Appendix G

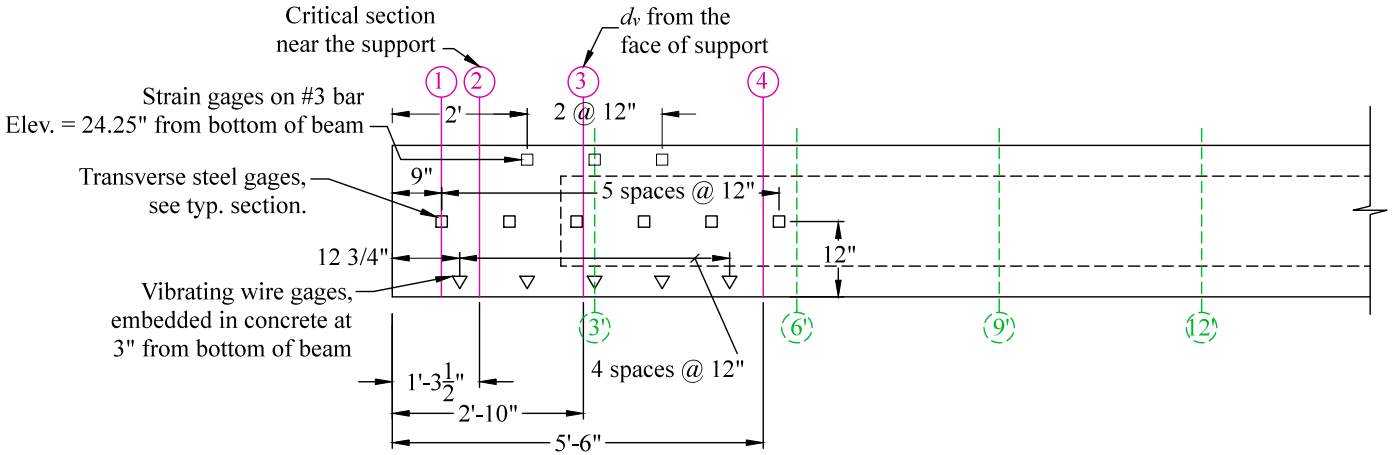
Internal and External Instrumentation

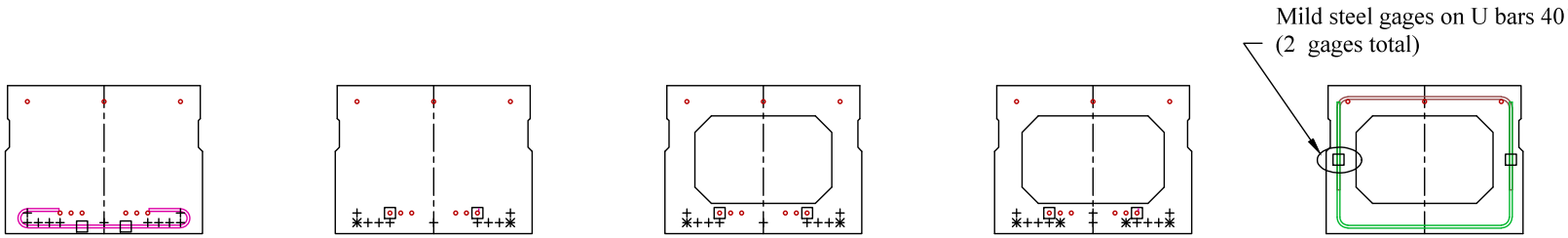
Strain Gages

Table G.1. Number of strain gages

Girder	End A				End B				Total SGs	
	Nonprestressed reinforcement	Prestressed reinforcement	Concrete		Nonprestressed reinforcement	Prestressed reinforcement	Concrete			
			Embedded*	Surface			Embedded*	Surface	End A	End B
AASHTO BI-36	23	8	5	6	17	8	5	6	37	31
AASHTO BT-54	25	12	5	6	21	10	5	6	43	37
AASHTO Type III-a	23	12	5	6	21	12	5	6	41	39
AASHTO Type III-b	23	12	5	6	23	12	5	6	41	41
Nebraska NU-1100	21	12	5	6	21	10	5	6	39	37
Texas U-40	31	12	5	3	31	12	5	3	46	46

* Vibrating wire strain gages





Section 1

Section 2

Section 3

Section 4

Typical section showing
transverse steel gages

The gages on the confining reinforcement
were at 8 $\frac{3}{4}$" from the end of the girder.

LEGEND

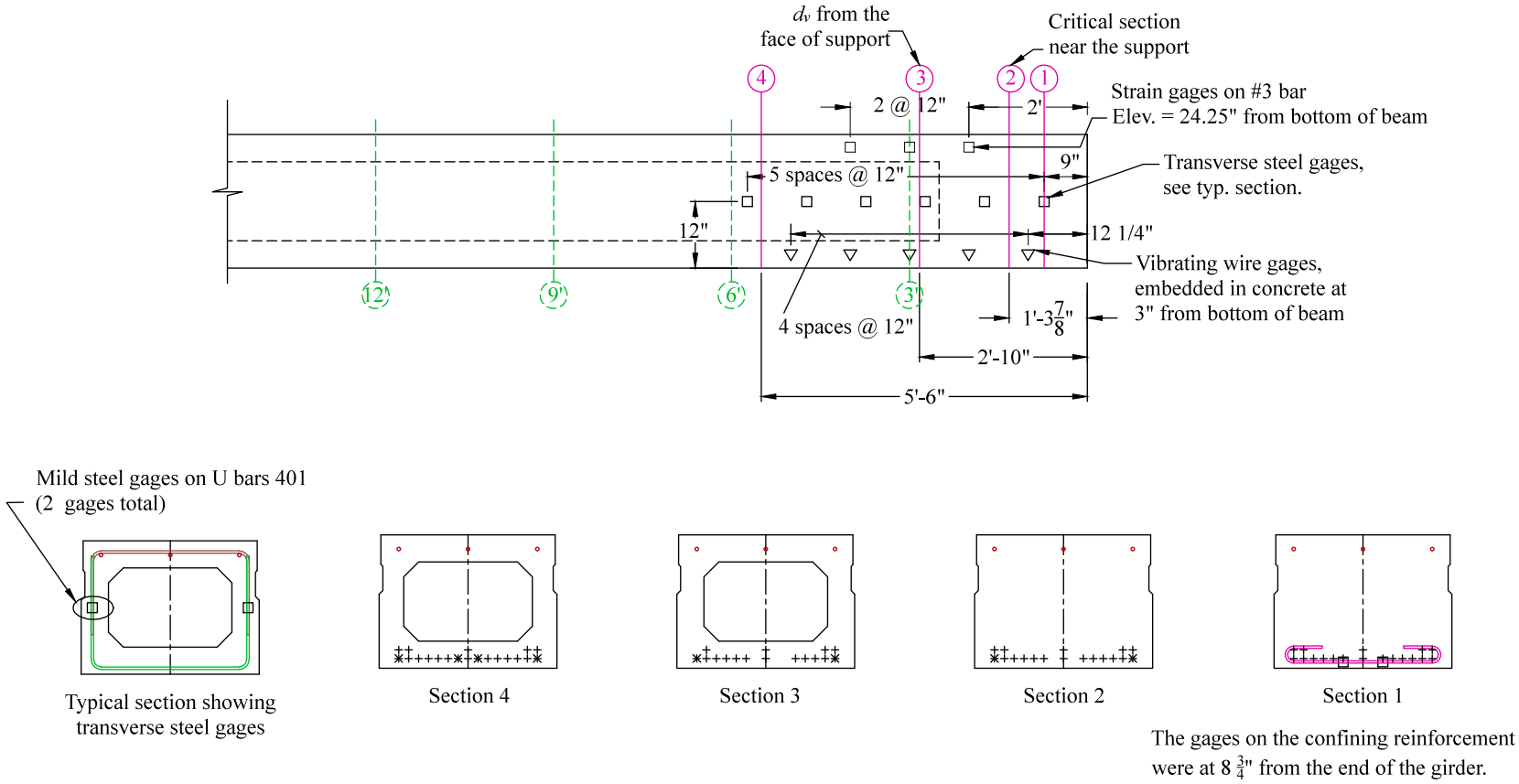
□ Mild steel strain gage

× Strand strain gage

▽ Vibrating wire gage

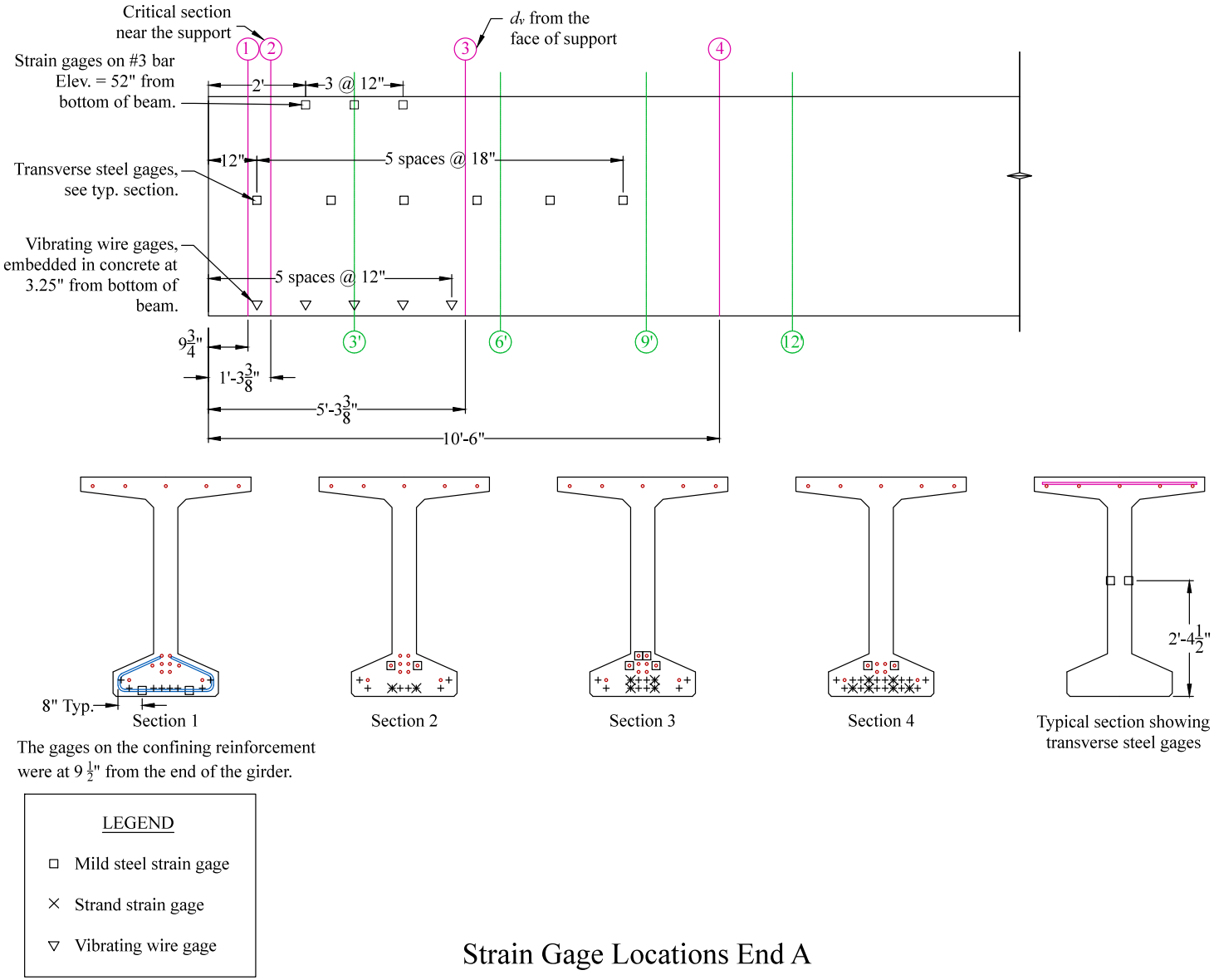
Strain Gage Locations End A

Figure G.1. AASHTO BI-36 (End A)



Strain Gage Locations End B

Figure G.1. (cont.) AASHTO BI-36 (End B)



