JOSEPH P. CARRARA & SONS, INC.

LETTER OF TRANSMITTAL

2464 CASE STREET
MIDDLEBURY, VERMONT 05753

TEL (802) 388-6363
FAX (802) 388-9010

DATE: November 22, 2013	JOB NO.: 23411-013
ATTENTION: Mr. Brian Emmons	
RE: Sand Hill Bridge No. 13	
VT 125 over Middlebury River	
Middlebury, VT	
Project No. RS 0174 (8)	
Transmittal #1	Precast Concrete

TO: **T. Buck Construction**
249 Merrow Road
Auburn, Maine 04210

207-783-6223 x205

WE ARE SENDING YOU [x] Attached [ ] Under separate cover via **Email** the following items:

[x] Shop Drawings [ ] Prints [ ] Plans [ ] Samples [ ] Specifications

[ ] Copy of Letter [ ] Change Order [ ] Other:

COPIES	DATE	NO.	DESCRIPTION
1	11/22/13	-	J. P. Carrara & Sons' Precast Framing and Individual Piece Detail Drawings for Arch Panels
			"For Approval" Drawings: F5, AR1, AR2, AR3, AR4, & AR5
			"For Coordination" Drawings: F6, F7, & F8
1	11/22/13	-	Precast Arch Panel Design Calculations prepared by Eriksson Technologies
1	11/22/13	-	J. P. Carrara & Sons' Submittal Notes

THESE ARE TRANSMITTED as checked below:

[x] For approval [ ] Approved as submitted [ ] Resubmit ____ copies for approval

[ ] For your use [ ] Approved as noted [ ] Submit ____ copies for distribution

[ ] As requested [ ] Returned for corrections [ ] Return ____ corrected prints

[ ] For review and comment [ ] ____

[ ] FOR BIDS DUE ____ 20 ____ [ ] PRINTS RETURNED AFTER LOAN TO US

REMARKS **Brian,**

Attached please find our framing drawings, individual piece details and design calculations for the precast arch panels which are submitted for approval. As previously discussed, drawing submittals are phased and subsequent submittals will be forthcoming. Also attached are submittal notes to highlight several layout and detailing considerations for the precast arch panels.

Please contact us at 802-388-6363 with any questions.

COPY TO:

SIGNED: Michael Weigand

If enclosures are not as noted, please notify us at once.

J.P. Carrara & Sons, Inc.
2464 CASE STREET, MIDDLEBURY, VT 05753
T (802) 388-6363 F (802) 388-9010

Submittal Notes

To:	T. Buck Construction	**From:**	Mike Weigand
Fax:		**Pages:**	1
Phone:		**Date:**	11/22/13
Re:	Sand Hill Bridge, Middlebury, VT	**Attn:**	Brian Emmons

☐ **Urgent** X **For Review** X **Please Comment** ☐ **Please Reply** X **For Your Use**

Precast Arch Panel Submittal

General Notes

1. The precast arch panel framing drawings, individual piece details and design calculations are submitted "for approval" including drawings 'F5' and 'AR1' through 'AR5' all of which are stamped. This submittal is a phased submittal for the above project. JPC respectfully requests that the submittal is reviewed and approved to allow for the commencement of fabrication of (12) precast arch panels.

2. East and west elevations of 5" precast architectural panels on JPC drawings 'F6' and 'F7' and a detail section on JPC drawing 'F8' are submitted 'for coordination' only to show the interface of the arch panels with the 5" architectural panels and other structural elements, although these other precast panels are not submitted for approval at this time. Drawings 'F6', 'F7', and 'F8' are not stamped.

