Caltrans

Project Delivery Engineering Services

California Department of Transportation

Western Bridge Engineers' Seminar

The New California Wide-Flange Girder

A Super Girder for California Bridges

Presented by: Michael Pope, P.E.
Jay Holombo, Pd.D., P.E.

September 22rd, 2009
Sacramento Convention Center
Sacramento, California

California Department of Transportation

Western Bridge Engineers' Seminar

Contract for Performance and Innovation

2007/08
Contract for Performance and Innovation

Project Delivery

- Deputy director's commitment for innovation
  - *Establish a candidate list of projects to be considered for a pilot program to demonstrate <u>accelerated bridge construction (ABC)</u> practices.*

Deputy Director's Contract for Innovation:

- Improve teamwork and awareness of support costs through emphasis on management of project delivery tasks; fully implement Task Management.
- Pursue additional innovative project delivery procurement methods.
- Establish a candidate list of projects to be considered for a pilot program to demonstrate Accelerated Bridge Construction practices.
- Facilitate the use of cement substitutes in the construction of transportation projects.
- Enhance awareness of the Department's Stewardship Goal among project delivery functions; specifically focus on environmental stewardship.
- Enhance Partnering on construction contracts by implementing Caltrans Construction Partnering Steering Committee (CCPSC) process improvement recommendations, including: revising specifications; updating the Field Guide to Partnering; and conducting joint Caltrans/industry training.
- Develop a plan for securing or developing a state-of-the art Caltrans Land Management System (CLMS).
- Improve existing processes for collecting, distributing, and incorporating lessons learned.
- Continue the partnership effort with Planning and Modal Programs to enhance the development of and follow through on Project Purpose and Need.
- Establish a partnership effort with Information Technology (IT) to facilitate the Department's compliance with statewide IT policies and enhance IT support for project delivery functions.
- Continue the partnership with Maintenance and Operations to minimize and address the impact of transportation improvement projects on the ability to safely maintain and operate those improvements.

1/25/08		1-25-08	
Richard D. Land, Chief Engineer and Deputy Director, Project Delivery	Date	Will Kempton, Director	Date

Recent ABC Projects in California

MacArthur Maze Reconstruction - Oakland

I-5 Truck Route Fire Repair - San Fernando

Russian River Bridge Replace - Geyserville

SR 40 Mojave Bridges - Needles/Barstow

California Cast-in-Place Box Girder

- Advantages
  - *Seismically Resilient*
  - *Shallow Superstructure / Aesthetics*
  - *Cost*
- Drawbacks
  - *Construction Time*
  - *Urban Issues / Vertical Clearance*
  - *Driver Inconvenience / Safety*

California Cast-in-Place P/T Box Girder

Folsom Bridge Over Lake Natoma

California Pre-tensioned I-Girder

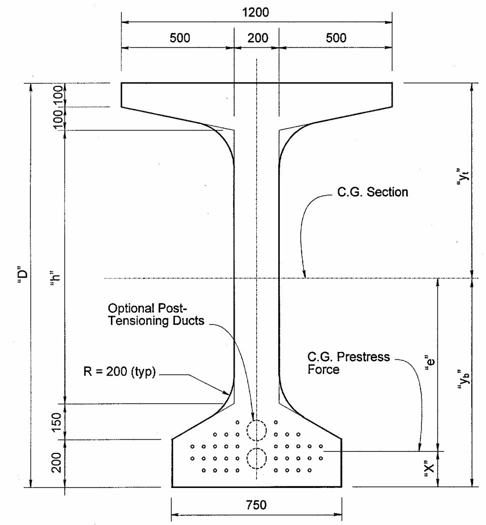
- Facts About The California I-Girder
  - *Used in California Since the 1960's*
  - *Common Span Lengths 50 – 100 ft.*
  - *Great for Widening Existing Bridges*
  - *Good Deflection Control*
  - *Deck Removal / Replacement*
  - *Reduced Construction Time*

California Department of Transportation

California Pre-tensioned I-Girder

California Bulb-Tee Girder

- Girder Characteristics:
  - *Used to Span Between Bents, or Spliced to Achieve Longer Spans*
  - *Simple Pre-tensioned D/S = 0.050*
    Multi-Span Cont. for LL D/S = 0.045
    Spliced Multi-Span P-T D/S = 0.042
    - *Spans 150+ feet Un-spliced – Hauling Length Limitations*
    - *Span Lengths up to 200+ feet When Segments are spliced Together with Post-Tensioning*

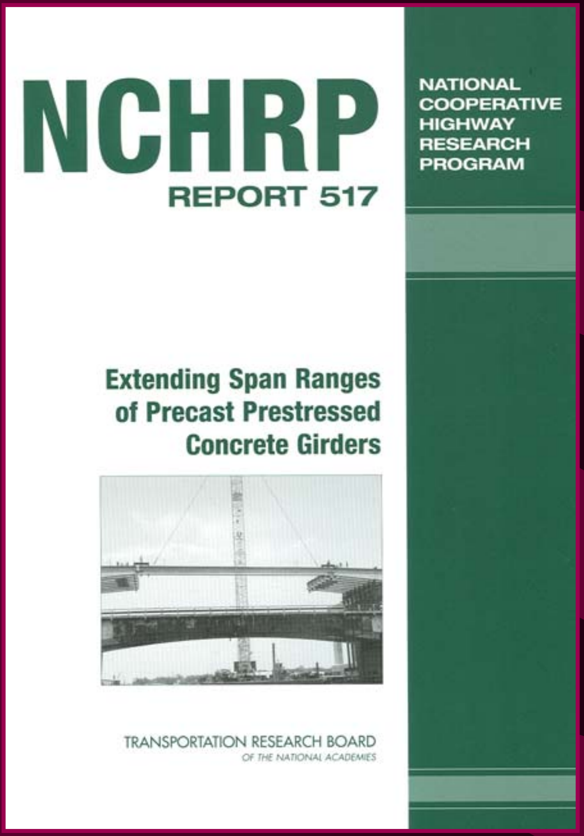


SECTION PROPERTIES

"D" (mm)	"h" (mm)	Area (mm^2)	I (mm^4)	y_b (mm)	y_t (mm)	S_b (mm^3)	S_t (mm^3)	r (mm)	Mass (N/m)	Wt. (Kg/m)
1400	850	596 500	155 400 E6	721	679	215.5 E6	228.8 E6	510	14 060	1433
1550	1000	626 500	201 200 E6	795	755	253.0 E6	266.5 E6	567	14 770	1505
1700	1150	656 700	254 200 E6	870	830	292.1 E6	306.2 E6	622	15 480	1577
1850	1300	686 100	314 500 E6	945	905	333.0 E6	347.5 E6	677	16 180	1650
2000	1450	716 300	382 600 E6	1019	981	375.4 E6	390.0 E6	731	16 890	1722
2150	1600	746 500	458 800 E6	1094	1056	419.4 E6	434.5 E6	784	17 600	1794

Genesis of Spliced Girder Design

- Spliced Girder Research
  - *NCHRP 12-57 "Extending Span Ranges of Precast, Prestressed Concrete Girders"*
  - *Ralph Whitehead & Associates*
  - *LRFD Article 5.14.1.3 - Spliced Precast Girders*
  - *Three Comprehensive Design Examples*



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LRFD Introduces Spliced Girders

- AASHTO LRFD Code
  - *Defines "Spliced Girders" as a Unique Structure Type in 2005 Interims*
  - *4 Pages of Code & Commentary Devoted to Spliced Girders*
  - *Three Comprehensive Design Examples*

AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

5.14.1.3 Spliced Precast Girders

5.14.1.3.1 General

The provisions herein apply to precast girders fabricated in segments that are joined or spliced longitudinally to form the girders in the final structure.

The requirements specified herein shall supplement the requirements of other sections of these Specifications for other than segmentally constructed bridges. Therefore, spliced precast girder bridges shall not be considered as segmental construction for the purposes of design. For special design cases, additional provisions for segmental construction found in Article 5.14.2 and other articles in these Specifications may be used where appropriate.

C5.14.1.3.1

Bridges consisting of spliced precast girder segments have been constructed in a variety of locations for many different reasons. An extensive database of spliced girder bridge projects has been compiled and is present in the appendix to Castrodale and White (*2004*).

Splicing of girder segments is generally performed in place, but may be performed prior to erection. The final structure may be a simple span or a continuous span unit.

In previous editions of these Specifications, spliced precast girder bridges were considered as a special case of both conventional precast girders and segmental

The provisions herein apply to precast girders fabricated in segments that are joined or spliced longitudinally to form the girders in the final structure.

Interim 2005

NCHRP Report 517 Design Examples

- Design Example 1
  - *200 foot Single Span Spliced PCI BT Girder*
  - *14 inch Wet Splice on Temporary Towers*
  - *96 in. Deep Modified PCI Bulb-tees with an 8 in. Web*
  - *3 Girder Segments – Center Segment = 90 feet*
  - *Depth-to-Span Ratio = 0.044*

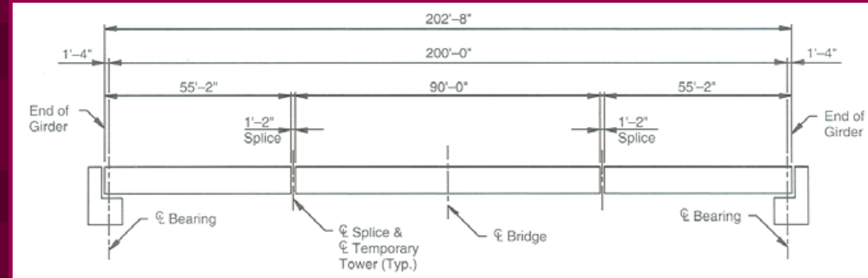


Figure 2-1 Elevation – Girder Erection – Initial Design

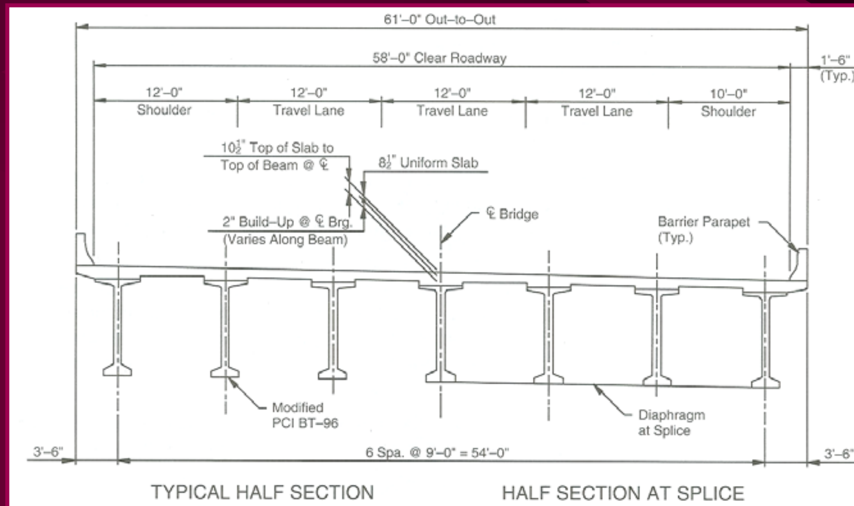
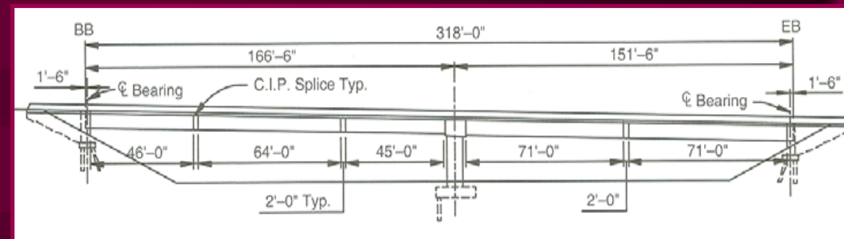
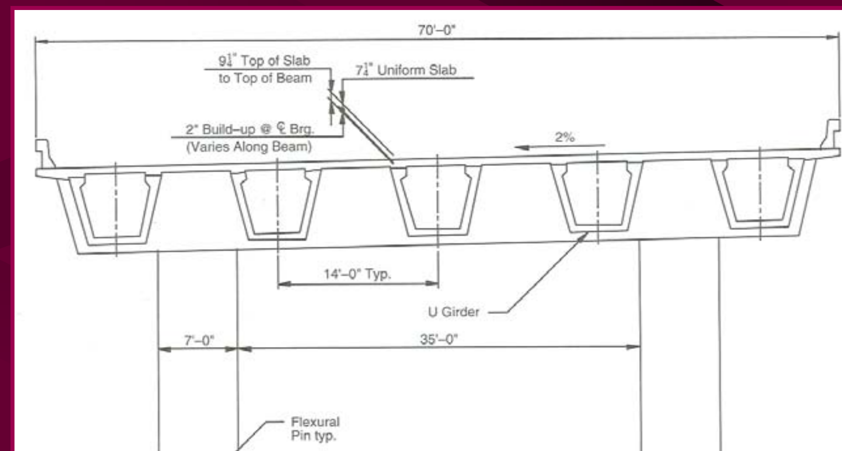