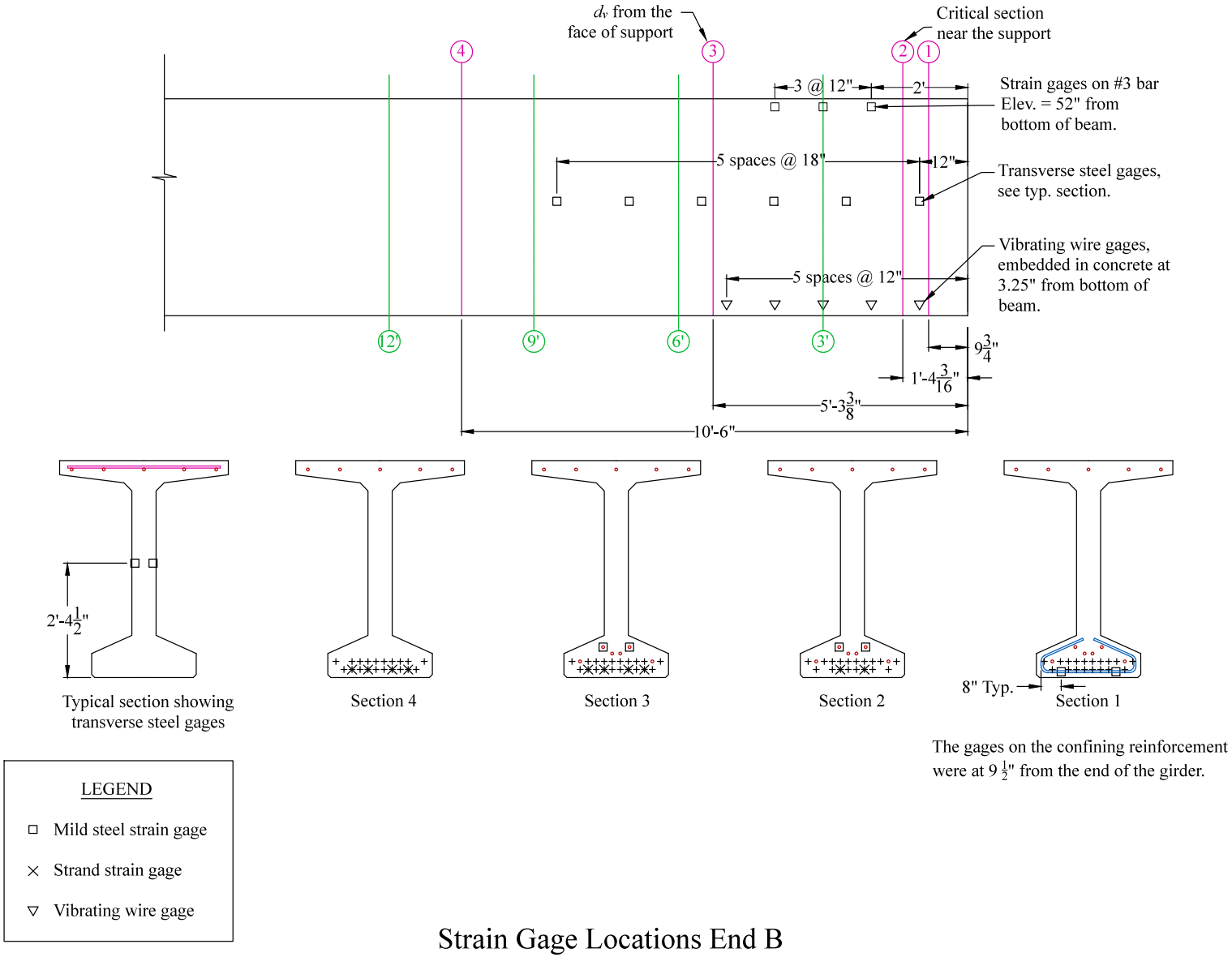
The gages on the confining reinforcement were at 9 $\frac{1}{2}$" from the end of the girder.

LEGEND

- □ Mild steel strain gage
- × Strand strain gage
- ▽ Vibrating wire gage

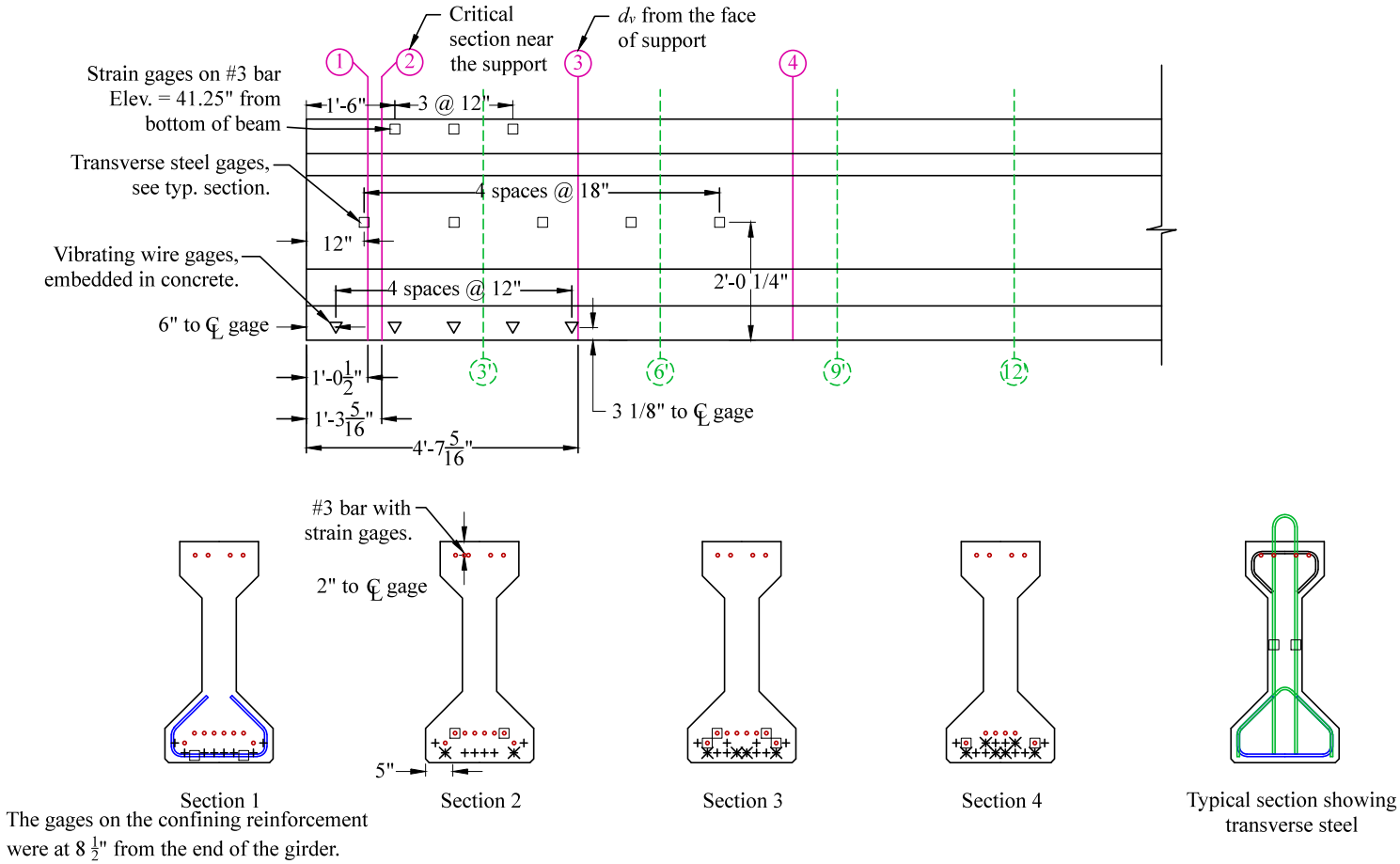
Strain Gage Locations End A

Figure G.1. (cont.) AASHTO BT-54 (End A)



Strain Gage Locations End B

Figure G.1. (cont.) AASHTO BT-54 (End B)



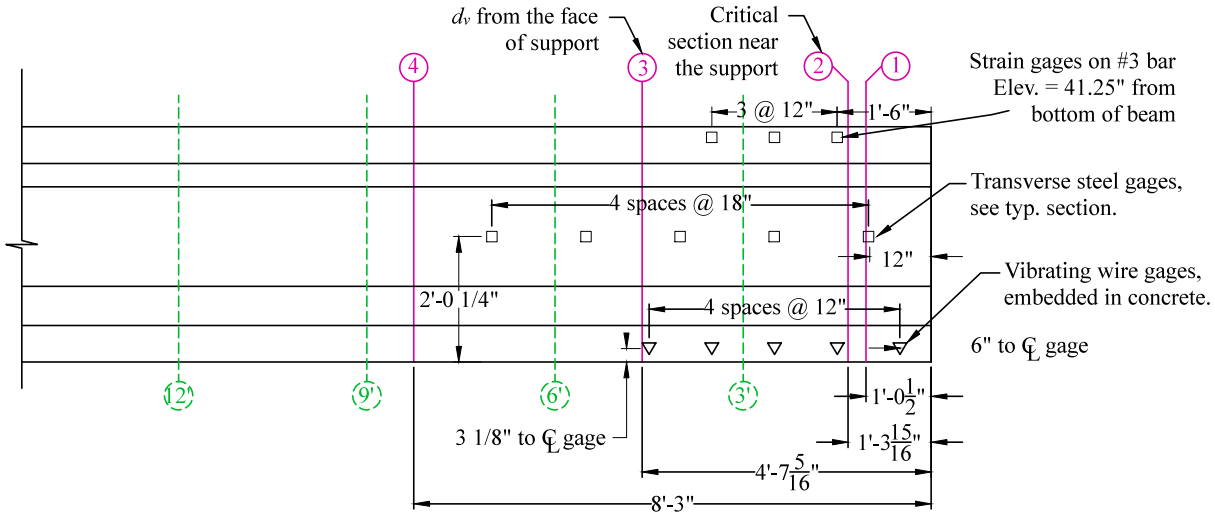
The gages on the confining reinforcement were at 8 $\frac{1}{2}$" from the end of the girder.

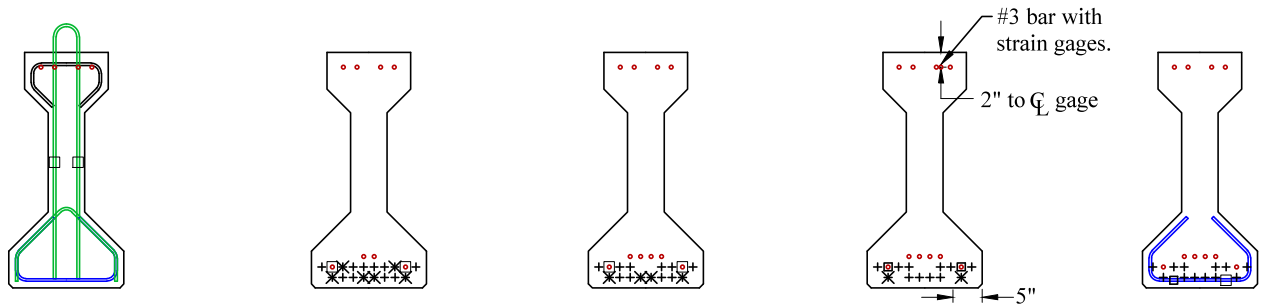
LEGEND

- □ Mild steel strain gage
- × Strand strain gage
- ▽ Vibrating wire gage

Strain Gage Locations End A

Figure G.1. (cont.) AASHTO Type III-a (End A)