3. Please note the layout and geometry of the cast-in-place arch panel footings on JPC drawing 'F5'.

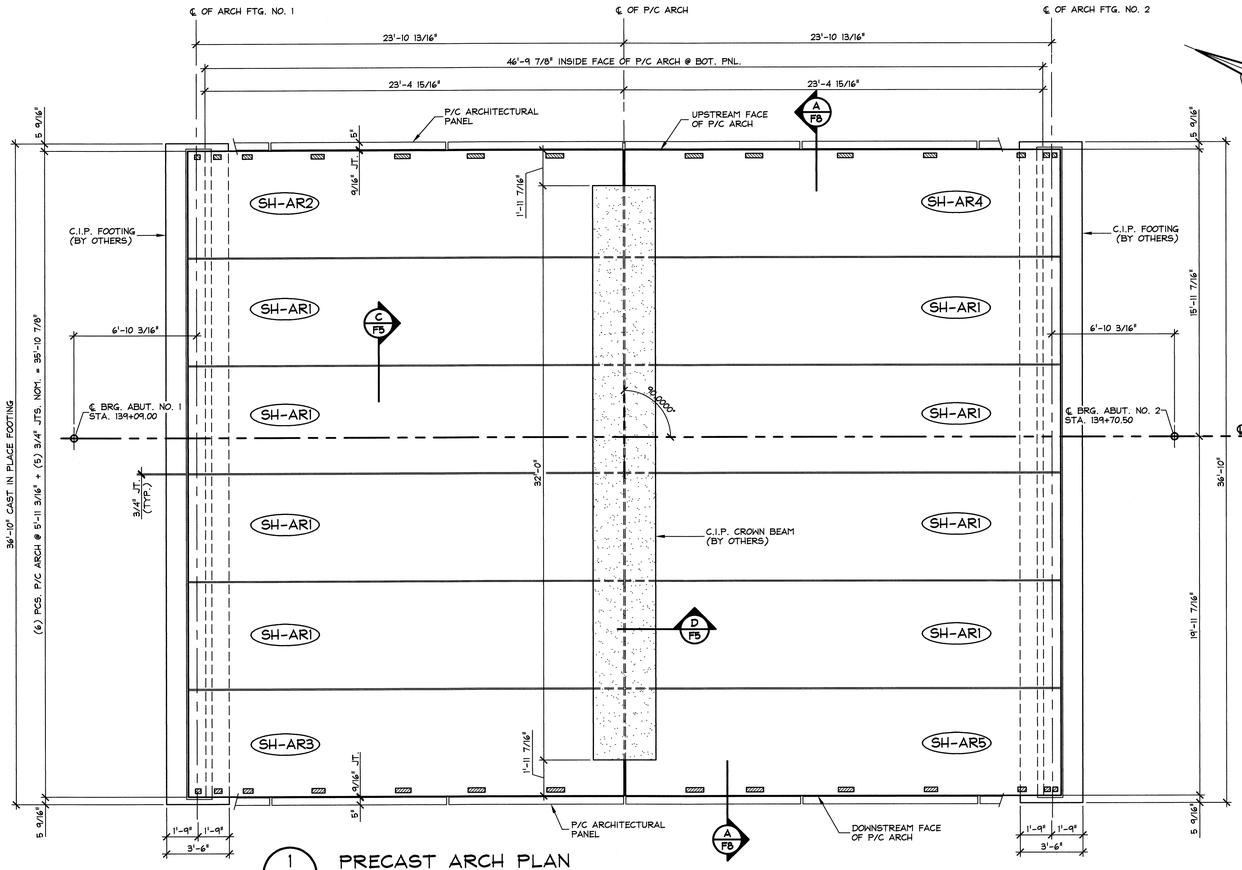
4. The layout of precast arch panels is based on the 36'-10" dimension between the outside faces of the 5" precast architectural wall panels. The detailing allows for a 9/16" joint between the precast arch panels and the 5" precast architectural wall panels and it allows for ¾" joints between the individual precast arch panels.

5. An erection sequence for the arch panels is included on the last page of the design calculations.

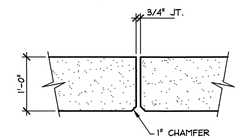
6. For the installation of inspection ladder rungs, JPC recommends the post-cast installation of the following manhole step system from M. A. Industries: http://www.manholestep.com/index.php?option=com_virtuemart&Itemid=87

7. Reinforcing steel is Level 1 and is black steel. Reinforcing steel clear cover is detailed as 1 ½".

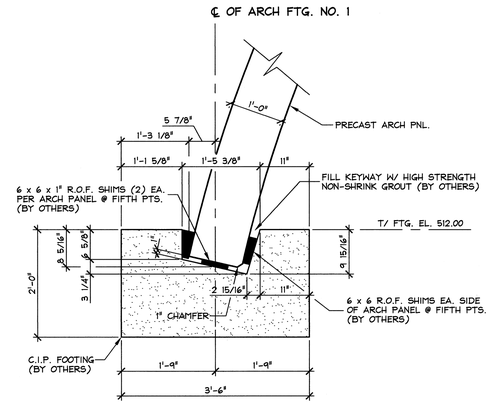
Please contact us at 802-388-6363 with any questions.