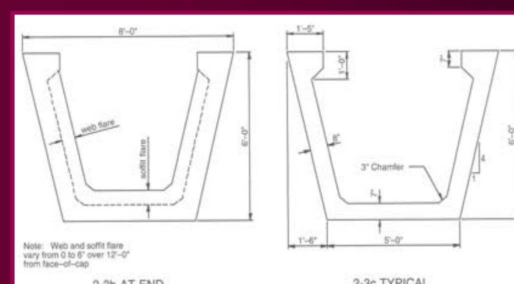
Figure 2-4 Typical Section of Bridge

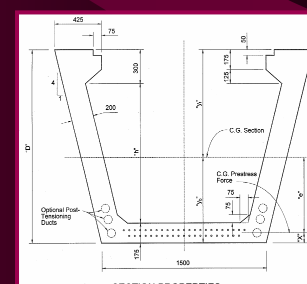
NCHRP Report 517 Design Examples

- Design Example 2
  - *Two-Span Spliced U – Beam Girder*
  - *Precast Alternative for Typical California CIP Box Girder Overcrossing*
  - *6 Foot Deep U-Beams (California Bathtub)*
  - *Spans Designed with both 2 and 3 Girder Segments*
  - *Depth-to-Span Ratio = 0.041*









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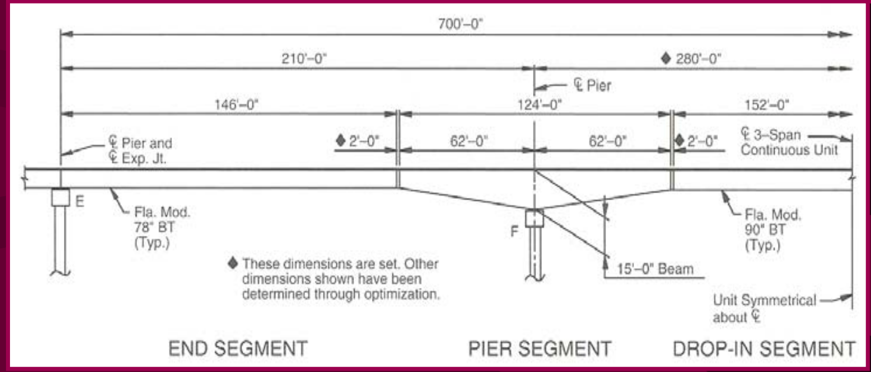
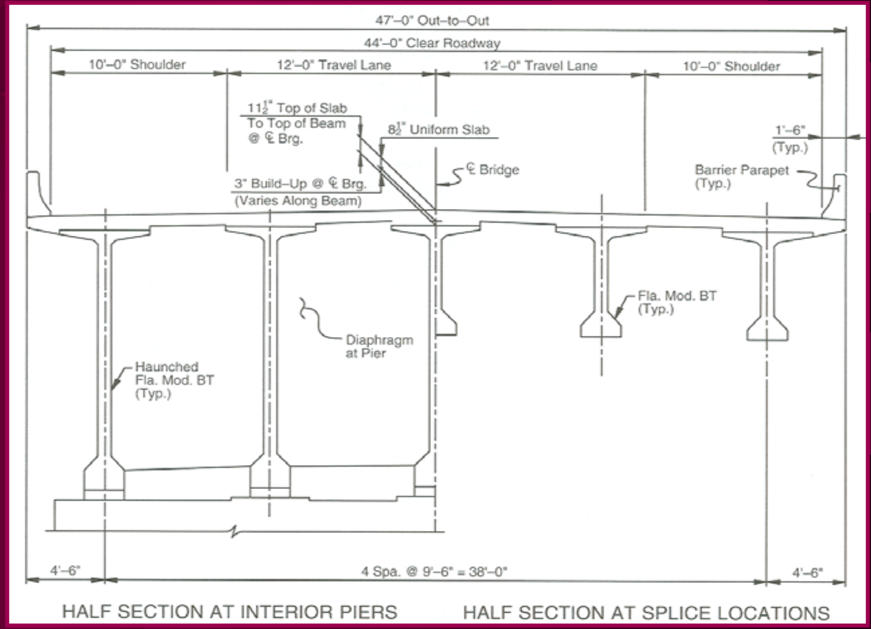
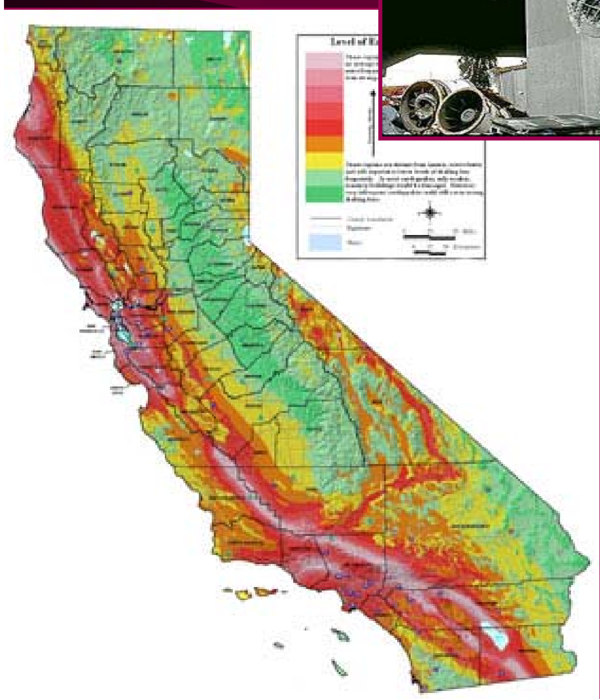
NCHRP Report 517 Design Examples

- Design Example 3
  - *Continuous Three Span Haunched Spliced Girder*
  - *Concept Developed for Water Crossings in Florida*
  - *280 foot Main Span, with Equal 210 foot End Spans*
  - *Midspan Girder Depth = 7'-6" (overall D/S = 0.030)*
  - *Haunched Girder Depth = 15'-0" (overall D/S = 0.057)*





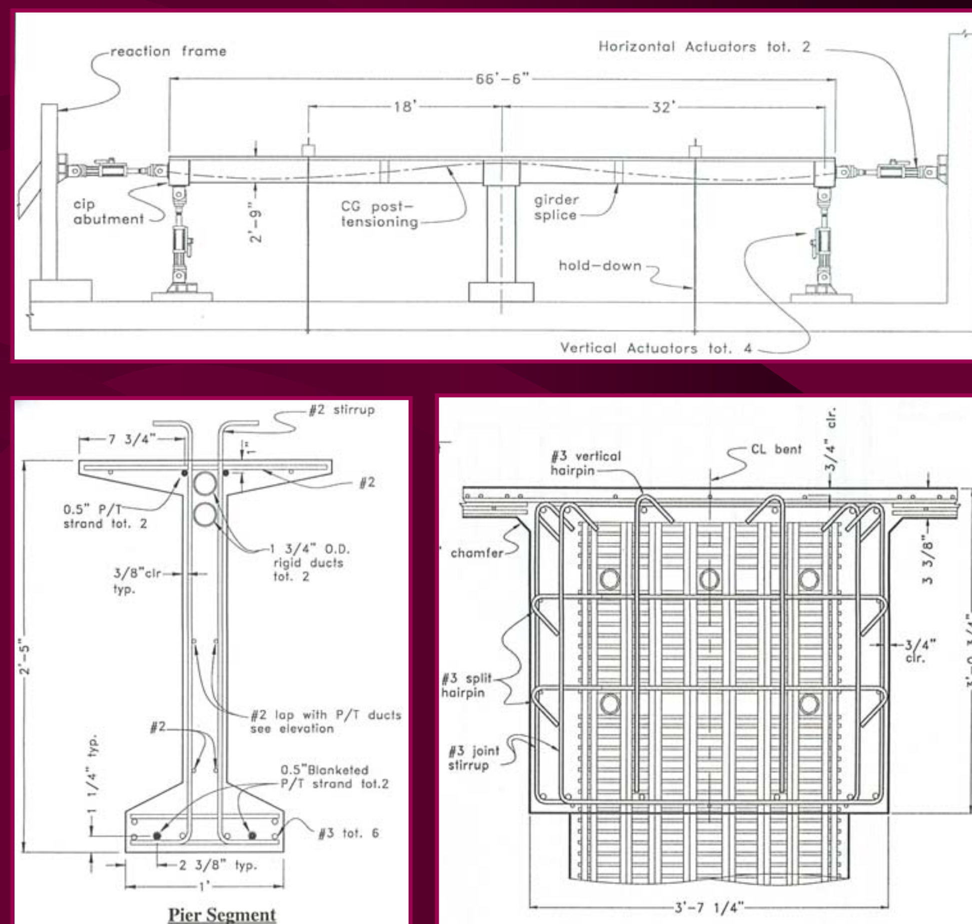
Seismic Performance



Seismic Testing - UCSD

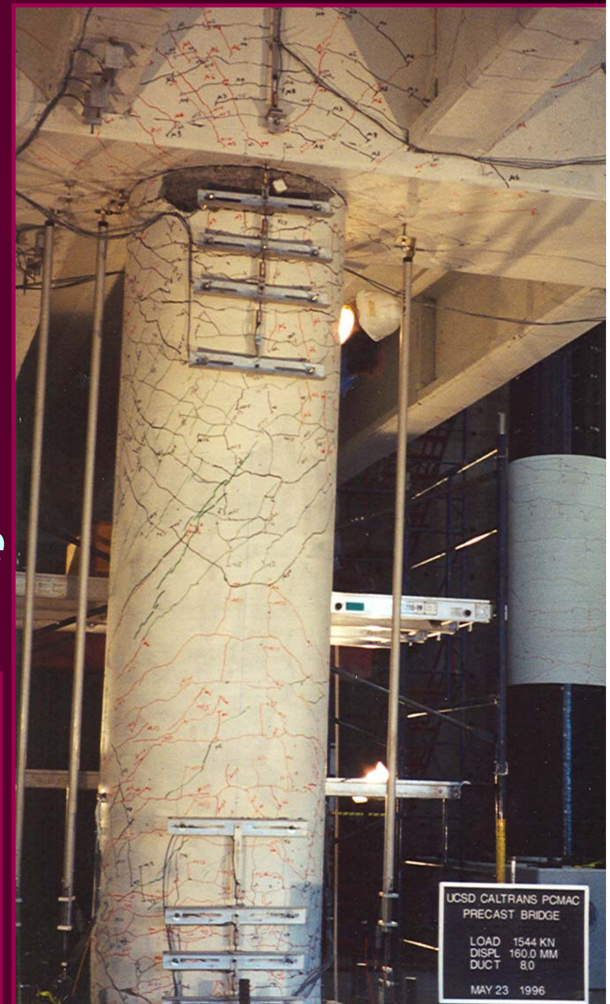
- UCSD Seismic Testing
  - *Fully reversed horizontal Displacement cycles until target ductilities have been reached.*
  - *Return specimen to undisplaced position, disengage horizontal actuators for subsequent vertical displacement cycles to failure.*

Girder and Bent Cap Details in the Integral Column to Cap connection Region:



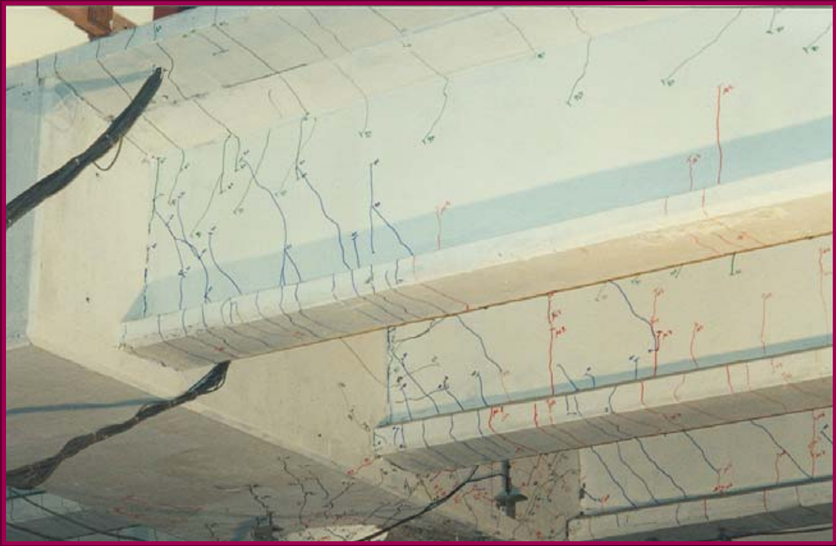
Seismic Testing - UCSD

- Applied Seismic Loading
  - *Column Subjected to Incremental Displacement Cycles, up to a ductility $\mu_\Delta = 8$*
  - *With a Column Diameter to Structure of about 1, a Large Plastic Moment delivered to the Bent Cap.*



Seismic Testing - UCSD

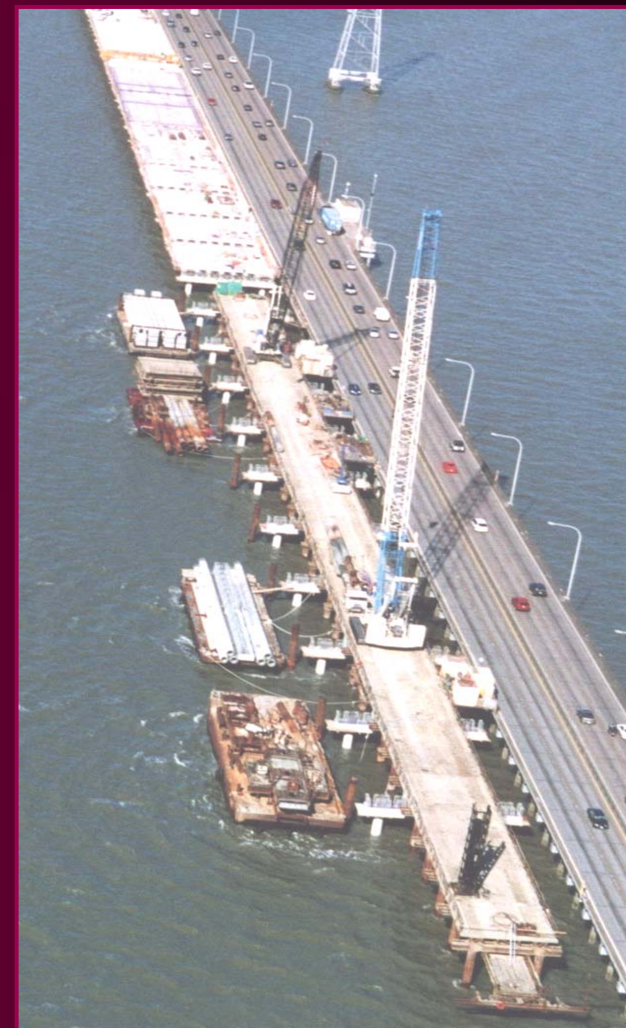
- Superstructure Performance
  - *Bent Cap Withstands Plastic Moment Induced by Column*
  - *Girders Remain "Essentially Elastic" with Small Cracks*
    - *Bent Cap Torsional Mechanism - Forces to Exterior Girders*
    - *Post-Tensioned Bent Cap Clamps Girders Together - Increases Torsional Rigidity*



California Pre-tensioned Bulb-Tee Girder

San Mateo – Hayward Bridge Widen

2169 ea – 90 foot Bulb-Tee Girders



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California Pre-tensioned Bulb-Tee Girder

Main Street Bridge – Cottonwood Creek

California Post-tensioned Bulb-Tee Girder

Sacramento River Bridge – Interstate 5

California Post-tensioned Bulb-Tee Girder

Fiberboard Undercrossing – Interstate 80

California Post-tensioned Bulb-Tee Girder

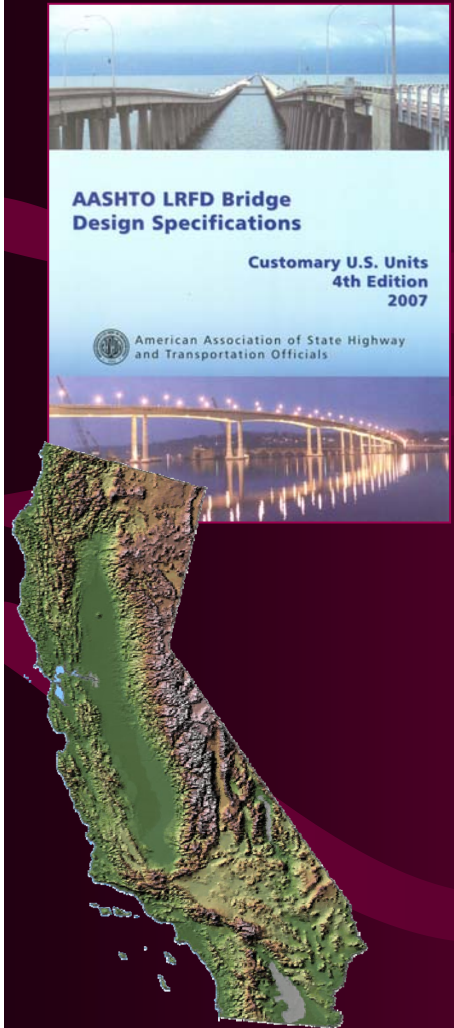
Jefferson Boulevard Canal Bridge

California Post-tensioned Bulb-Tee Girder

Angeles Crest Bridge – State Route 39

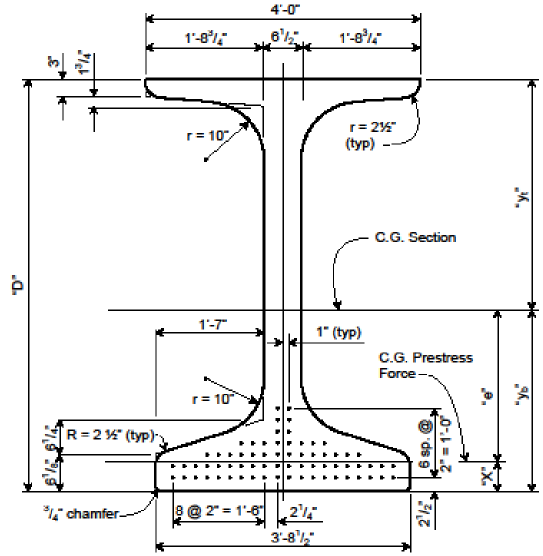
California Wide-Flange Girder

Why Is California Interested in this New Shape?



BRIDGE DESIGN AIDS 6-1 • MAY 2009 DRAFT

CALTRANS PRETENSIONED "WIDE-FLANGE" GIRDER



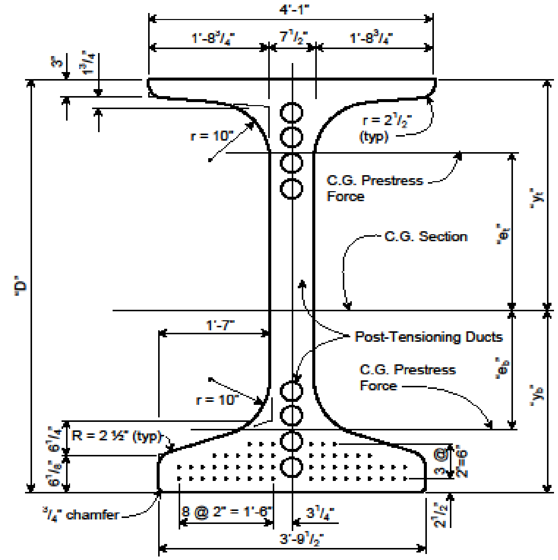
SECTION PROPERTIES

Size (ft-in)	"D" (in)	A (in^2)	I (in^4)	"y_b" (in)	"y_t" (in)	S_b (in^3)	S_t (in^3)	r (in)	w (lb/ft)
3'-0"	36	797	131 480	15.79	20.21	8 327	6 506	12.84	830
3'-6"	42	836	194 940	18.27	23.73	10 670	8 215	15.27	871
4'-0"	48	875	273 010	20.79	27.21	13 132	10 033	17.66	911
4'-6"	54	914	366 470	23.35	30.65	15 694	11 956	20.02	952
5'-0"	60	953	476 050	25.95	34.05	18 345	13 981	22.35	993
5'-6"	66	992	602 500	28.57	37.43	21 089	16 097	24.64	1033
6'-0"	72	1031	746 560	31.23	40.77	23 905	18 311	26.91	1074
7'-0"	84	1109	1 090 400	36.62	47.38	29 776	23 014	31.36	1155
8'-0"	96	1187	1 513 400	42.09	53.91	35 955	28 072	35.71	1236
9'-0"	108	1265	2 021 200	47.62	60.38	42 444	33 474	49.97	1318
10'-0"	120	1343	2 619 600	53.21	66.79	49 231	39 221	44.17	1399

6-1 STANDARD "SUPER" GIRDER 1

BRIDGE DESIGN AIDS 6-1 • MAY 2009 DRAFT

CALTRANS POST-TENSIONED "WIDE-FLANGE" GIRDER



SECTION PROPERTIES

Size (ft-in)	"D" (in)	A (in^2)	I (in^4)	"y_b" (in)	"y_t" (in)	S_b (in^3)	S_t (in^3)	r (in)	w (lb/ft)
3'-0"	36	833	135 540	15.89	20.11	8 530	6 740	12.76	868
3'-6"	42	878	201 410	18.40	23.60	10 948	8 534	15.15	915
4'-0"	48	923	282 700	20.95	27.05	13 494	10 451	17.50	961
4'-6"	54	968	380 270	23.55	30.45	16 147	12 488	19.82	1008
5'-0"	60	1013	494 980	26.19	33.81	18 900	14 640	22.10	1055
5'-6"	66	1058	627 670	28.85	37.15	21 756	16 896	24.36	1102
6'-0"	72	1103	779 190	31.54	40.46	24 705	19 258	26.58	1149
7'-0"	84	1193	1 142 100	37.00	47.00	30 866	24 299	30.94	1243
8'-0"	96	1283	1 590 200	42.53	53.47	37 390	29 740	35.21	1336
9'-0"	108	1373	2 130 200	48.12	59.88	44 269	35 575	39.39	1430
10'-0"	120	1463	2 768 700	53.76	66.24	51 501	41 798	43.50	1524

6-1 PRETENSIONED SUPER GIRDER 2

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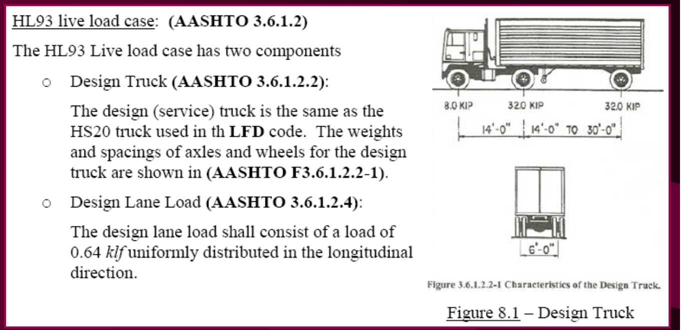
California Wide-Flange Girder

LRFD Code Requirements

- HL93 Live Load Case for Service III Design
- California P-15 Permit Vehicle for Strength II Design (versus the P-13)
  - *7 Pairs of Axles vs. 6 Pairs*
  - *Increase from 48 to 54 kips / Pair*
- Permit Truck Load Factor Increase
- Dynamic Load Allowance (IM) = 1.33
- Live Load Distribution Factors



HL93 live load case: **(AASHTO 3.6.1.2)**

The HL93 Live load case has two components

- Design Truck **(AASHTO 3.6.1.2.2)**:

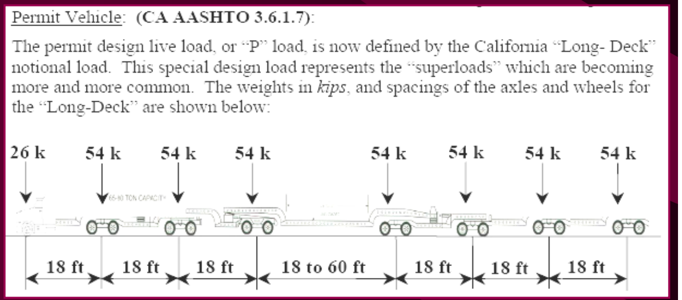
  The design (service) truck is the same as the HS20 truck used in th **LFD** code. The weights and spacings of axles and wheels for the design truck are shown in **(AASHTO F3.6.1.2.2-1)**.