Typical section showing transverse steel

Section 4

Section 3

Section 2

Section 1

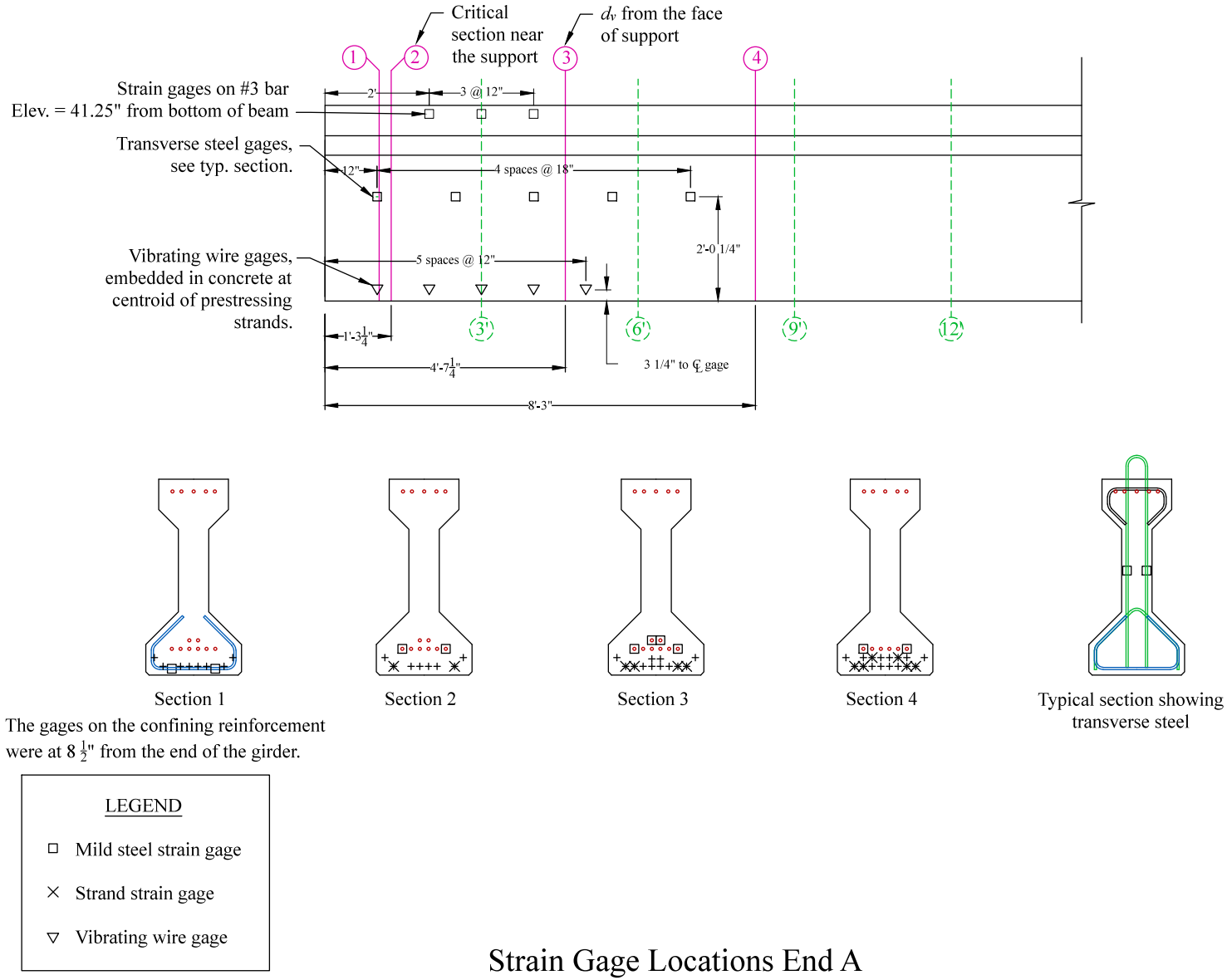
The gages on the confining reinforcement were at 8 $\frac{1}{2}$" from the end of the girder.

LEGEND

- □ Mild steel strain gage
- × Strand strain gage
- ▽ Vibrating wire gage

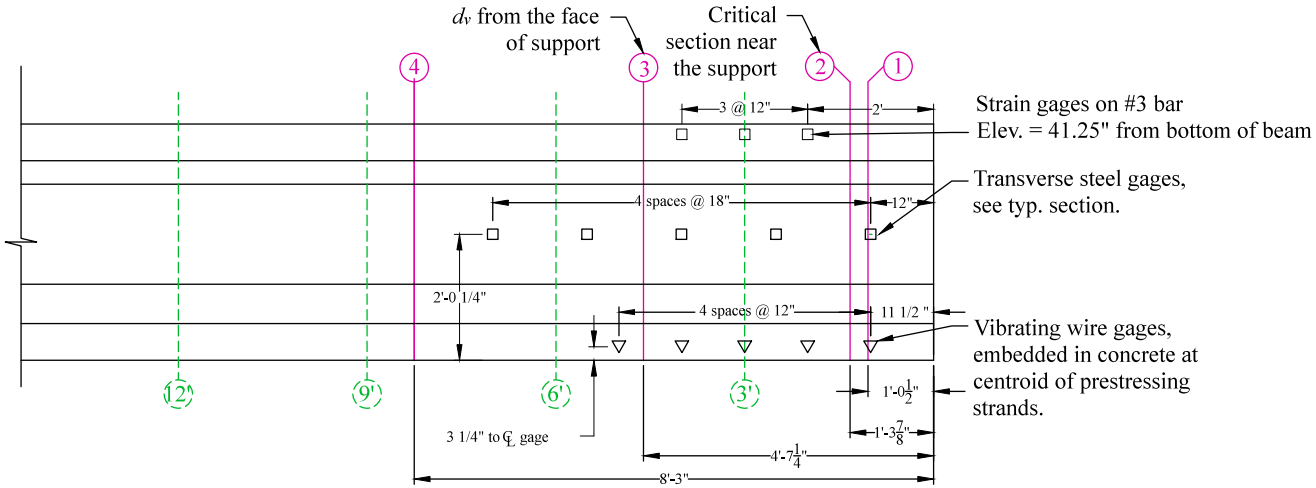
Strain Gage Locations End B

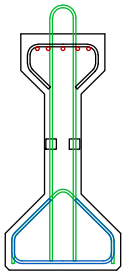
Figure G.1. (cont.) AASHTO Type III-a (End B)



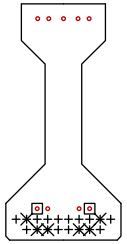
Strain Gage Locations End A

Figure G.1. (cont.) AASHTO (Type III-b)

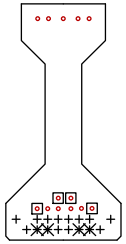




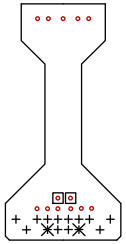
Typical section showing transverse steel



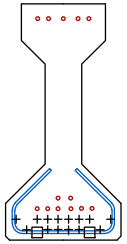
Section 4



Section 3



Section 2



Section 1

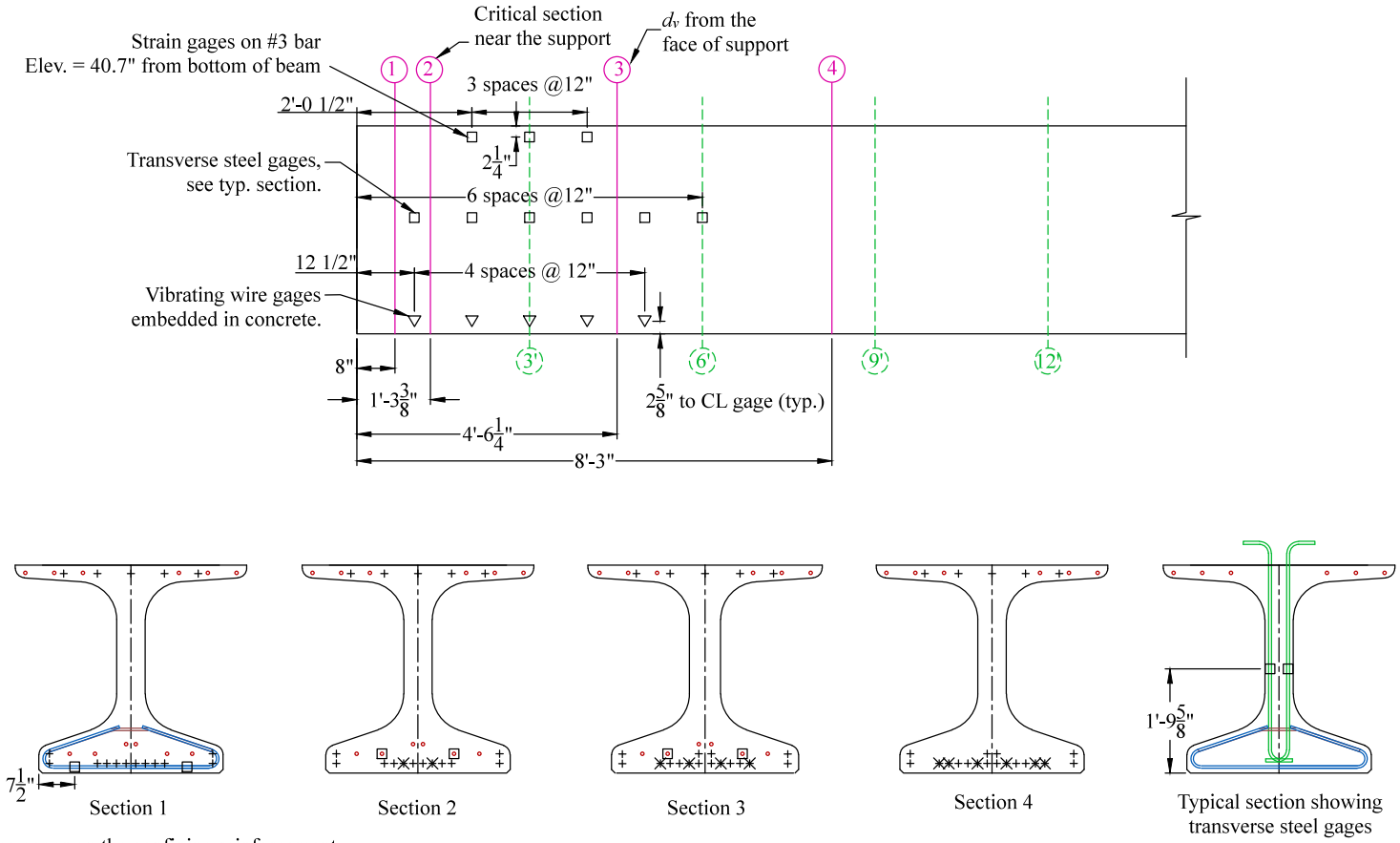
The gages on the confining reinforcement were at 8 $\frac{1}{2}$" from the end of the girder.

LEGEND

- □ Mild steel strain gage
- × Strand strain gage
- ▽ Vibrating wire gage

Strain Gage Locations End B

Figure. G.1 (cont.) AASHTO Type III-b (End B)