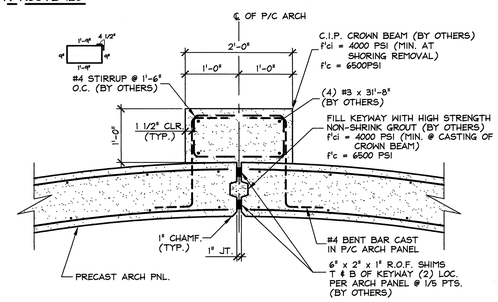
1 F5 PRECAST ARCH PLAN
1/4" = 1'-0"



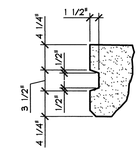
C F5 P/C ARCH PARALLEL JT.
3/4" = 1'-0"



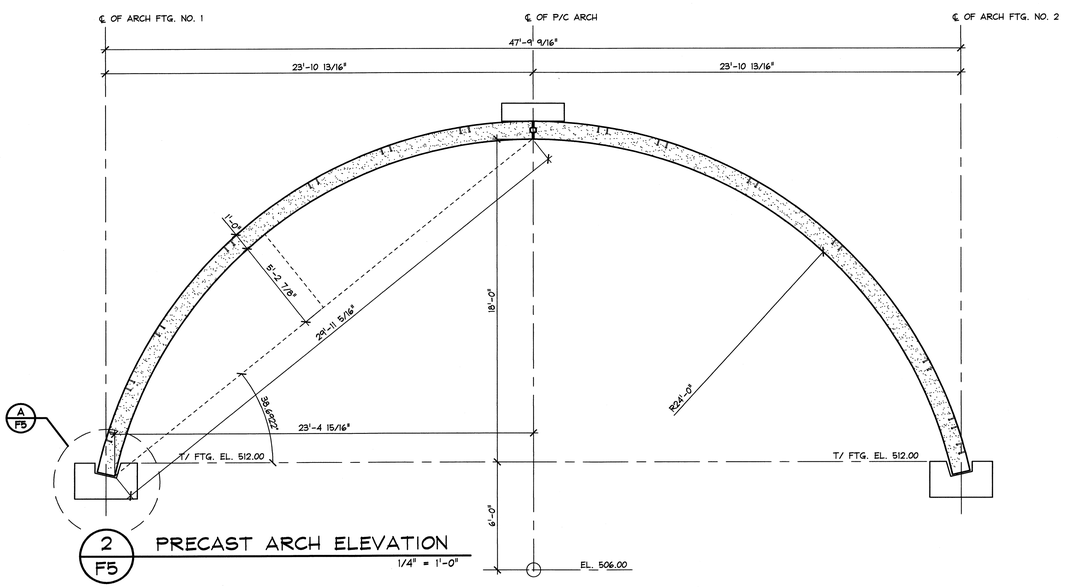
A F5 P/C ARCH FOOTING DETAIL
3/4" = 1'-0"



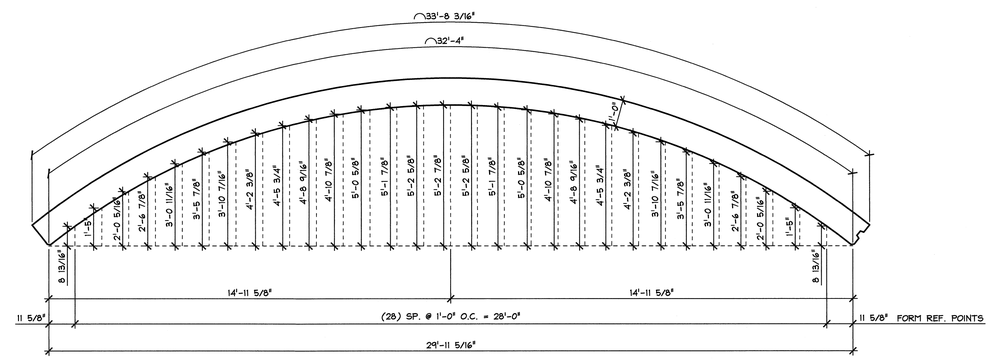
D F5 C.I.P. CROWN BEAM DETAIL
3/4" = 1'-0"