- Design Lane Load **(AASHTO 3.6.1.2.4)**:

  The design lane load shall consist of a load of 0.64 *klf* uniformly distributed in the longitudinal direction.

Figure 3.6.1.2.2-1 Characteristics of the Design Truck.

Figure 8.1 – Design Truck



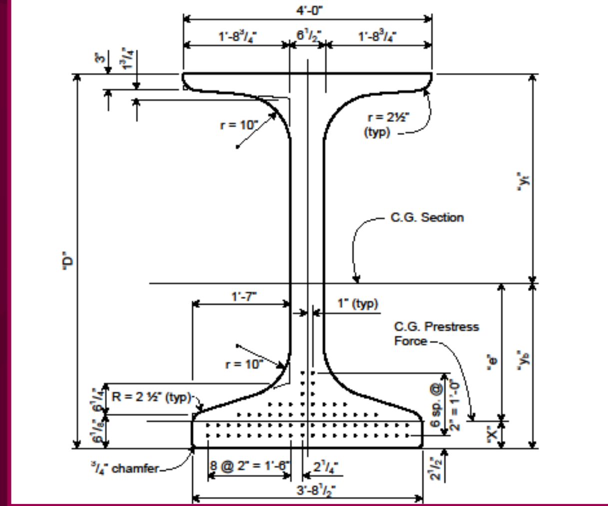
Permit Vehicle: **(CA AASHTO 3.6.1.7)**:

The permit design live load, or "P" load, is now defined by the California "Long- Deck" notional load. This special design load represents the "superloads" which are becoming more and more common. The weights in *kips*, and spacings of the axles and wheels for the "Long-Deck" are shown below:

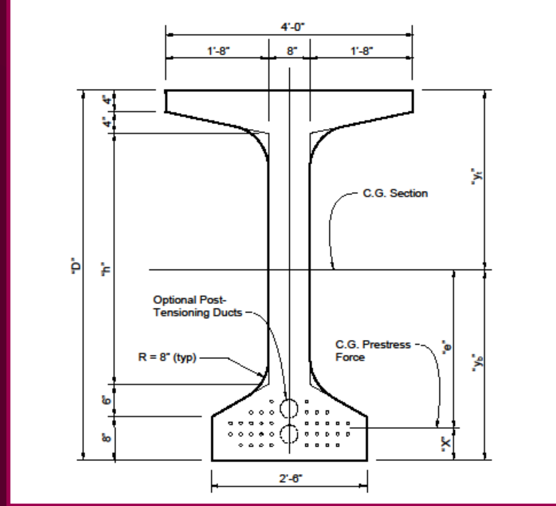
California Wide-Flange Girder

Comparison With Existing California Bulb-Tee

- Wider Bottom Flange (3'-8 ½" and 3'-9 ½")
- Greater Capacity for Pretensioned Strand (38% Increase)
- Thinner Web (6 ½" and 7 ½")
- Thinner Top Flange



66 Strands



48 Strands

California Wide-Flange Girder

Additional Benefits of the New Shape

- A Wider Bottom Flange Results in:
  - *Increased Eccentricity with Lower Strand Pattern*
  - *Enhanced Lateral Stability During Transportation*
  - *Decrease in Initial Concrete Strength, f'ci*
  - *Decrease in Final Concrete Strength, f'c, at Bent Cap*
- Thinner Top Flange Reduces Weight
- Web: 6 ½ in. Pretensioned and 7 ½ in. Post-tensioned
- LRFD Shear Requirements Satisfied With Thinner Web

Caltrans

Project Delivery Engineering Services

California Department of Transportation

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The New California Wide-Flange Girder

A Super Girder for California Bridges

Thank You!!!

Introducing: Jay Holombo, Ph.D., P.E.

September 22rd, 2009
Sacramento Convention Center
Sacramento, California

Comparative Design Example CAWF versus Cast-in-Place

Western Bridge Engineers' Seminar

September 22, 2009

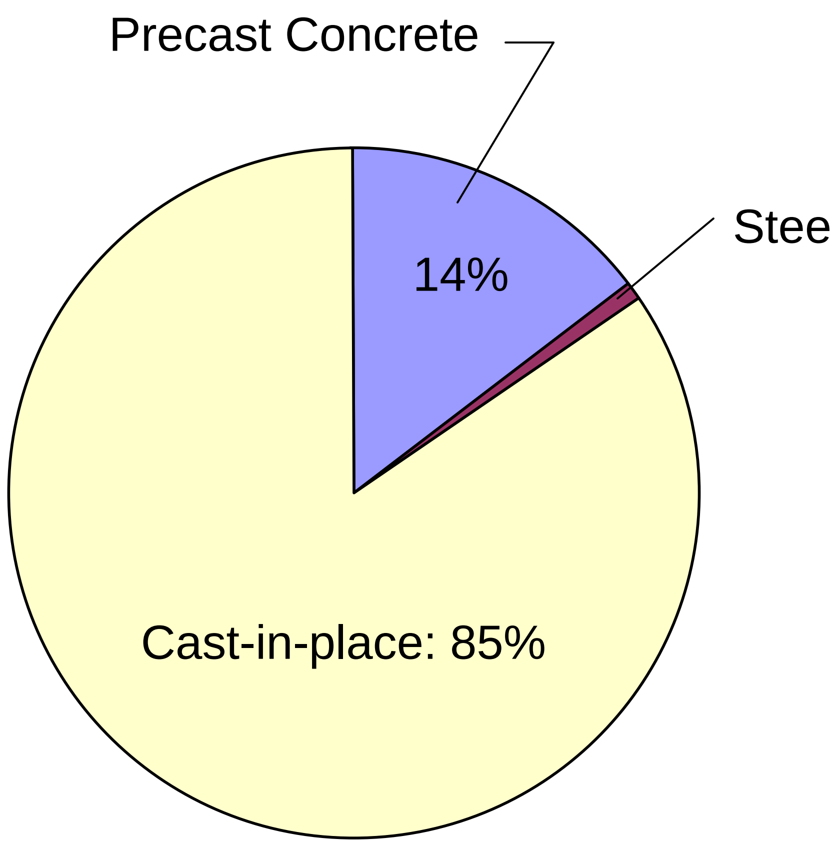
California Bridge Market

California Bridge Market

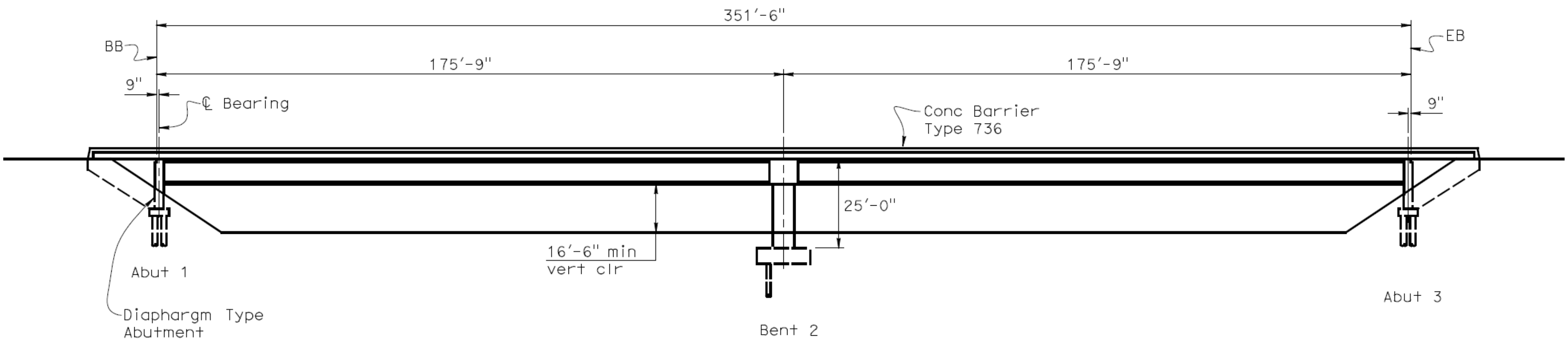
Caltrans administered (2003 – 2007)

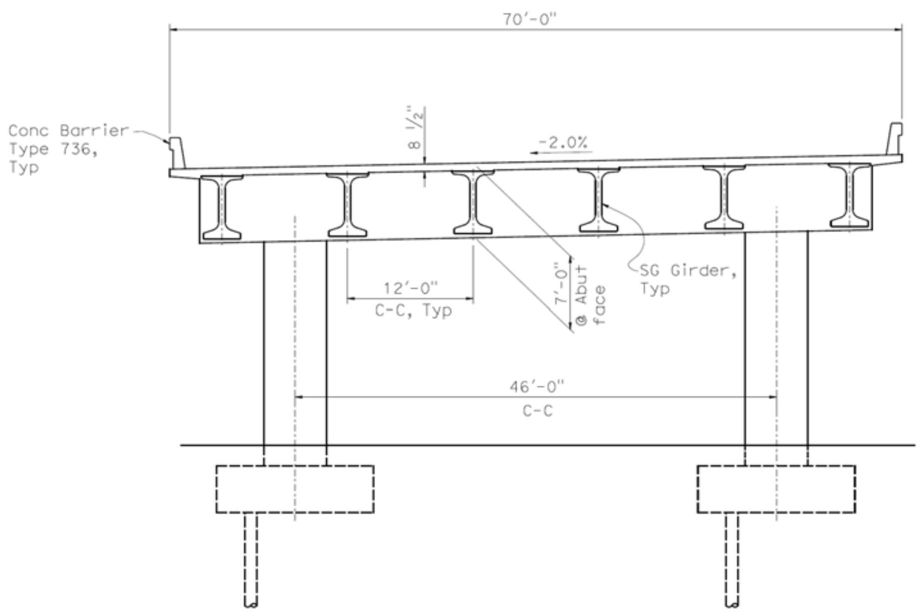
$167M / year

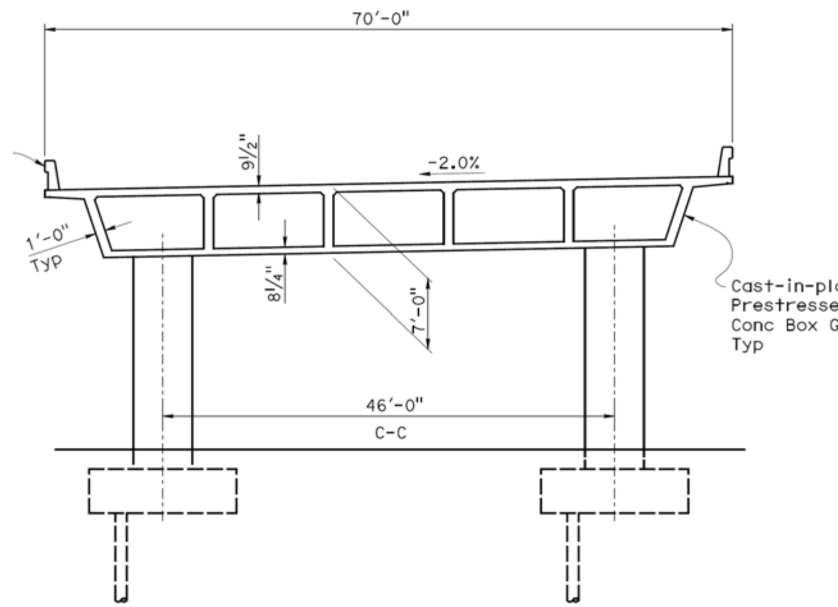
Cast-in-place:	$153 / sq. ft
Precast:	$257 / sq. ft
Steel:	$481 / sq. ft