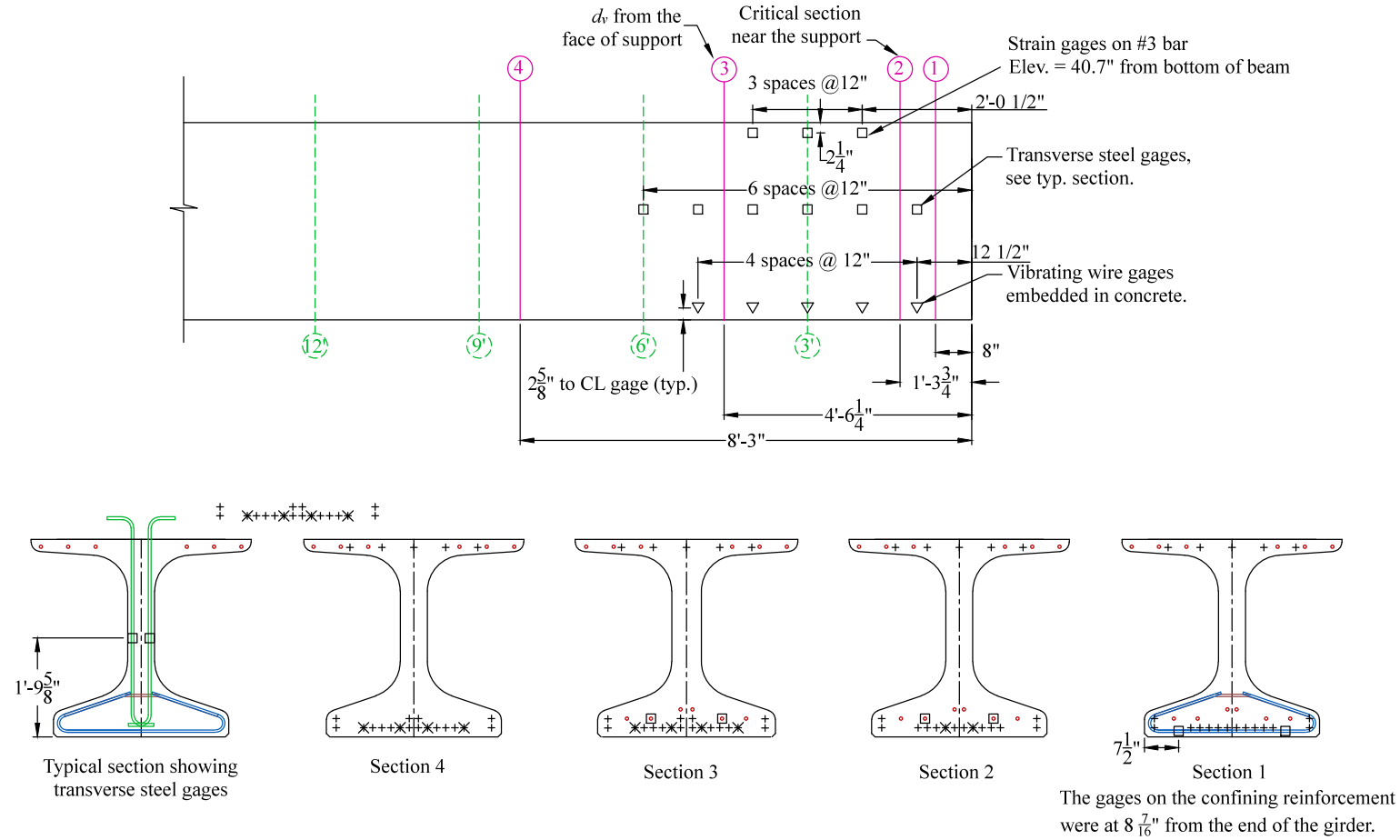
The gages on the confining reinforcement were at 8 $\frac{7}{16}$" from the end of the girder.

LEGEND

- □ Mild steel strain gage
- × Strand strain gage
- ▽ Vibrating wire gage

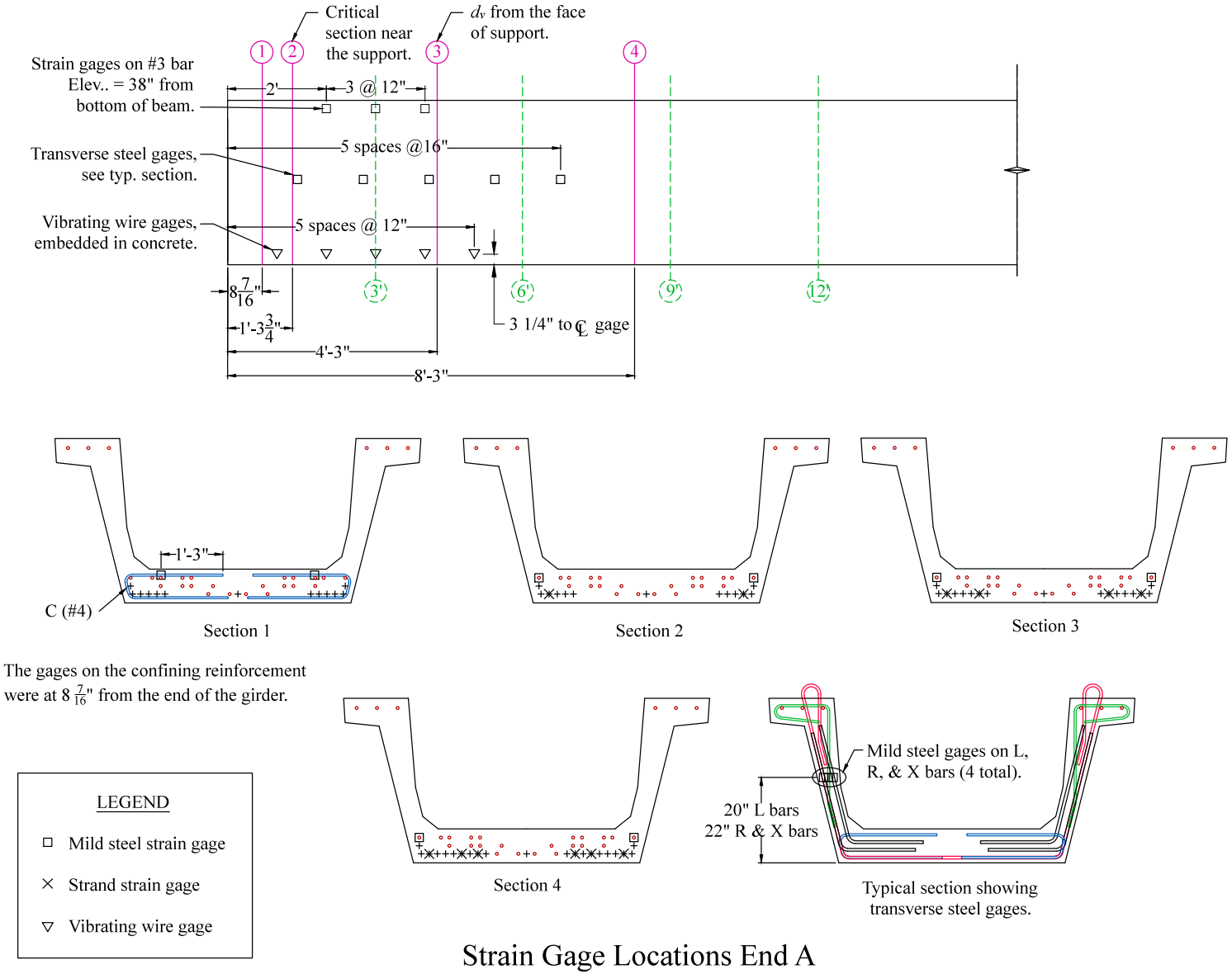
Strain Gage Locations End A

Figure G.1. (cont.) Nebraska NU-1100 (End A)



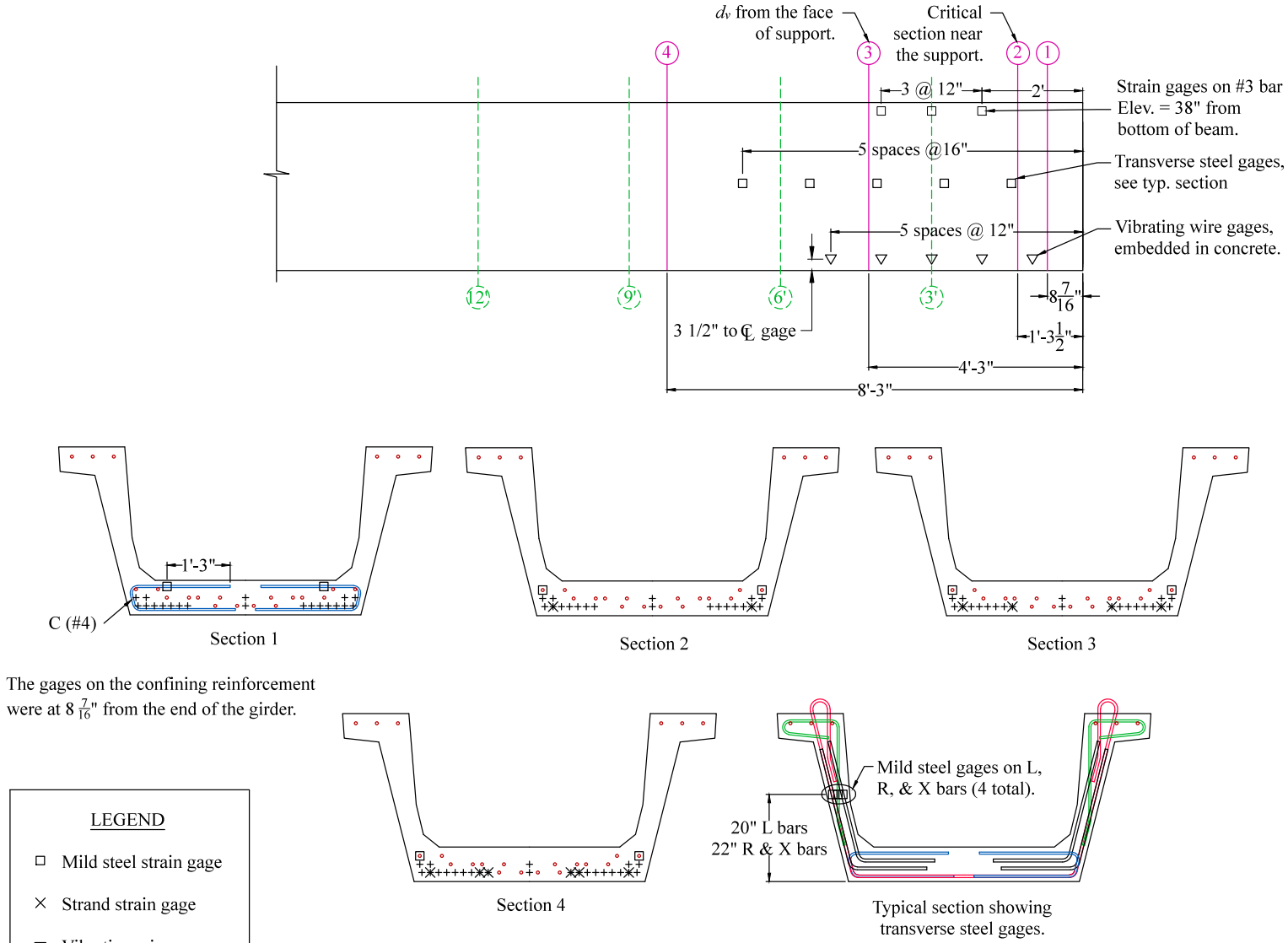
Strain Gage Locations End B

Figure G.1. (cont.) Nebraska NU-1100 (End B)



Strain Gage Locations End A

Figure G.1. (cont.) Texas U-40 (End A)



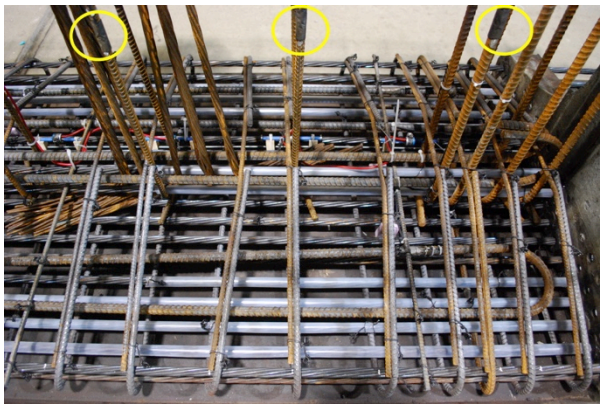
Strain Gage Locations End B

Figure G.1. (cont.) Texas U-40 (End B)

(a) Strain gage on a non-prestressed longitudinal reinforcing bar

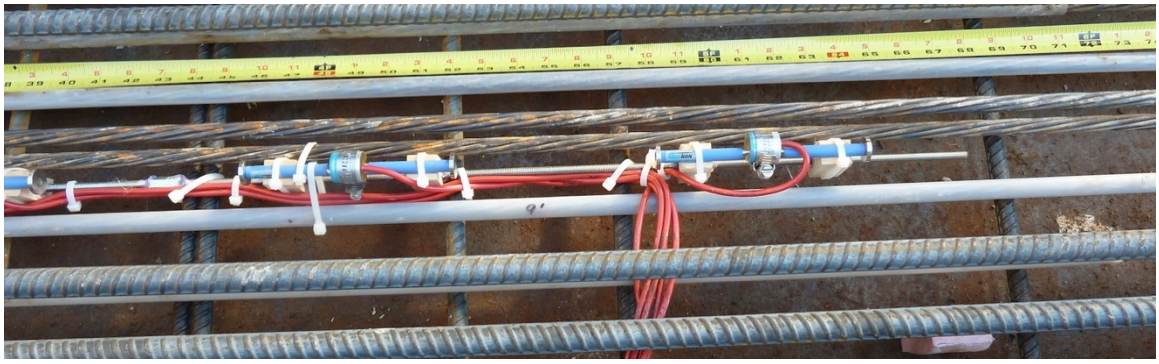
(b) Strain gage after water proofing and adding "mechanical" protection

