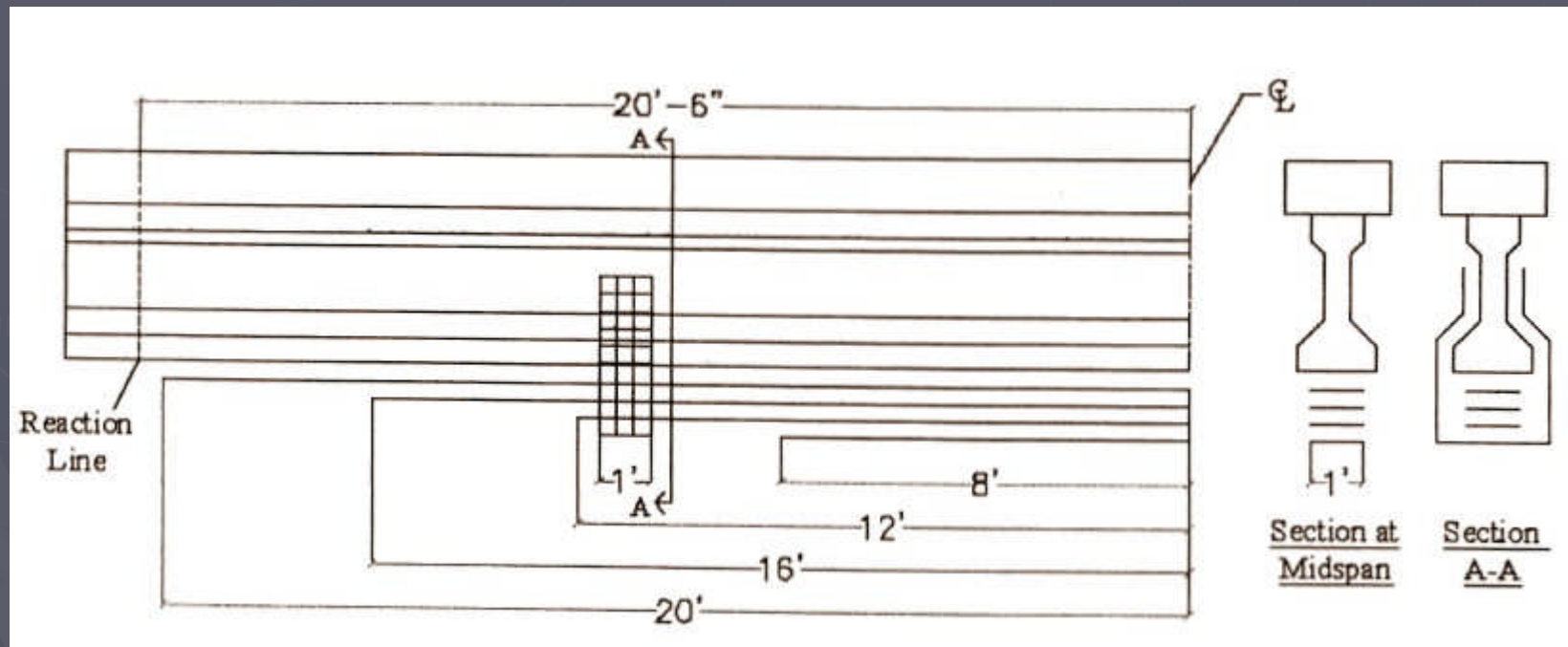
# Test 3 Beam Repair



# Test 3 Failure



# Test 4 Beam Repair

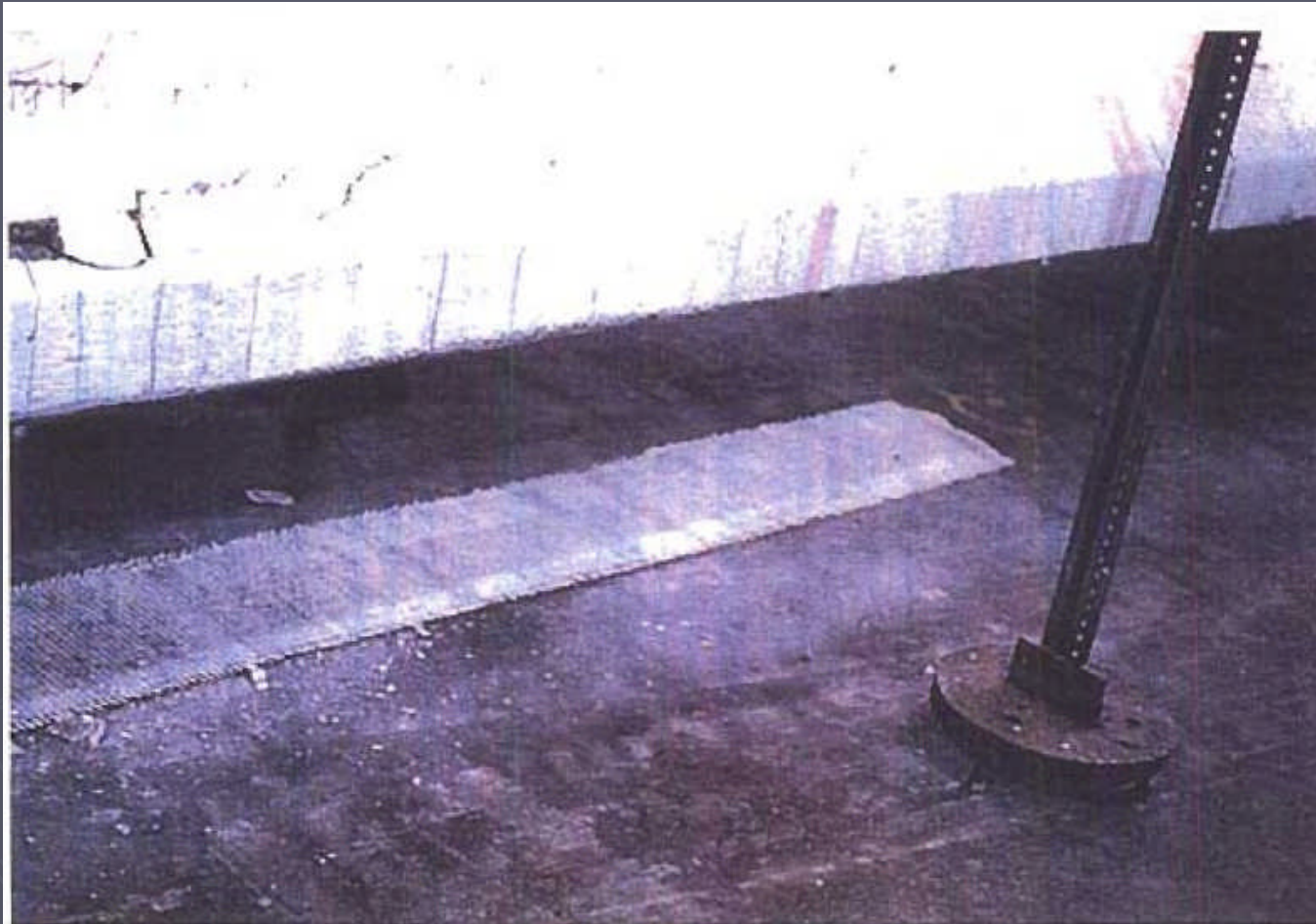