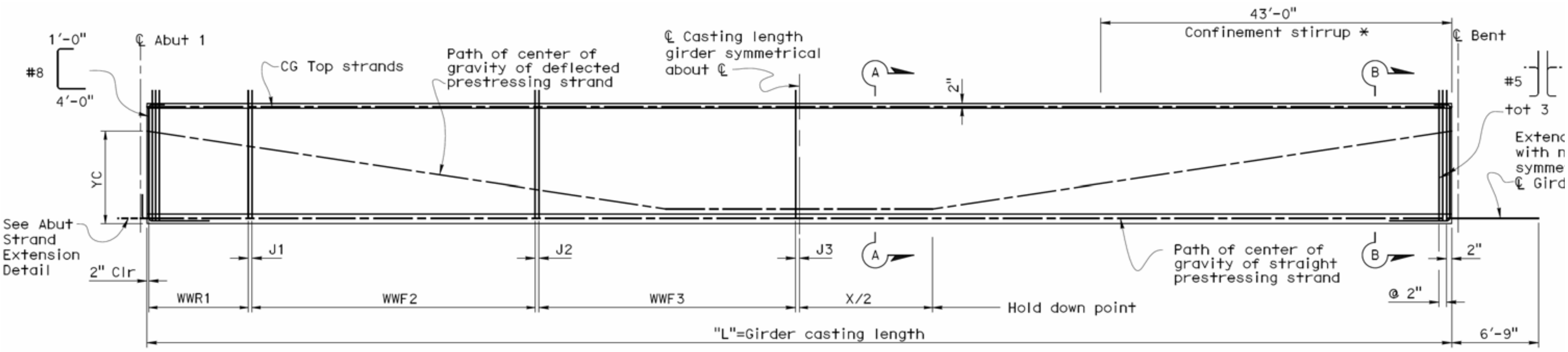
Comparative design study
CAWF vs. cast-in-place





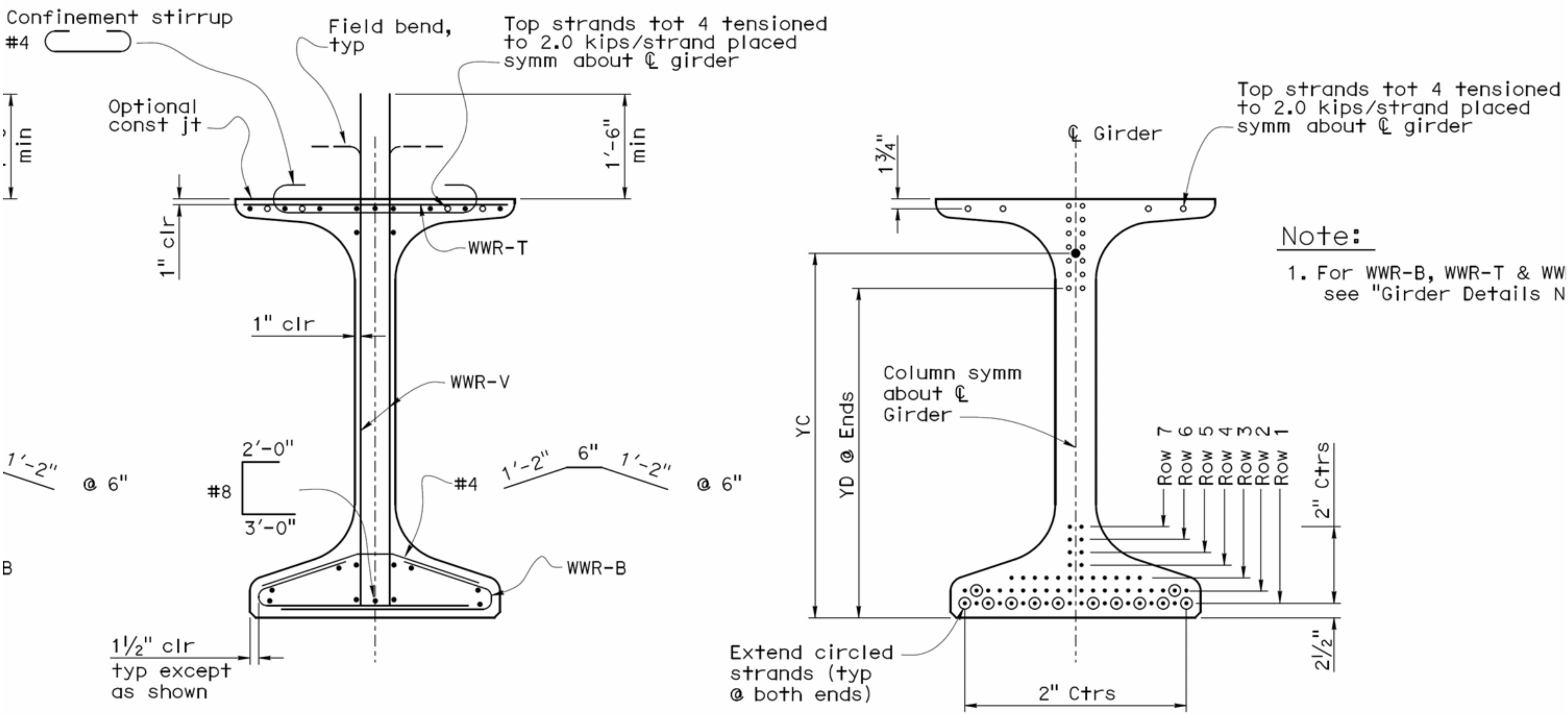


Super Girder

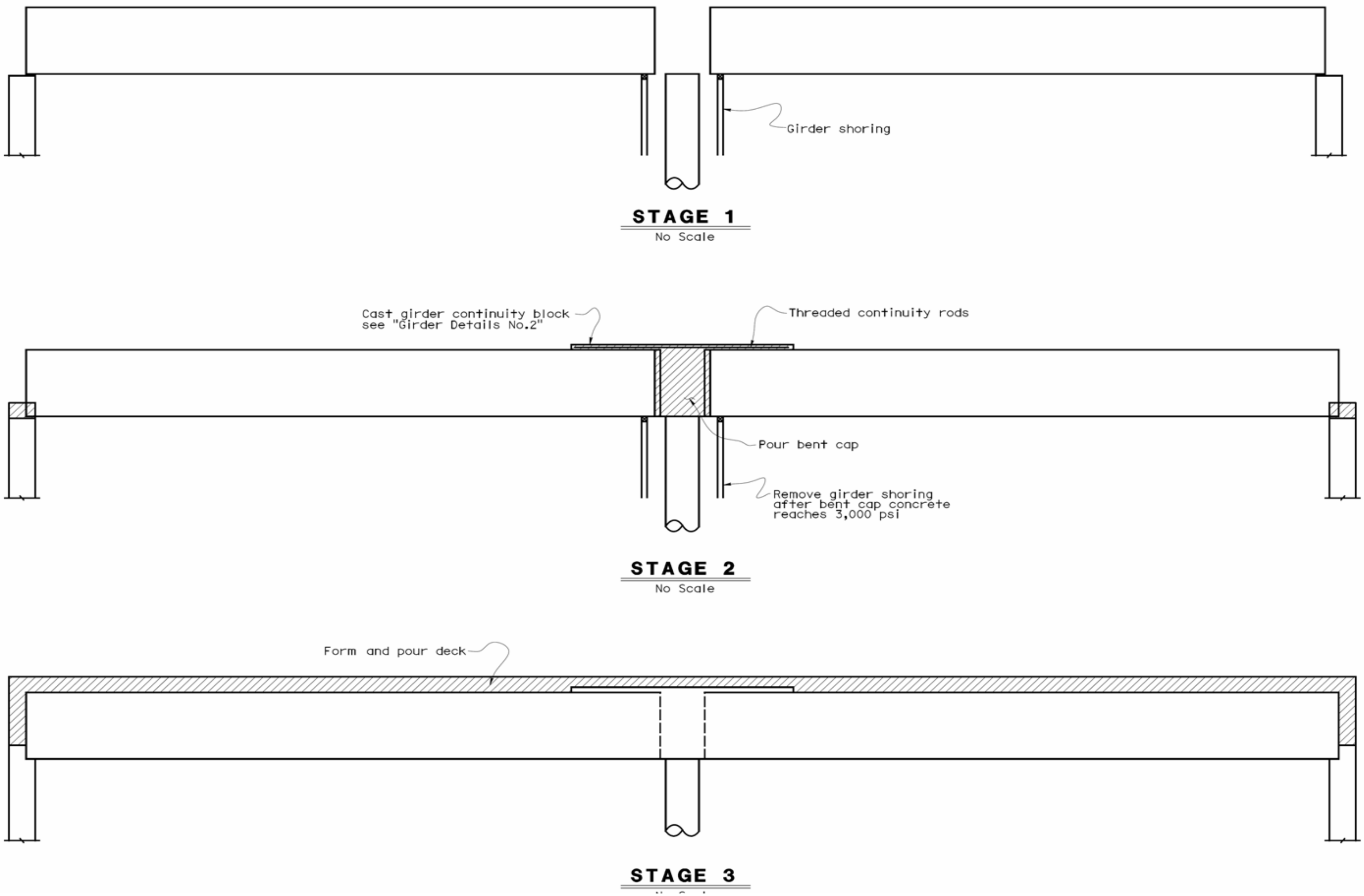


Girder Location	Length	No. of Strands Per Girder	Number of Deflected Strands	Deflected Strand Centroid at Ends YC (in.)	Strand Deflection at Ends YD (in.)	Distance between Holddown Pnts X	Concrete Strength (ksi)	
							f'ci	f'c
A to F	171'-3"	60	14	64	50	32'-0"	6	8.5