(c) Strain gage on prestressing strand



(d) Instrumented transverse reinforcement

(e) Instrumented embedded top bar



(f) Vibrating wire gages

Figure G.2. Strain gages

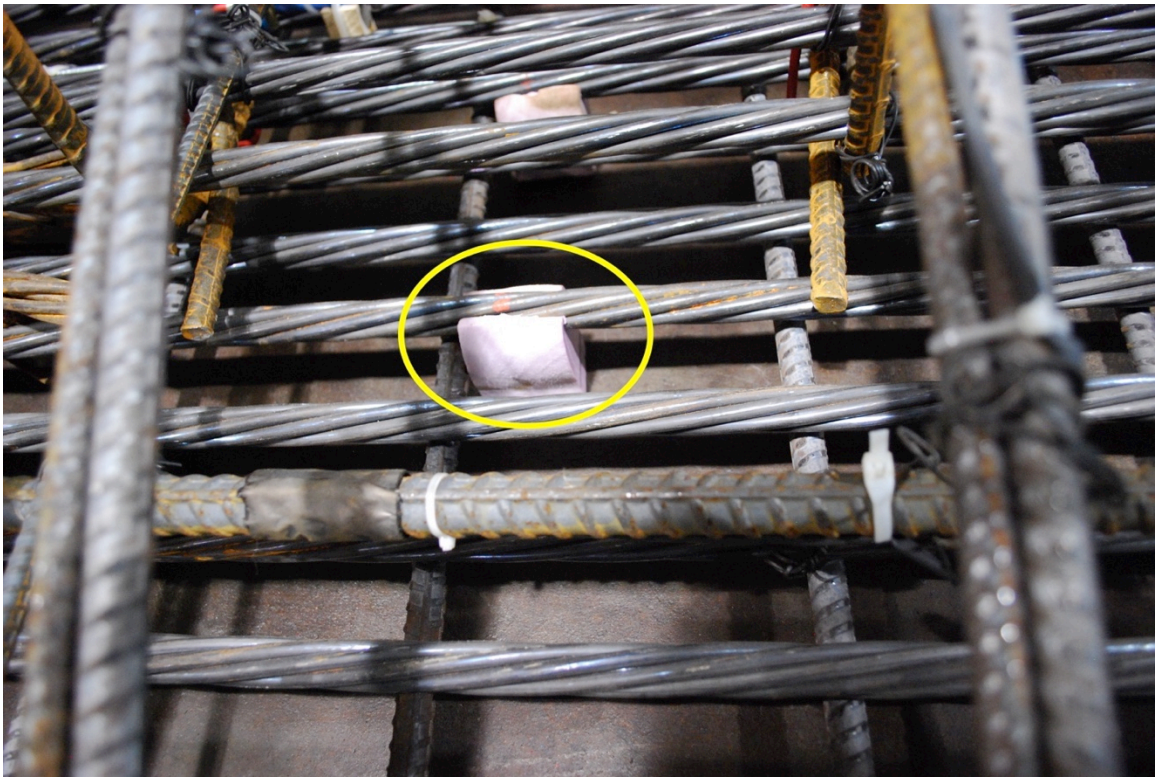


Figure C.3. Access foam block for installation of strain gages on prestressing strands

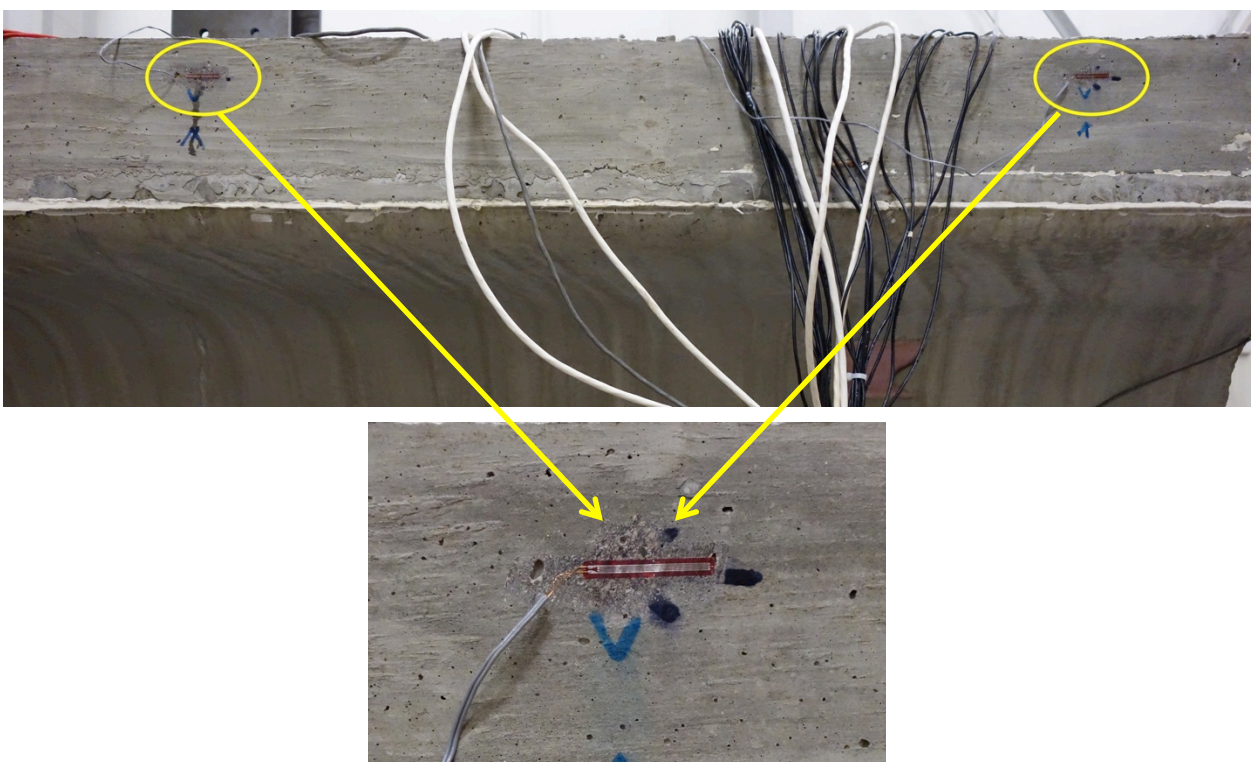
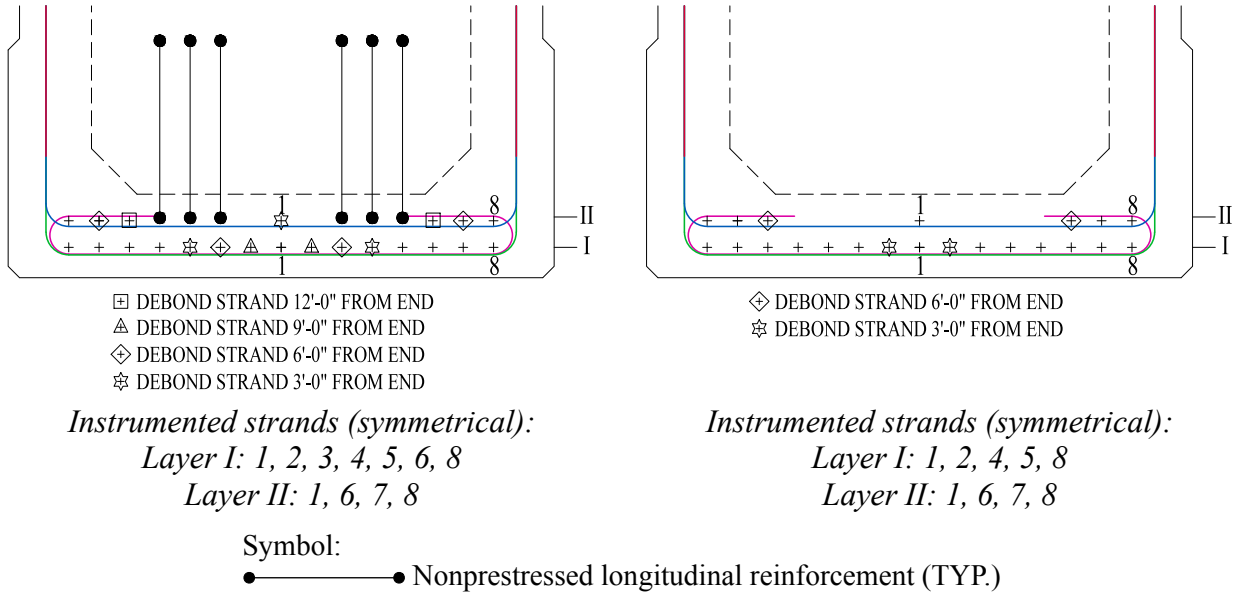
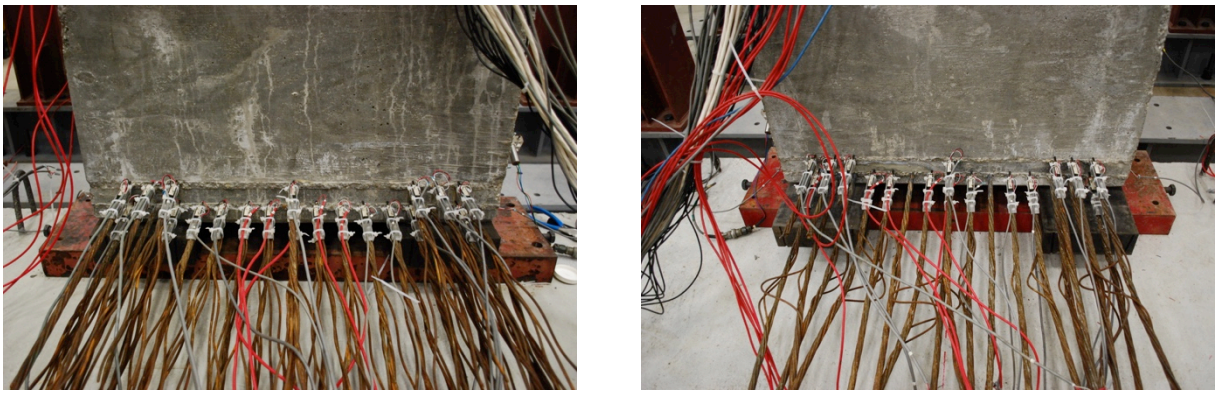


Figure G.4. Surface mounted strain gages

Measurement of Strand Slip

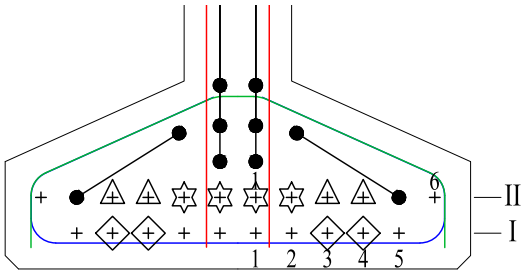


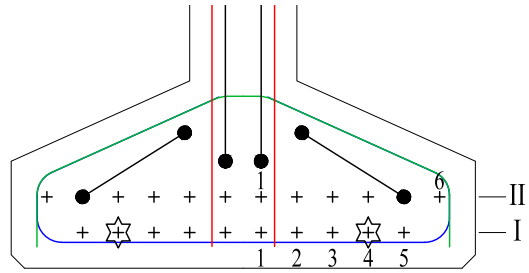


End A End B

(a) AASHTO BI-36

Figure G.5. Measurement of slip





DEBOND STRAND 9'-0" FROM END

DEBOND STRAND 6'-0" FROM END

DEBOND STRAND 3'-0" FROM END

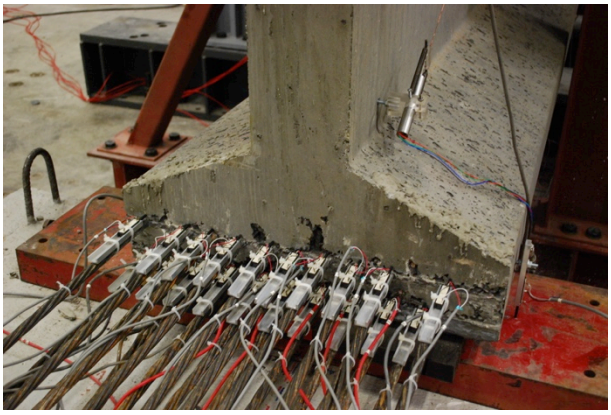
All strands were instrumented.