KEYWAY DETAIL
1" = 1'-0"



2 F5 PRECAST ARCH ELEVATION
1/4" = 1'-0"



B F5 ARCH PANEL ELEV. IN FORM
3/8" = 1'-0"

SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

STATE OF VERMONT
ROY L. ERIKSSON
No. 75908
Structural
LICENSED
PROFESSIONAL ENGINEER

11.21.13

APPROVAL STAMP:

J.P. CARRARA & SONS INC.
Precast & Prestress Manufacturer
2464 CASE STR., MIDDLEBURY, VERMONT 05753 Phone:(802)388-6361 Fax:(802)388-9010

T. BUCK CONSTRUCTION
CONTRACTOR
AUBURN, MAINE

STATE OF VERMONT AGENCY OF TRANSPORTATION
COUNTY OF ADDISON

DATE: OCT. 9, 2013
SCALE: NOTED

TOWN OF MIDDLEBURY
ROUTE NO. VT 125, EAST MIDDLEBURY GORGE
BRIDGE NO.: PROJECT NO.: RS 0174(8)

CHKD: DFTM: T.D.
JOB NO:

P/C ARCH LAYOUT & DETAILS

DWG. NO: F5

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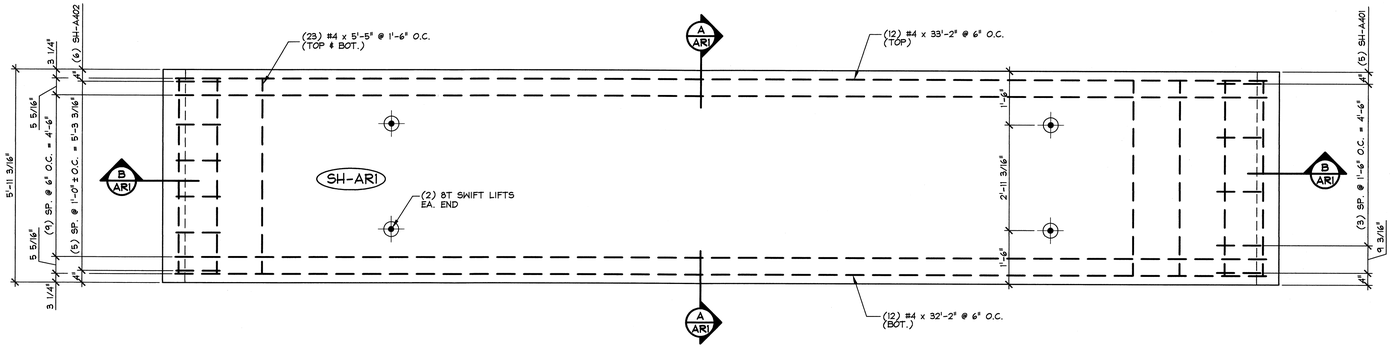
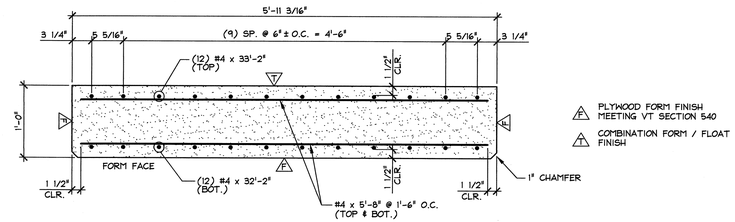
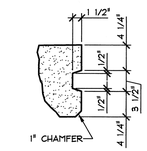