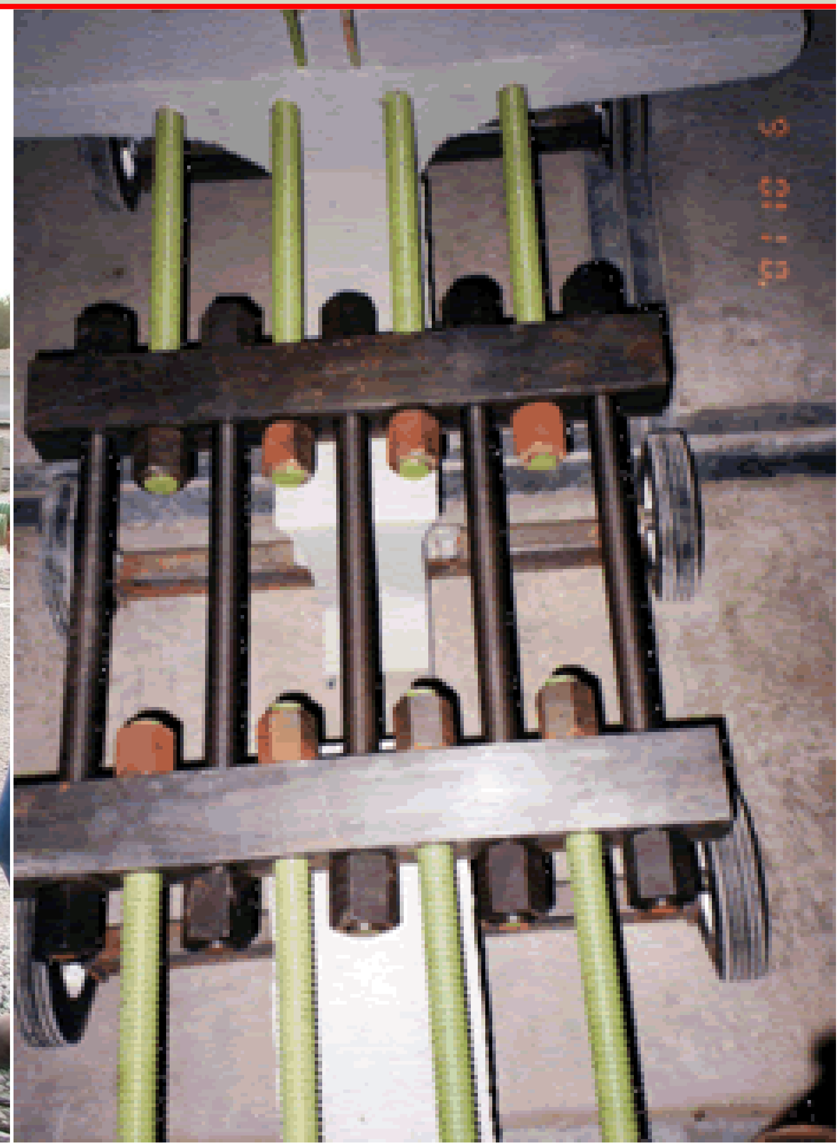
Super Girder



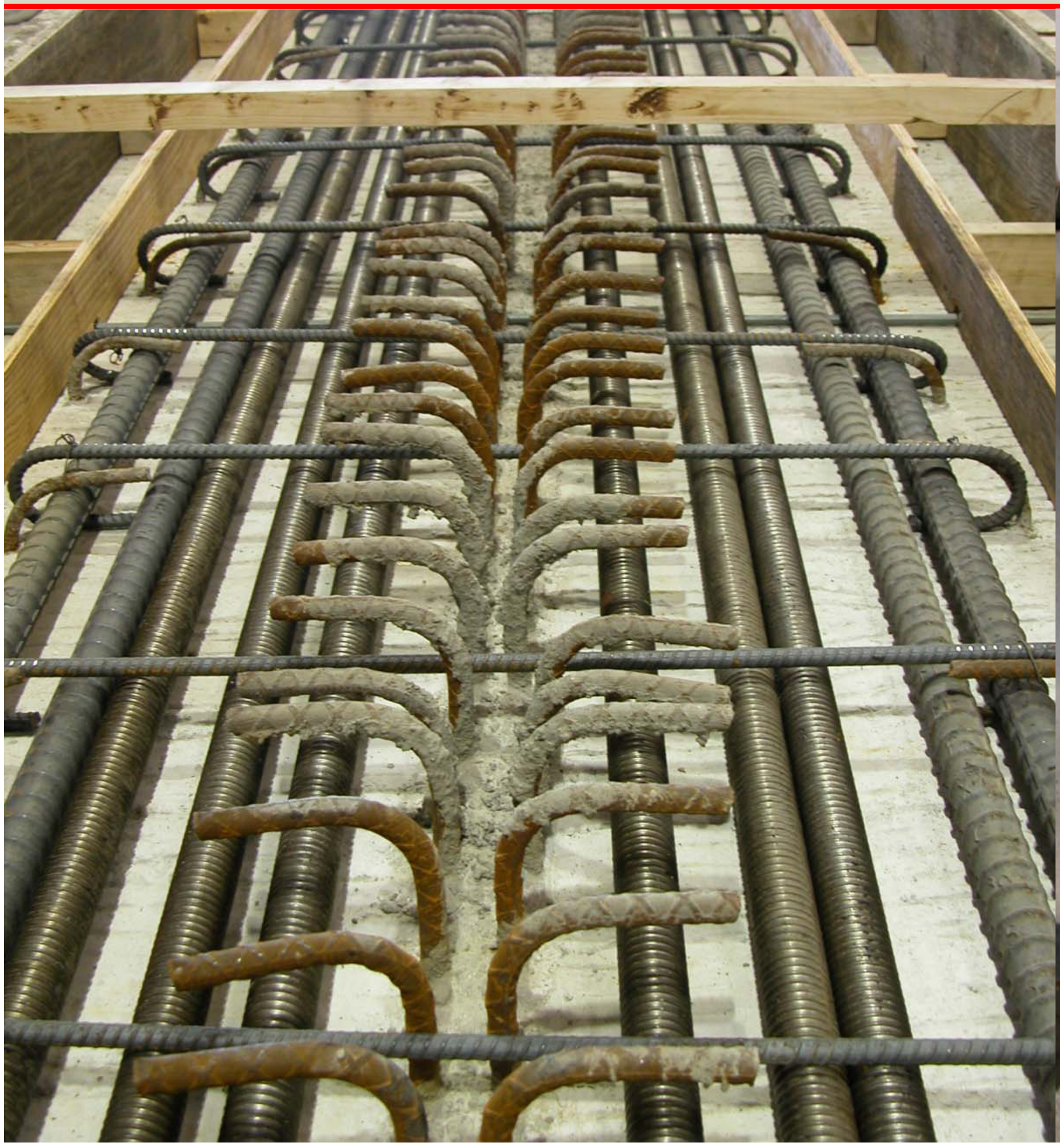
Threaded Rod Continuity



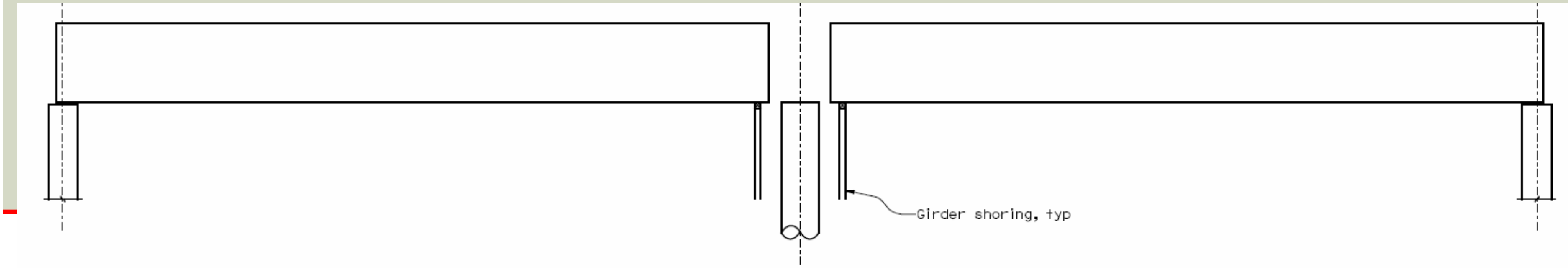
Threaded Rod Continuity – Internal



Threaded Rod Continuity - External

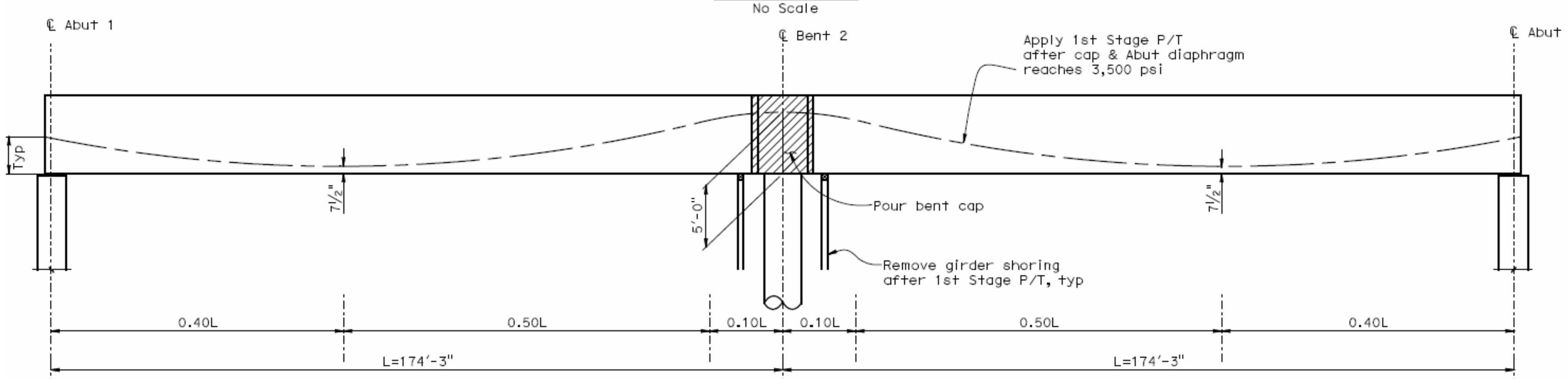


Threaded Rod Validation Testing



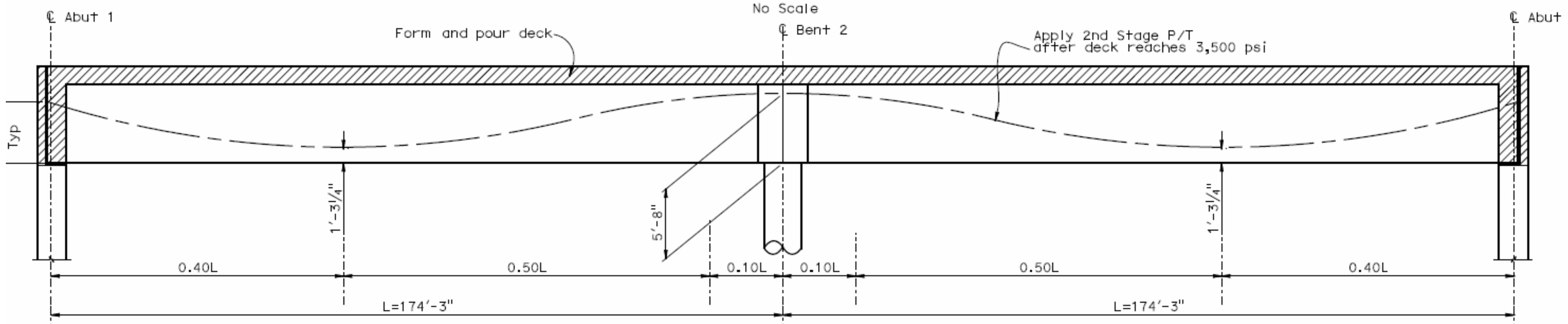
STAGE 1

No Scale



STAGE 2

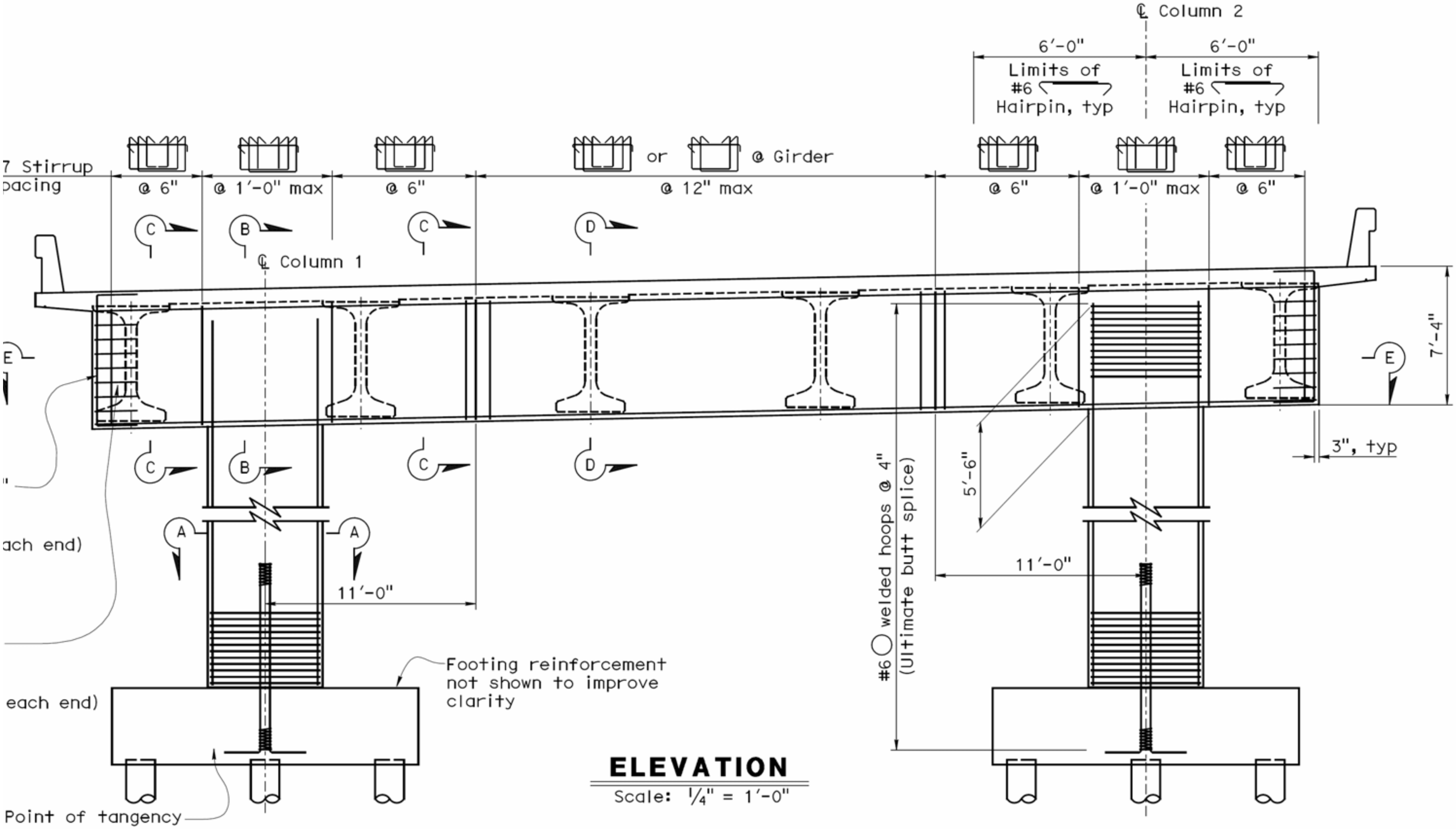
No Scale



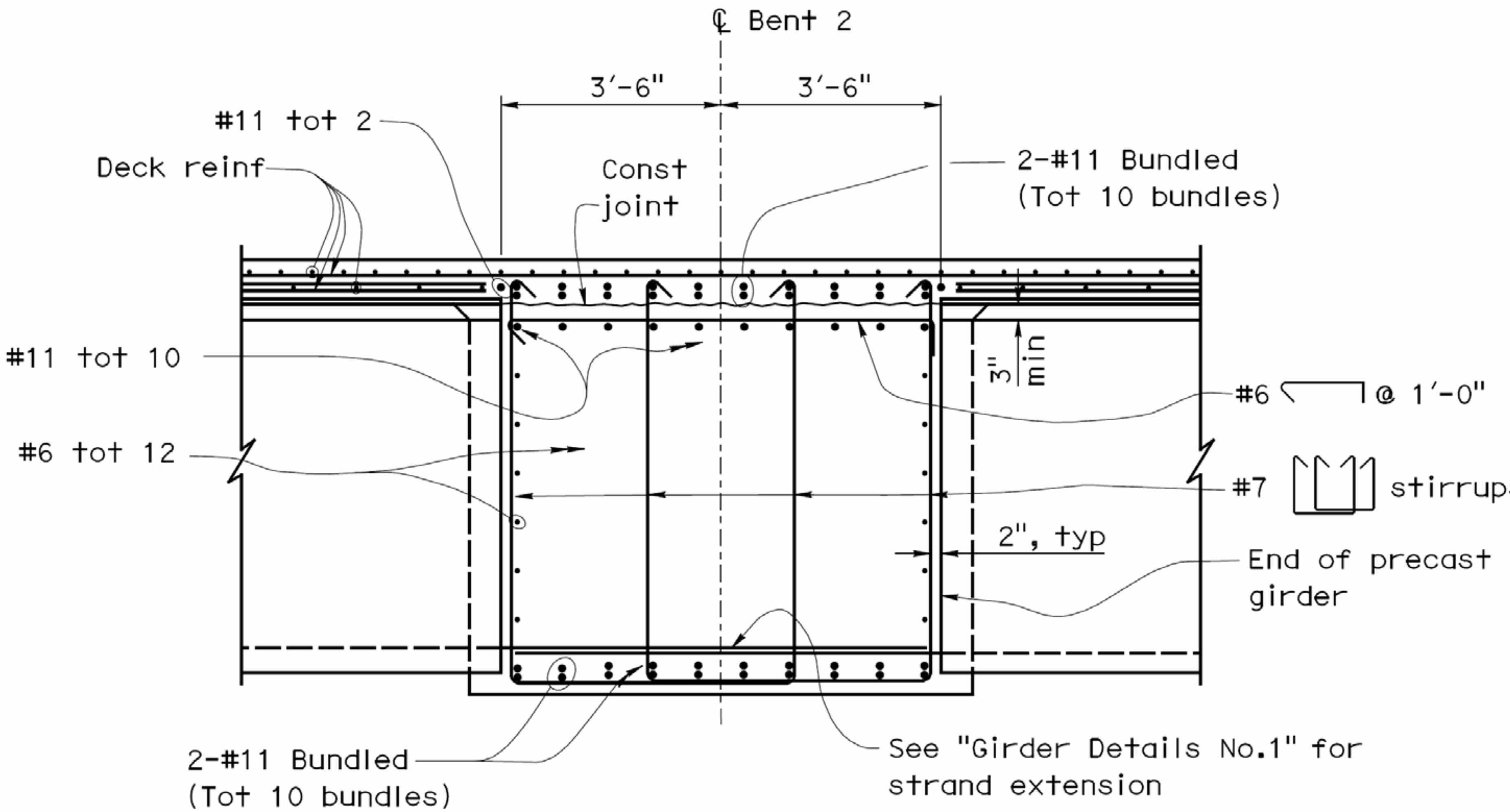
STAGE 3

No Scale

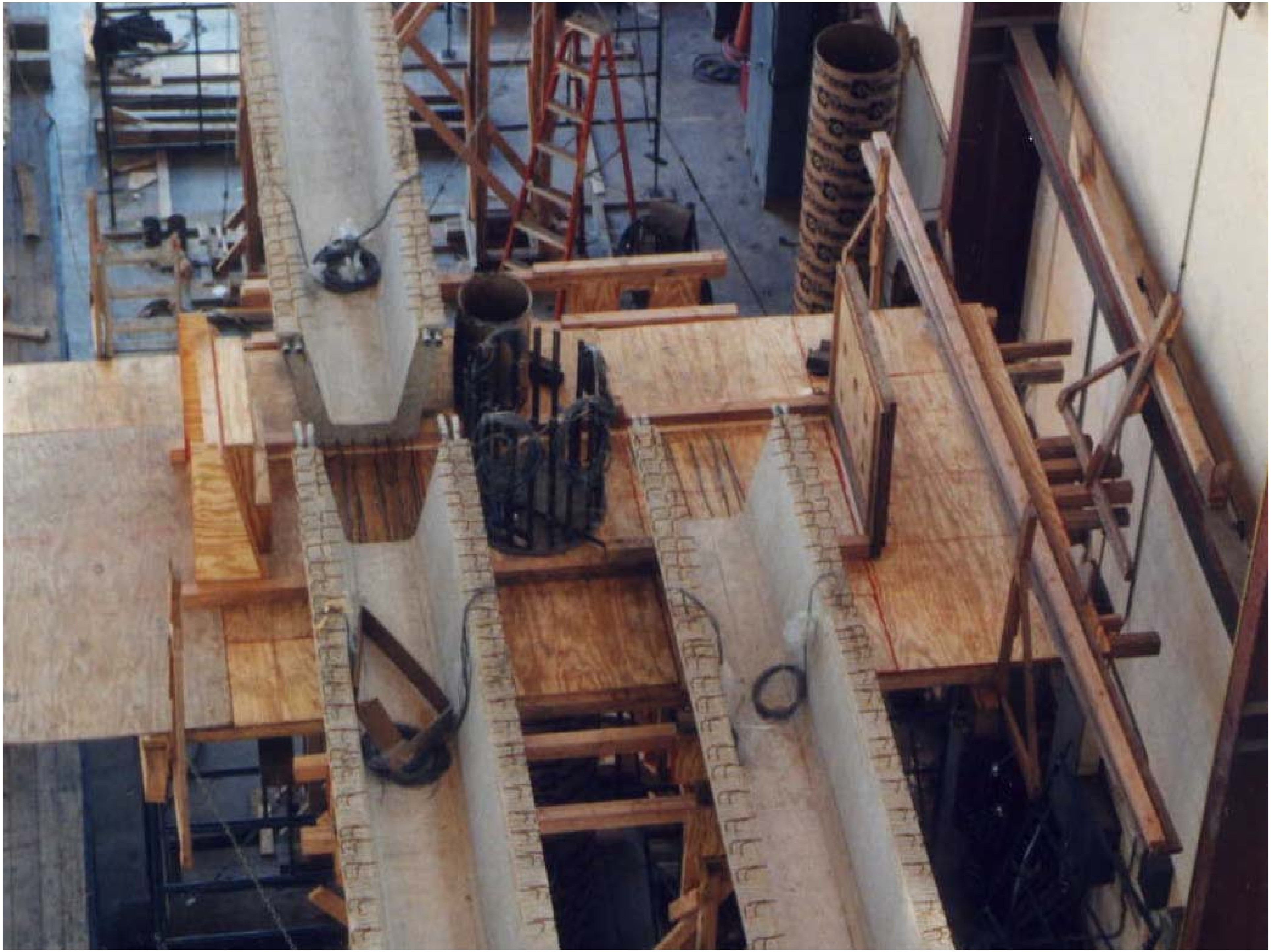
Bent Cap

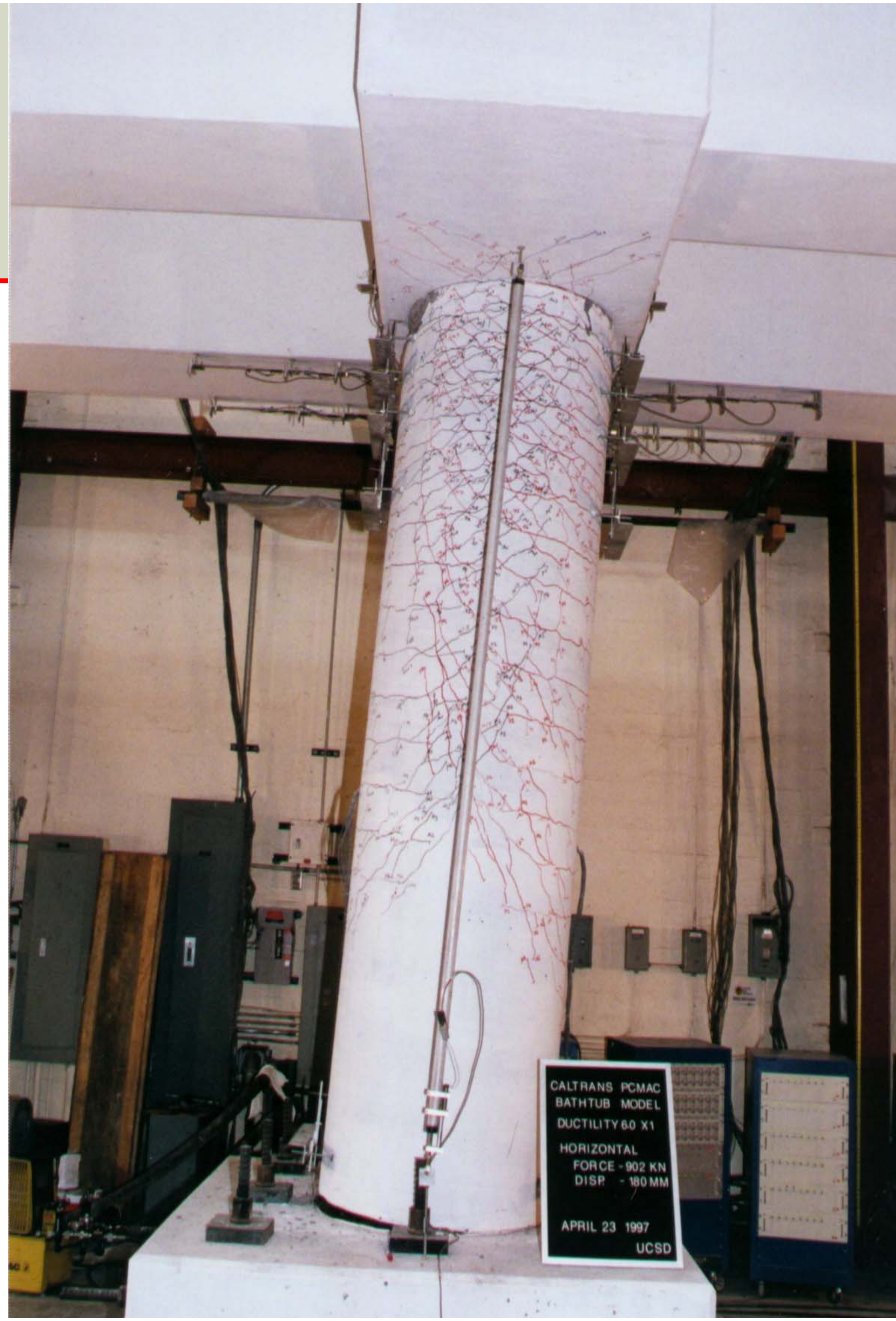

℄ Column 2
6′-0"
6′-0"
Limits of #6 Hairpin, typ
Limits of #6 Hairpin, typ
7 Stirrup
pacing
@ 6"
@ 1′-0" max
@ 6"
or