DEBOND STRAND 3'-0" FROM END

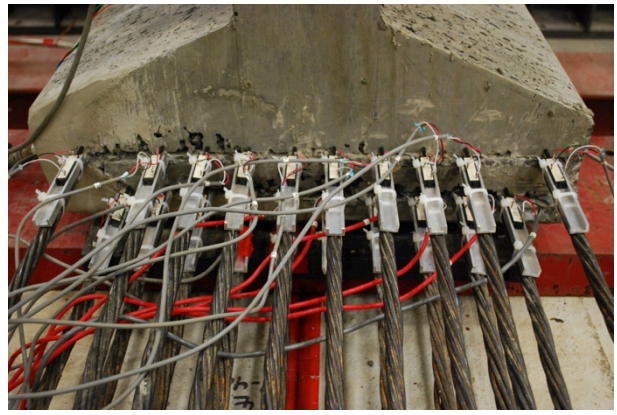
All strands were instrumented.

Symbol:

Nonprestressed longitudinal reinforcement (TYP.)



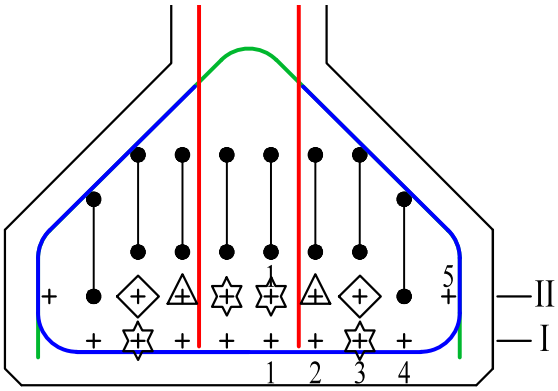
End A

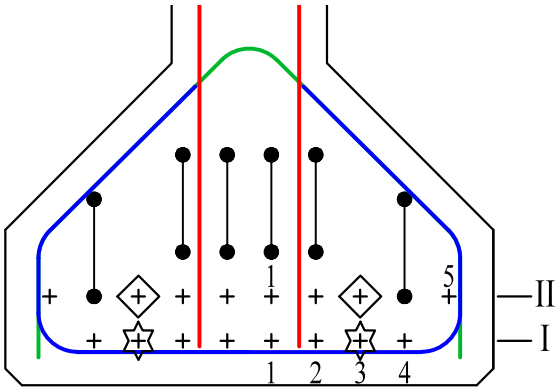


End B

(b) AASHTO BT-54

Figure G.5. (cont.) Measurement of slip





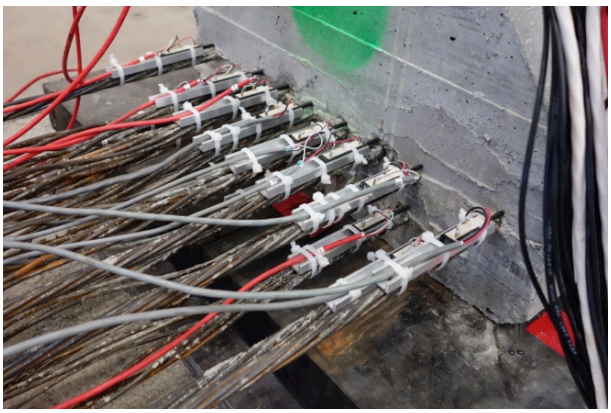
DEBOND STRAND 9'-0" FROM END
DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

Instrumented strands (symmetrical):
Layer I: 1, 3, 4
Layer II: 1, 2, 3, 5

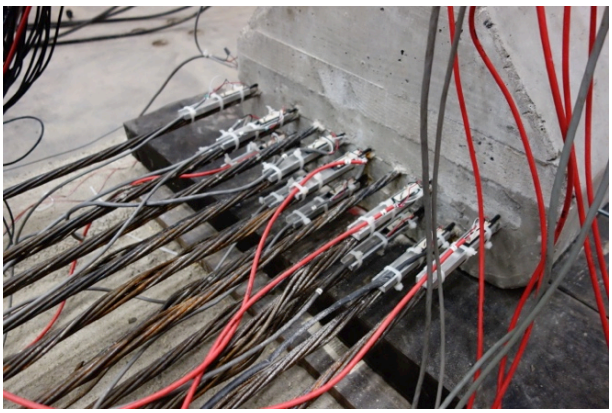
DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

Instrumented strands (symmetrical):
Layer I: 1, 3, 4
Layer II: 1, 3, 5

Symbol:
Nonprestressed longitudinal reinforcement (TYP.)



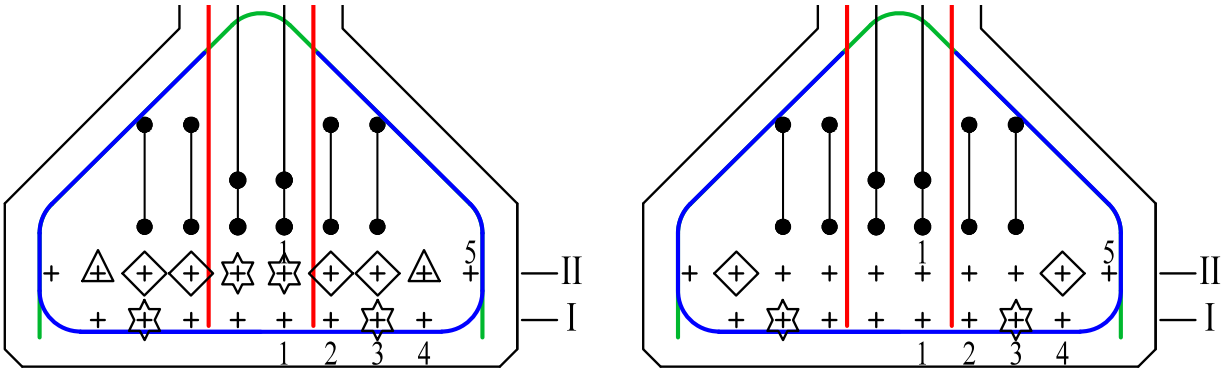
End A



End B

(c) AASHTO Type III-a

Figure G.5. (cont.) Measurement of slip



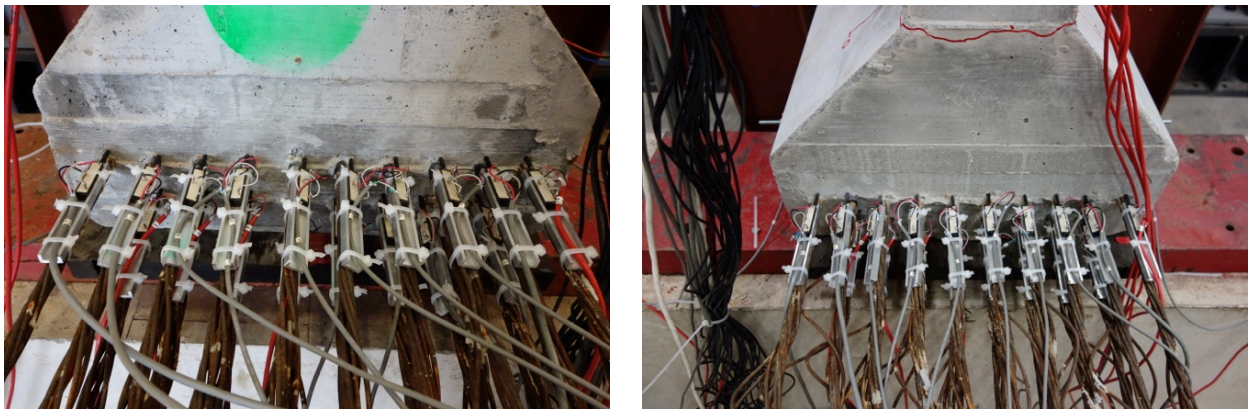
DEBOND STRAND 9'-0" FROM END
DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

All strands were instrumented.

DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

All strands were instrumented.

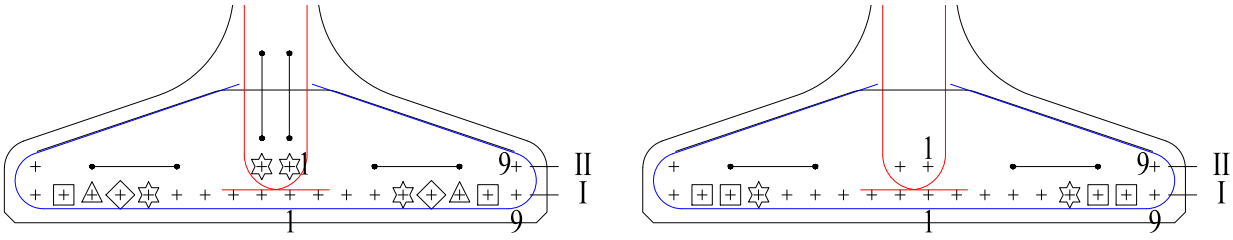
Symbol:
Nonprestressed longitudinal reinforcement (TYP.)



End A End B

(d) AASHTO Type III-b

Figure G.5. (cont.) Measurement of slip



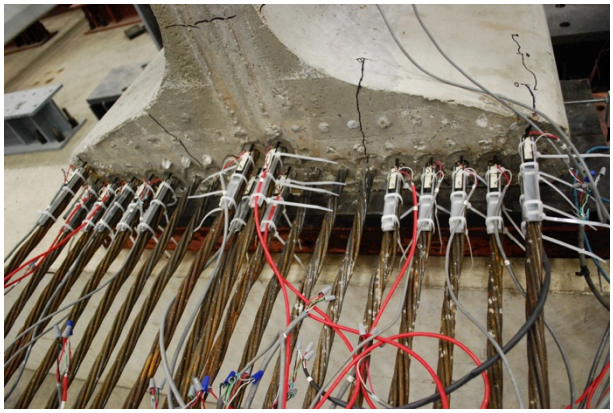
DEBOND STRAND 12'-0" FROM END
DEBOND STRAND 9'-0" FROM END
DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

Instrumented strands (symmetrical):
Layer I: 1, 5, 6, 7, 8, 9
Layer II: 1, 9

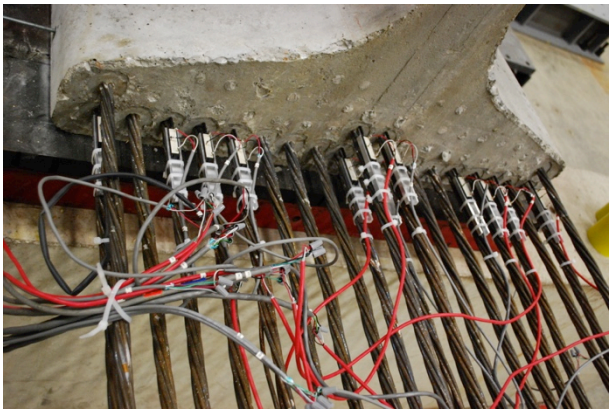
DEBOND STRAND 12'-0" FROM END
DEBOND STRAND 3'-0" FROM END

Instrumented strands (symmetrical):
Layer I: 1, 5, 6, 7, 9
Layer II: 1

Symbol:
Nonprestressed longitudinal reinforcement (TYP.)