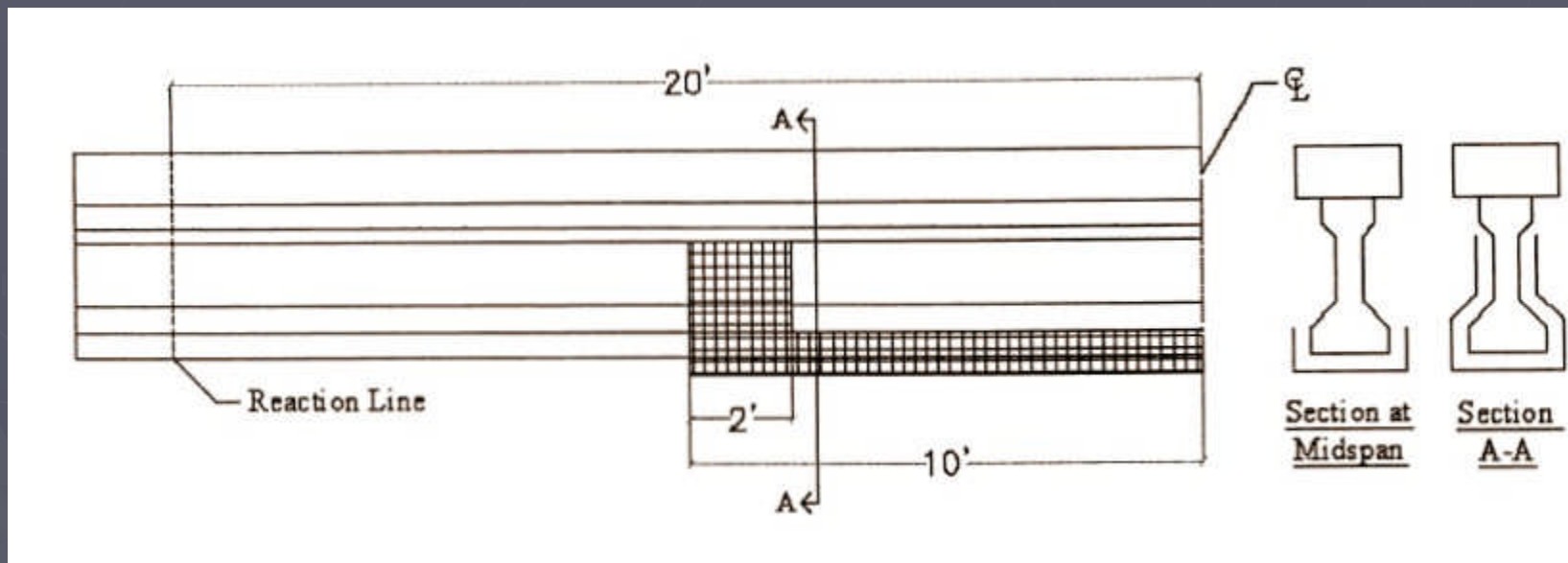
# Test 4 Anchorage



# Failure Test 4



# Test 5 Beam Repair