@ Girder
@ 12" max
@ 6"
@ 1′-0" max
@ 6"
℄ Column 1
7′-4"
3", typ
5′-6"
11′-0"
11′-0"
#6 welded hoops @ 4"
(Ultimate butt splice)
ach end)
each end)
Footing reinforcement not shown to improve clarity
Point of tangency
ELEVATION
Scale: 1/4" = 1′-0"

Bent Cap



℄ Bent 2
3′-6"
3′-6"
#11 tot 2
Deck reinf
Const joint
2-#11 Bundled (Tot 10 bundles)
#11 tot 10
3" min
#6 @ 1′-0"
#6 tot 12
#7 stirrups
2", typ
End of precast girder
2-#11 Bundled (Tot 10 bundles)
See "Girder Details No.1" for strand extension




CALTRANS PCMAC
BATHTUB MODEL
DUCTILITY 6.0 X1
HORIZONTAL
FORCE - 902 KN
DISP. - 180 MM
APRIL 23 1997
UCSD

PBS&J

UCSD

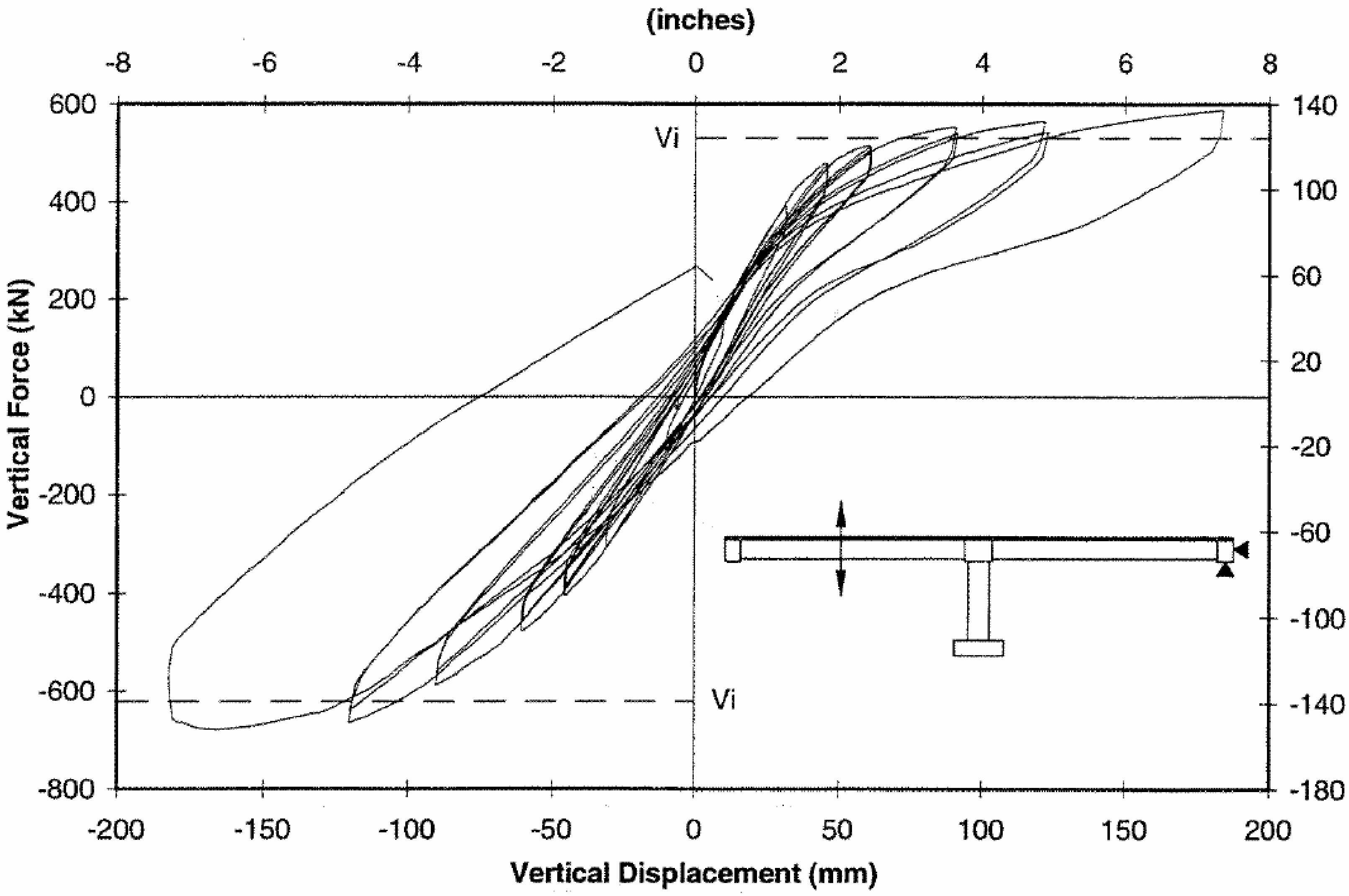
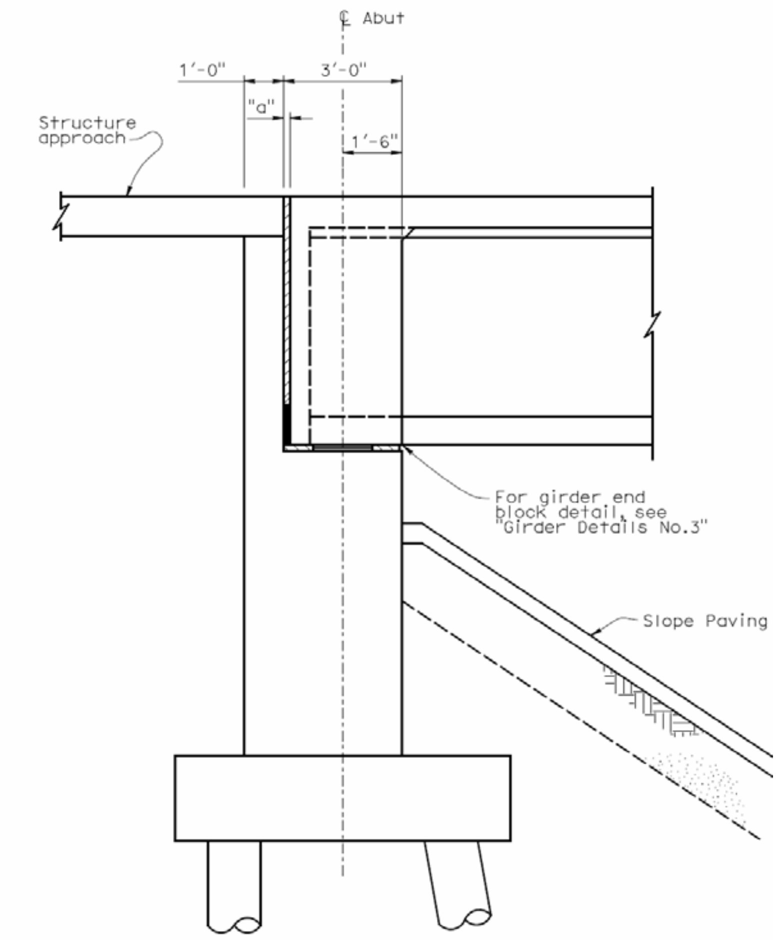