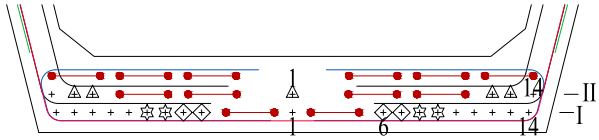
End A



End B

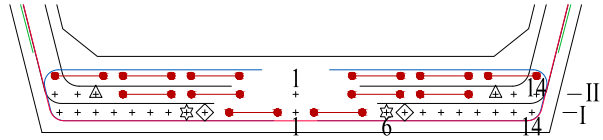
(e) Nebraska NU-1100

Figure G.5. (cont.) Measurement of slip



DEBOND STRAND 9'-0" FROM END
DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

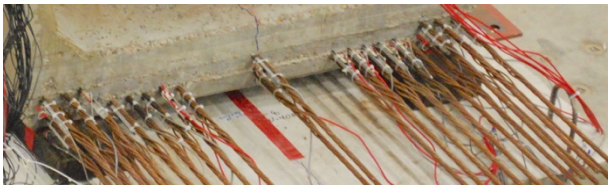
Instrumented strands (symmetrical):
Layer I: 1, 6, 7, 8, 9, 10, 14
Layer II: 1, 12, 13, 14



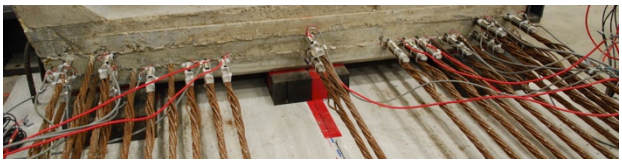
DEBOND STRAND 9'-0" FROM END
DEBOND STRAND 6'-0" FROM END
DEBOND STRAND 3'-0" FROM END

Instrumented strands (symmetrical):
Layer I: 1, 6, 7, 8, 10, 12, 14
Layer II: 1, 12, 14

Symbol:
Nonprestressed longitudinal reinforcement (TYP.)



End A

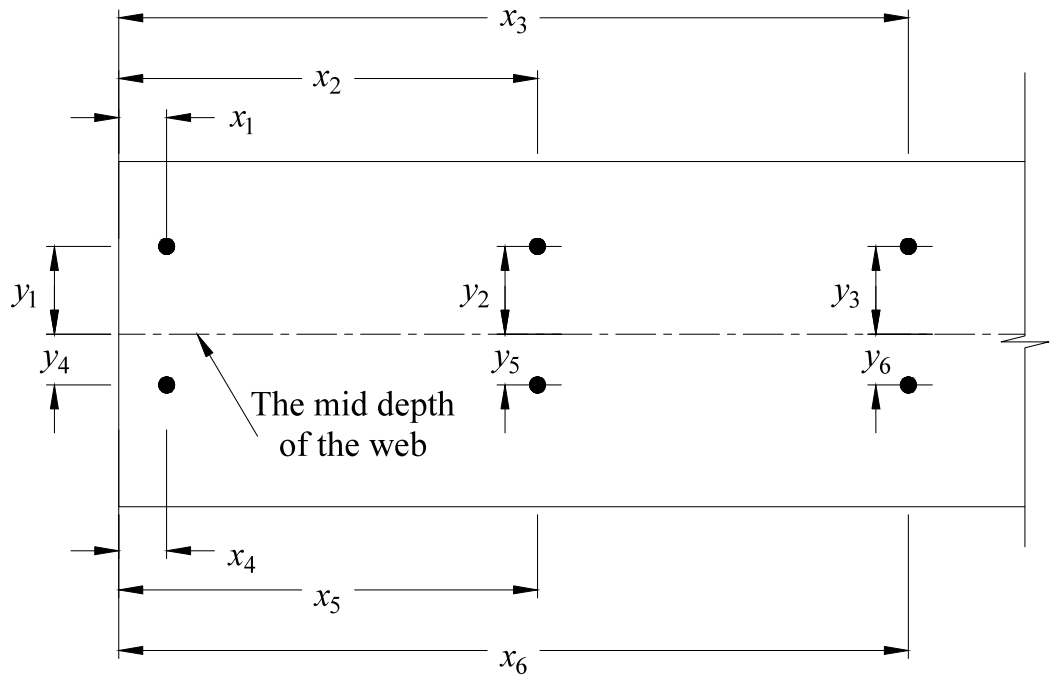


End B

(F) Texas U-40

Figure G.5. (cont.) Measurement of slip

Diagonal Displacement Transducers

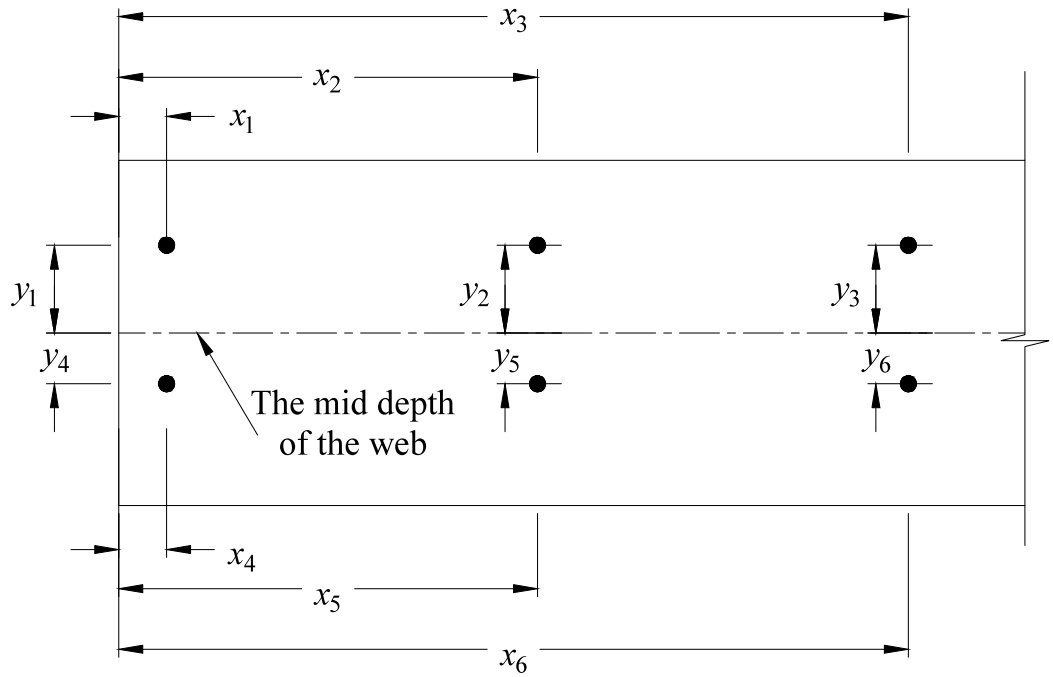


All the dimensions are in inches.

End A	x_1	x_2	x_3	x_4	x_5	x_6
	6	36 1/8	66 1/8	6	36	66 1/8
	y_1	y_2	y_3	y_4	y_5	y_6
	8 1/8	8	8	8	8	8 1/8
End B	x_1	x_2	x_3	x_4	x_5	x_6
	6	36	66	6	35 7/8	66 1/8
	y_1	y_2	y_3	y_4	y_5	y_6
	8 1/8	7 7/8	8	8 1/8	8	8 1/8

(a) AASHTO BI-36

Figure G.6. Locations of displacement transducers

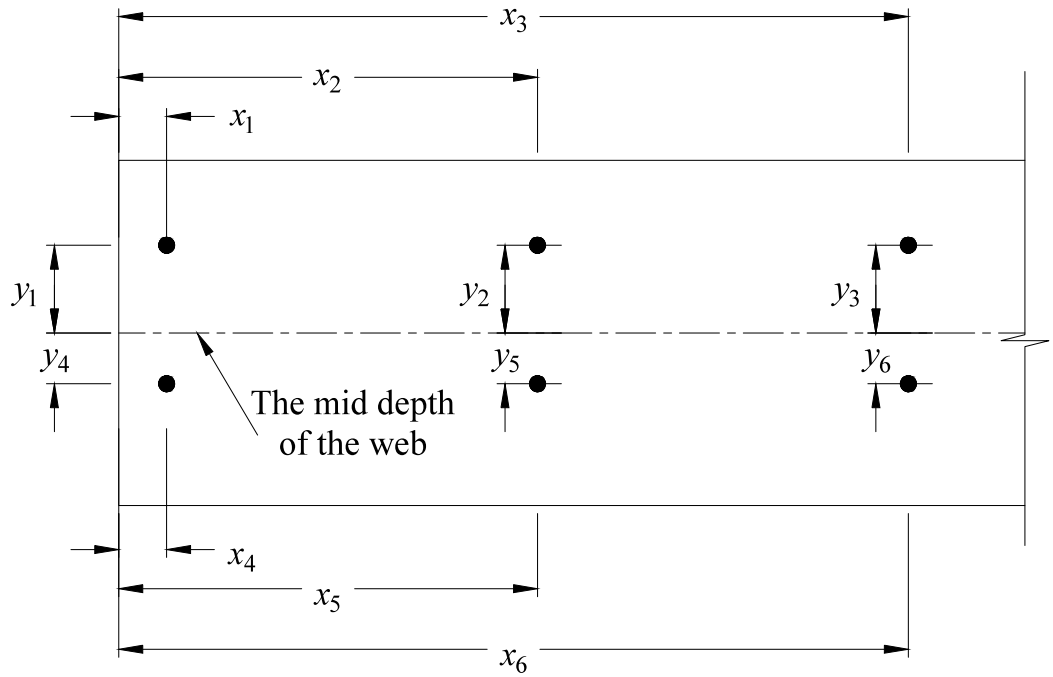


All the dimensions are in inches.

End A	x_1	x_2	x_3	x_4	x_5	x_6
	6	66	126	6 1/8	66	126
	y_1	y_2	y_3	y_4	y_5	y_6
	15	15	15	17 1/8	17 1/8	16 7/8
End B	x_1	x_2	x_3	x_4	x_5	x_6
	6	66	125 7/8	6	65 7/8	126 1/8
	y_1	y_2	y_3	y_4	y_5	y_6
	15	15 1/8	15 1/8	17	17	17

(b) AASHTO BT-54

Figure G.6. (cont.) Locations of displacement transducers

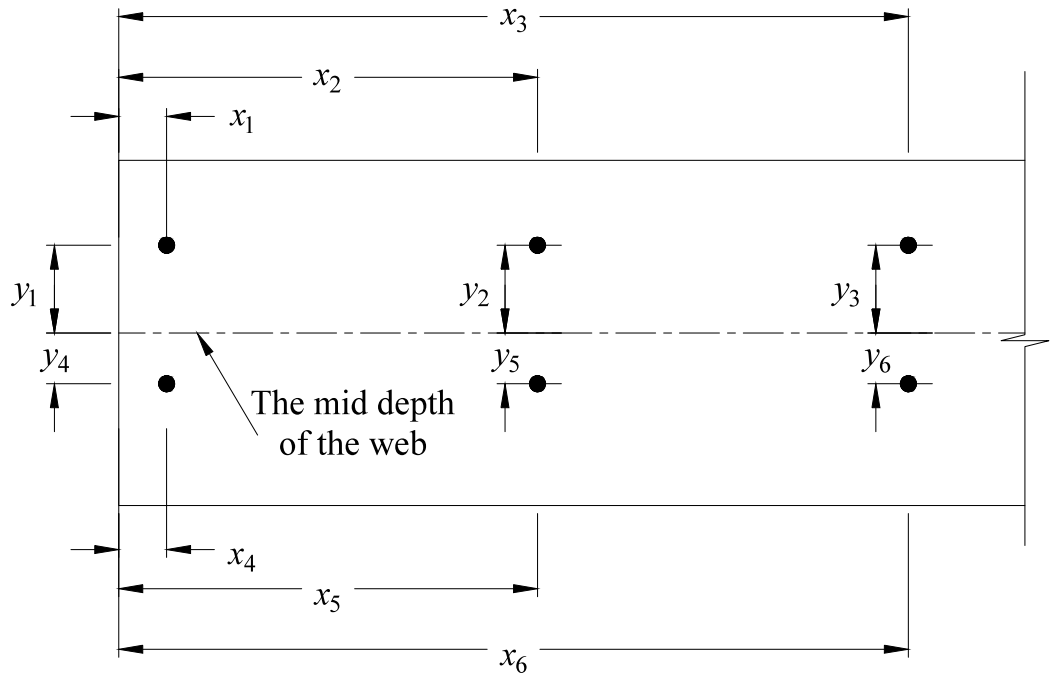


All the dimensions are in inches.