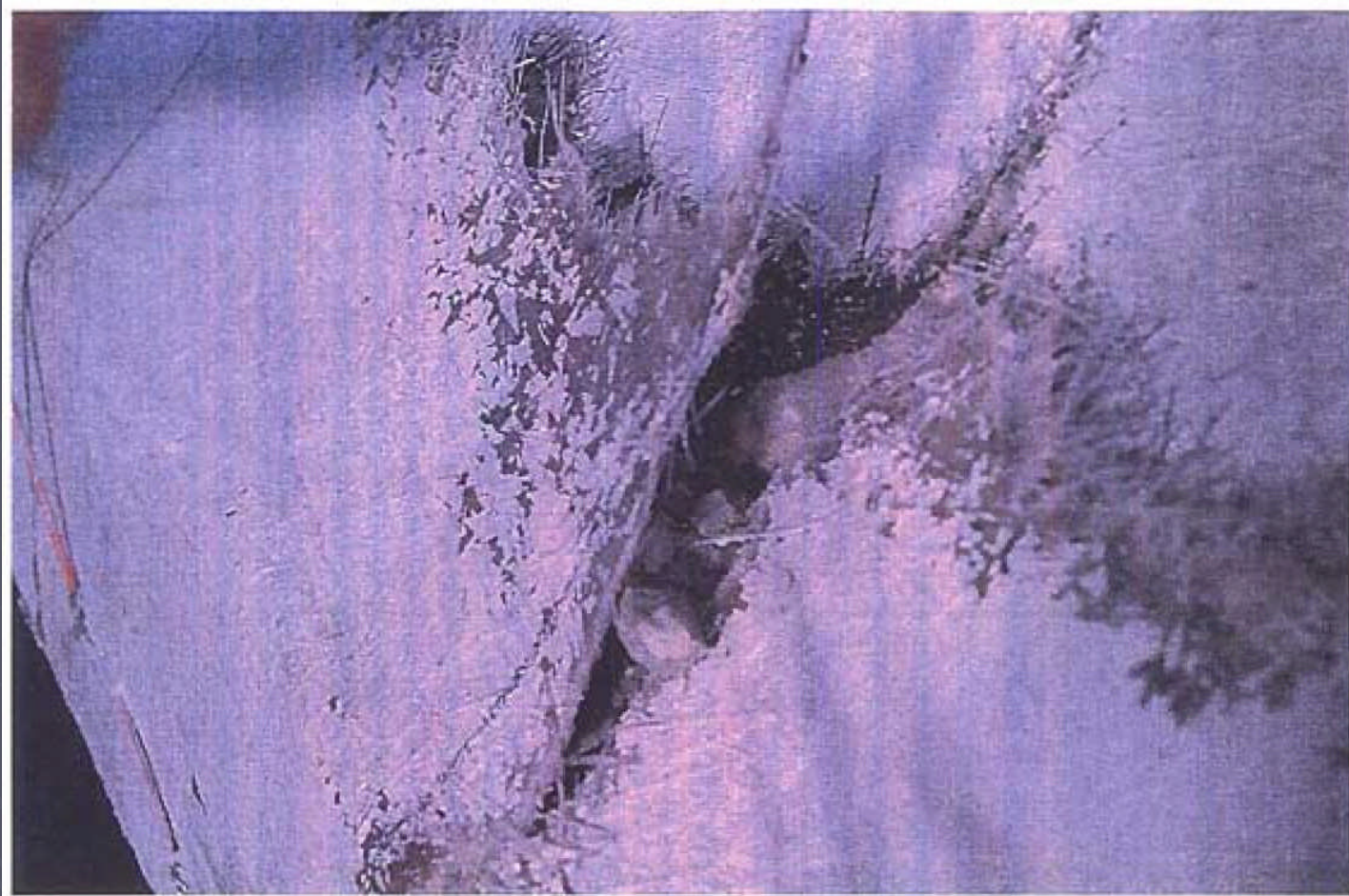


# Spray up being applied

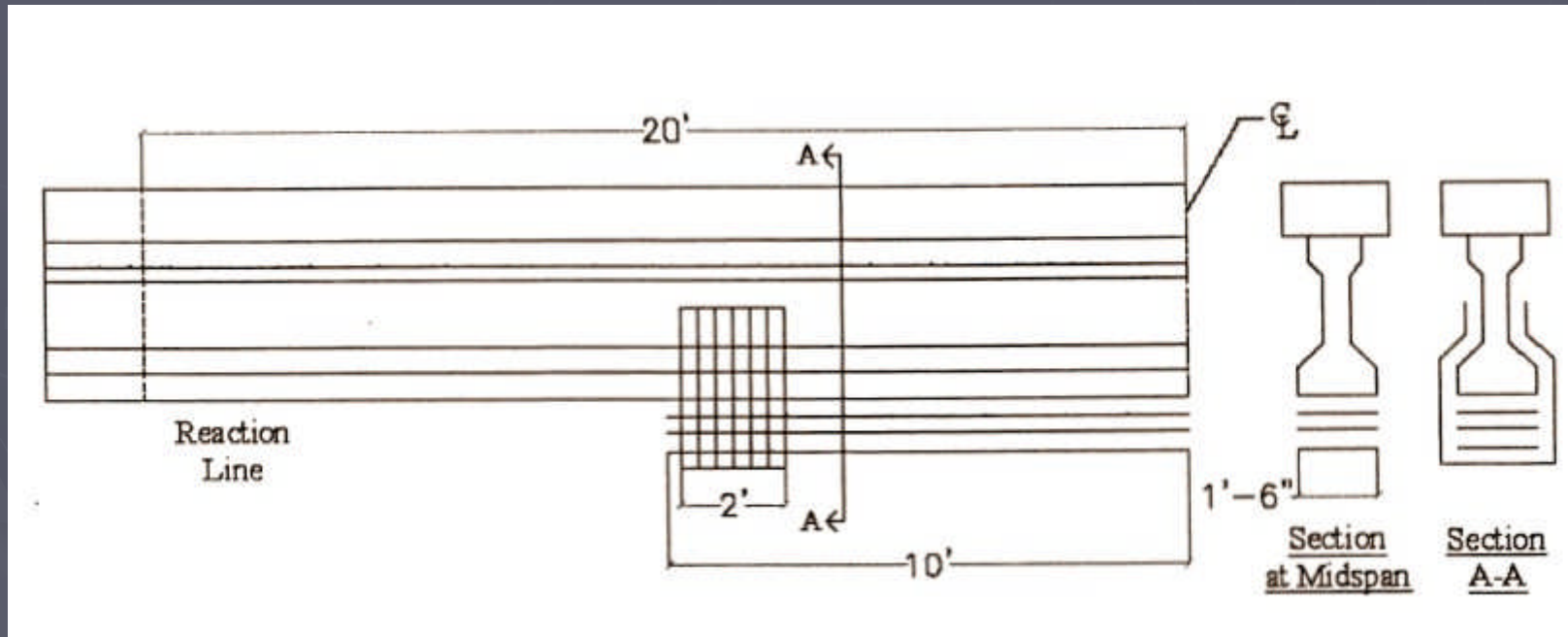




# Failure Test 5



# Test 6 Beam Repair