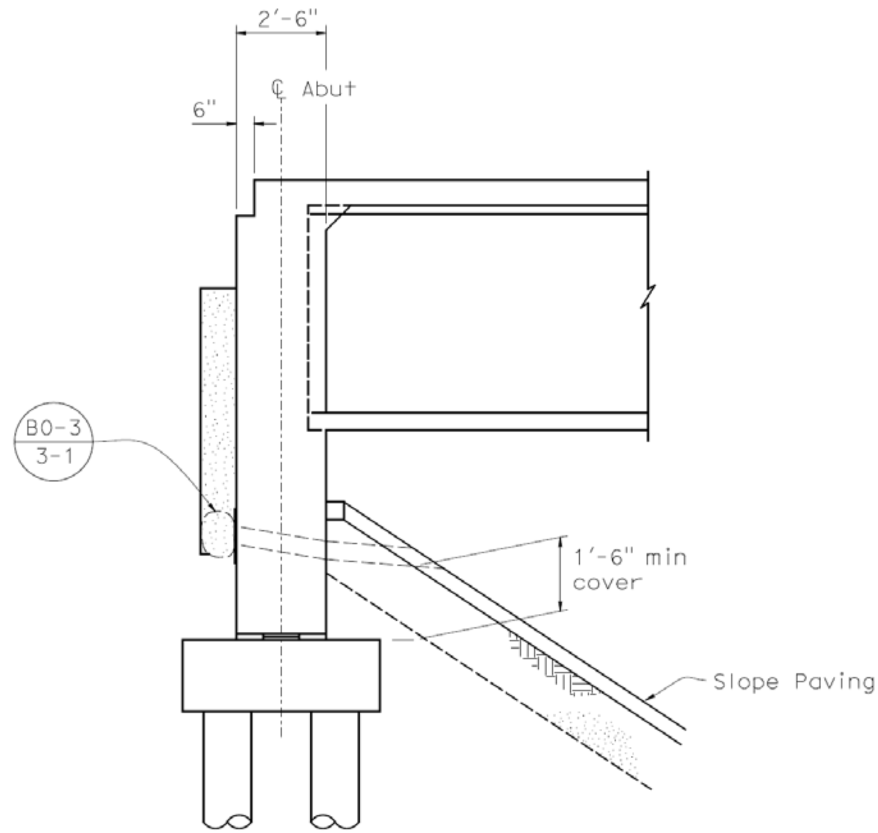


Figure 5.6 Vertical force-displacement hysteresis plot (Bathtub unit)

Abutments



CIP Box Girder Alternative



Threaded Rod Alternative

Comparison by Component

Item	Super G	CIP Box	CIP/Super G
Superstructure	$2,034,000	$2,515,000	1.24
Substructure	$770,000	$1,055,000	1.37
Other*	$398,000	$304,000	0.76
Total	$3,202,000	$3,874,000	1.21

Item	Super G	CIP Box	CIP/Super G
Superstructure	1.2 months	2.4 months	2.0
Substructure	2.2 months	2.2 months	1.0
Other*	0.4 months	0.4 months	1.0
Total	3.8 months	5.0 months	1.3

*Includes approach slab, concrete barriers and joint seal

Acknowledgements

pcmac

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TRANSPORTATION