End A	x_1	x_2	x_3	x_4	x_5	x_6
	6 1/4	52 1/8	99	6	52 11/16	99
	y_1	y_2	y_3	y_4	y_5	y_6
	8 3/4	8 1/2	8 1/4	8	8	8
End B	x_1	x_2	x_3	x_4	x_5	x_6
	6 1/16	52 1/2	99	5 13/16	52 1/4	98 3/4
	y_1	y_2	y_3	y_4	y_5	y_6
	8 9/16	8 5/8	8 5/8	8 1/2	8 1/2	8 9/16

(c) AASHTO Type III-a

Figure G.6. (cont.) Locations of displacement transducers

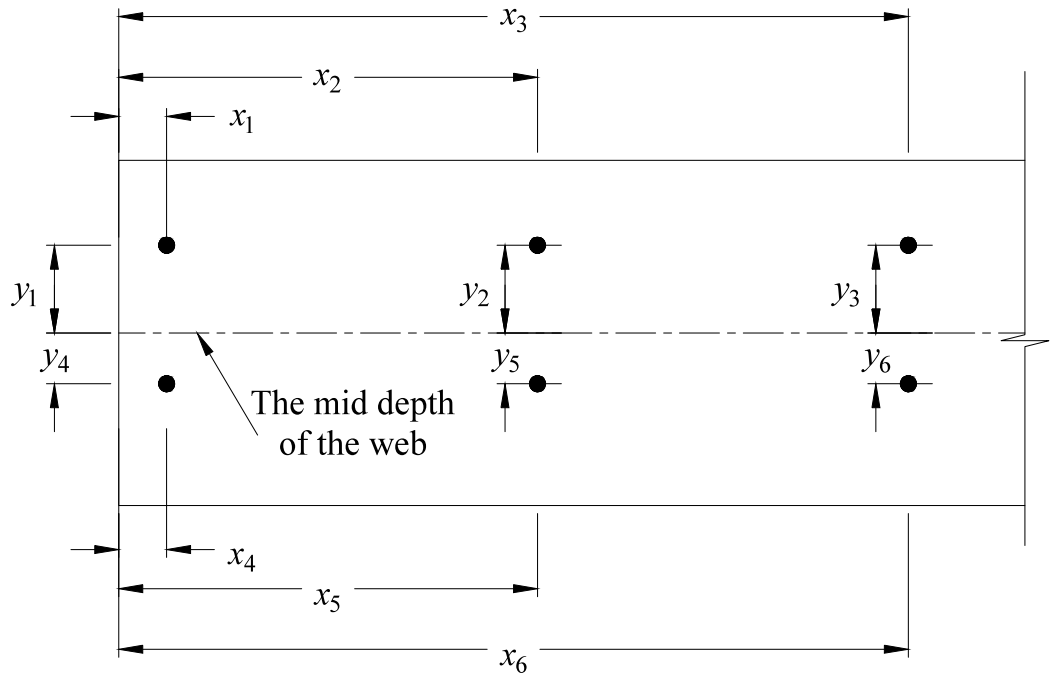


All the dimensions are in inches.

End A	x_1	x_2	x_3	x_4	x_5	x_6
	6	52	98 7/8	6	52 1/8	98 7/8
	y_1	y_2	y_3	y_4	y_5	y_6
	8 1/8	8 1/8	8	8	8 1/8	8
End B	x_1	x_2	x_3	x_4	x_5	x_6
	6	52 1/2	98 3/4	6	52 3/8	99
	y_1	y_2	y_3	y_4	y_5	y_6
	8 1/4	8 3/8	8 1/4	8 1/4	8 1/4	8 1/4

(d) AASHTO Type III-b

Figure G.6. (cont.) Locations of displacement transducers



All the dimensions are in inches.

End A	x_1	x_2	x_3	x_4	x_5	x_6
	6	52 1/2	99	6	52 1/2	99
	y_1	y_2	y_3	y_4	y_5	y_6
	11	10 7/8	10 5/8	6 3/8	6 3/8	6 3/8
End B	x_1	x_2	x_3	x_4	x_5	x_6
	5 7/8	52 1/2	99	6	52 1/2	98 15/16
	y_1	y_2	y_3	y_4	y_5	y_6
	10 7/8	10 3/8	9 7/8	6 1/8	6 5/8	7 1/16

(e) Nebraska NU-1100

Figure G.6. (cont.) Locations of displacement transducers

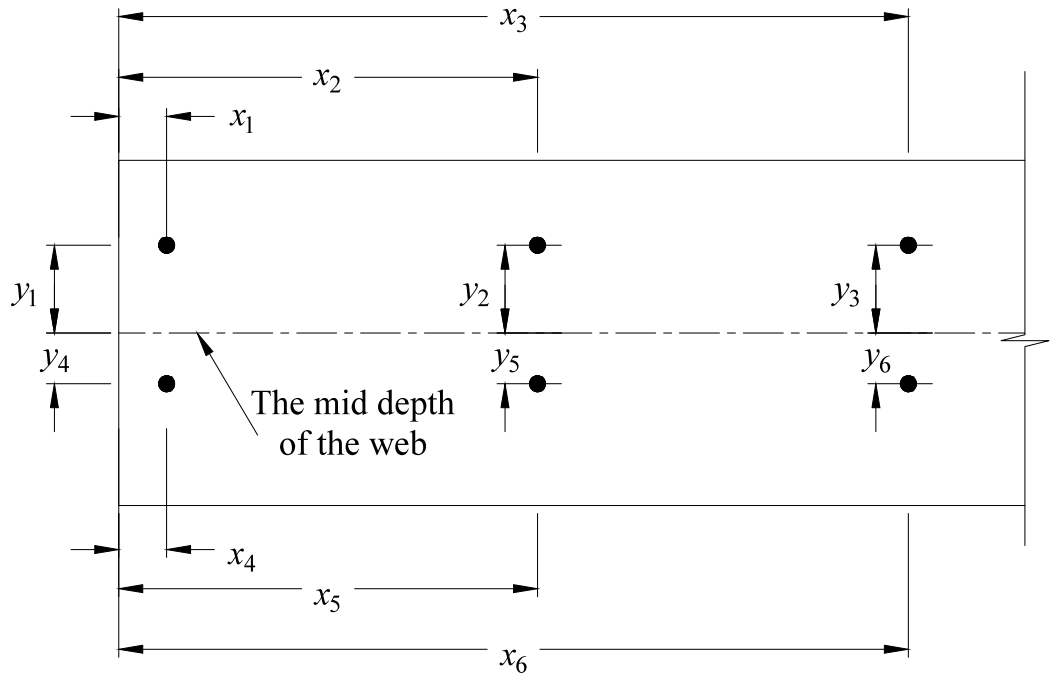


Figure C.5. (cont.) Locations of displacement transducers

All the dimensions are in inches.

End A	x_1	x_2	x_3	x_4	x_5	x_6
	6	52 1/4	98 3/4	6	52 1/4	98 3/4
	y_1	y_2	y_3	y_4	y_5	y_6
	14	13 3/4	13 7/8	7 1/2	7 1/2	7 5/8
End B	x_1	x_2	x_3	x_4	x_5	x_6
	6 1/8	52 1/2	99	6	52 1/2	99 1/8
	y_1	y_2	y_3	y_4	y_5	y_6
	11 5/8	11 1/2	11 1/2	11 1/2	9 1/2	11

(f) Texas U-40

Figure G.6. (cont.) Locations of displacement transducers

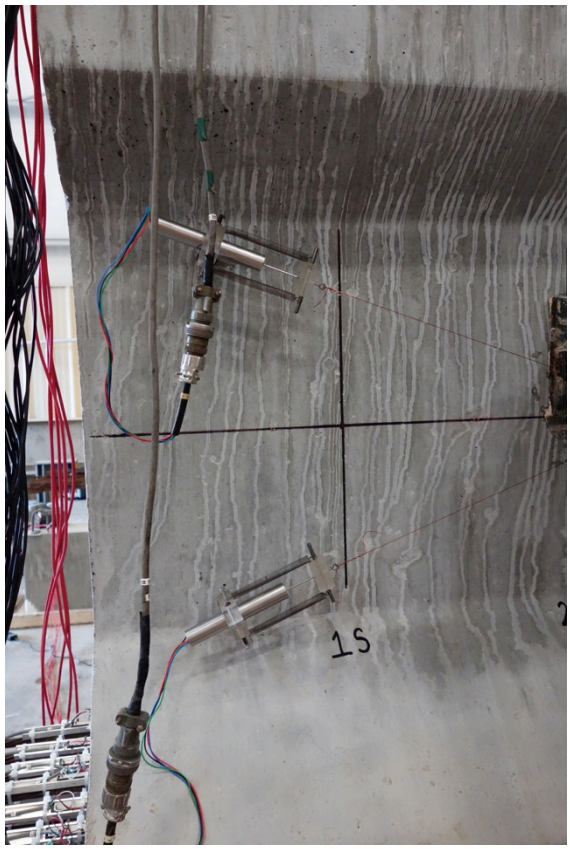


Figure G.7. Diagonal displacement transducers

With reference to Figure G.8, the following equations can be used to determine the shear angle based on the deformations measured by the diagonal displacement transducers.

Apply the law of cosines.

$$\left(L_1 + \Delta L_1\right)^2 = a^2 + b^2 - 2ab\cos\beta$$

$$\cos\beta = \frac{\left(\Delta L_1\right)^2 + 2L_1\Delta L_1}{-2ab}; \quad \beta = acos\left[\frac{\left(\Delta L_1\right)^2 + 2L_1\Delta L_1}{-2ab}\right]$$

$$\left(L_2 - \Delta L_2\right)^2 = a^2 + b^2 - 2ab\cos\alpha$$

$$\cos\alpha = \frac{\left(\Delta L_2\right)^2 + 2L_2\Delta L_2}{-2ab}; \quad \alpha = acos\left[\frac{\left(\Delta L_2\right)^2 + 2L_2\Delta L_2}{-2ab}\right]$$

$$Average\ shear\ angle = \frac{\beta - \alpha}{2}$$

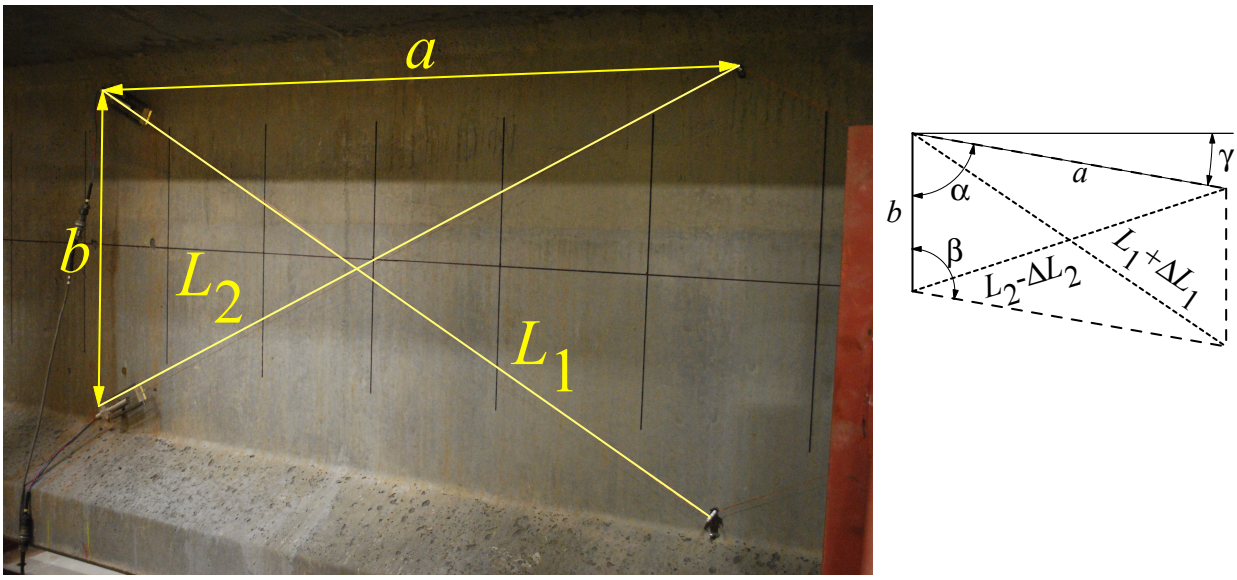


Figure G.8. Derivation of equation for computing shear angle