# Failure Test 6





# Results

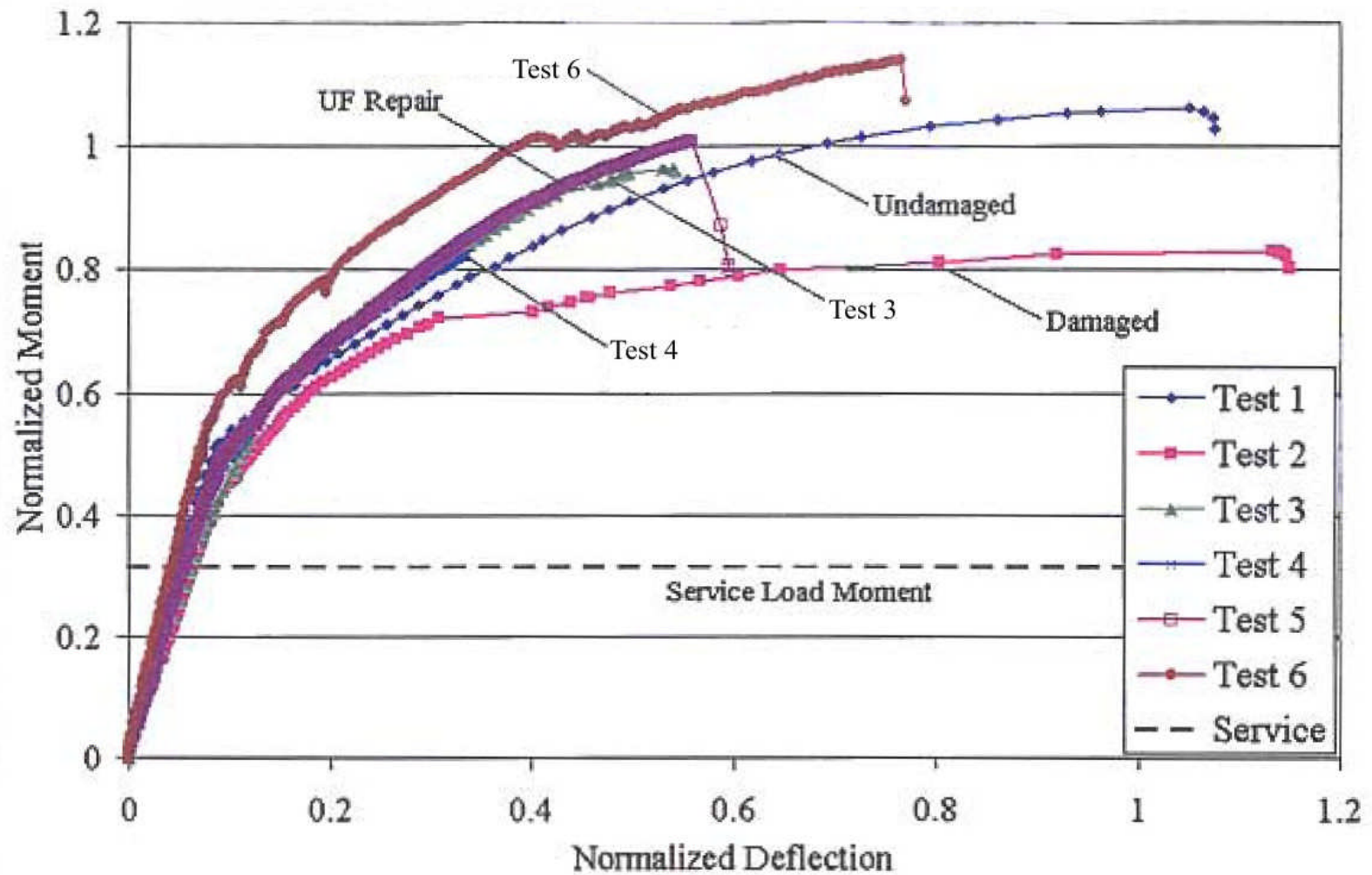


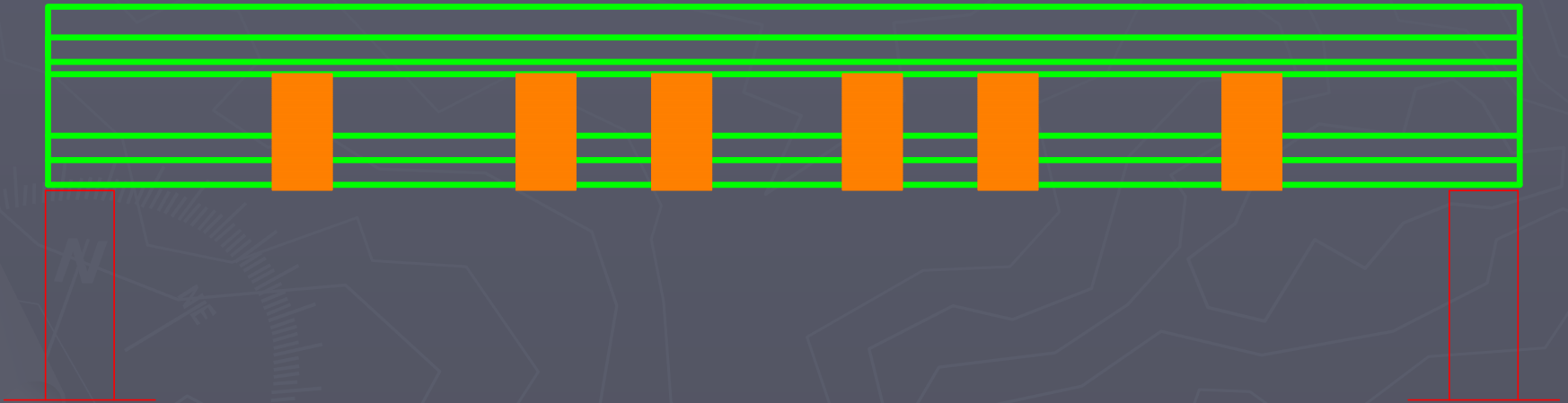
Figure 5-3: Normalized Moment versus Deflection for all Test Specimens and the Service

<b>Test Number</b>	<b>% Capacity of Undamaged Beam</b>
3	91
4	95
5	95
6	108

# What Did We Learn



# The importance of anchorage



# Anchorage

- ▶ How much
- ▶ How often
- ▶ What are the loads
- ▶ How to design