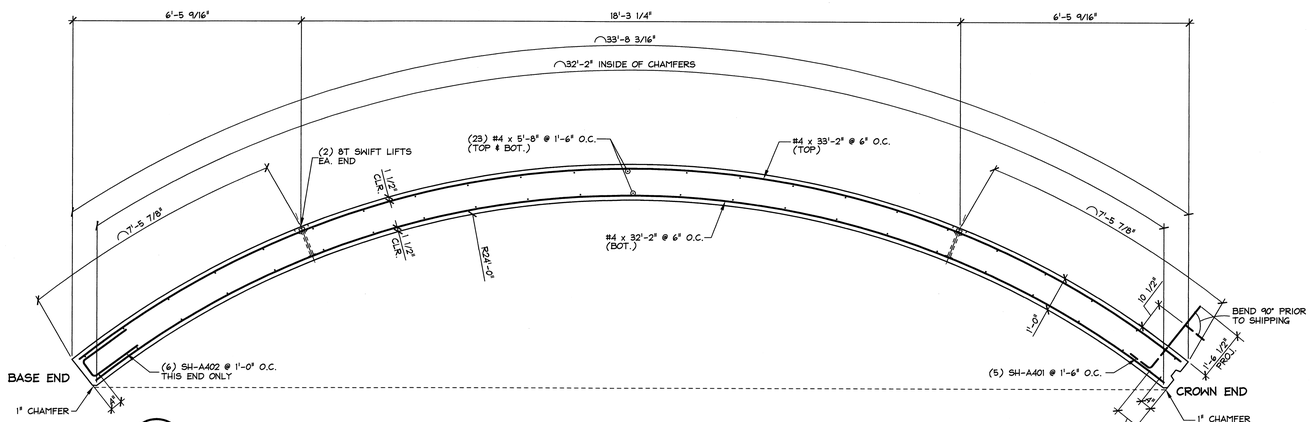
1 AR1 ARCH PANEL PLAN IN FORM W/ REINF.
1/2" = 1'-0"



A AR1 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



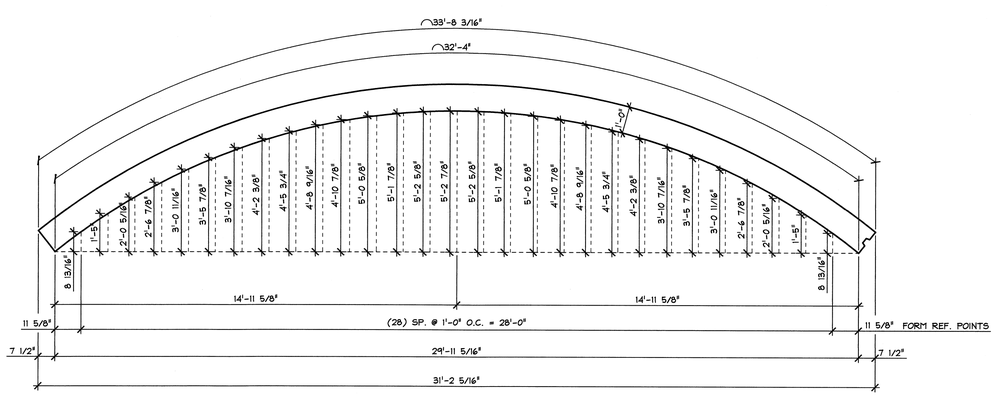
KEYWAY DETAIL
1" = 1'-0"



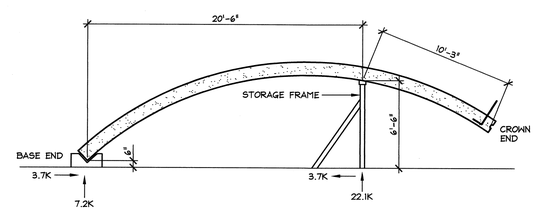
B AR1 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"

HANDLING NOTES:

1. ARCH PANEL SHALL BE HANDLED USING (4) 8T x 10" SL ANCHORS AT FIFTH POINTS.
2. ARCH PANEL SHALL BE STRIPPED USING (4) 8T x 10" SL ANCHORS.
3. FOR YARD STORAGE, ARCH PANEL SHALL BE LOWERED USING (4) 8T x 10" SL ANCHORS UNTIL PANEL CONTACTS THE STORAGE FRAME, PLACED 10'-3" FROM THE PANEL END AS SHOWN. THE BASE OF THE PANEL SHALL THEN BE LOWERED TO THE HARDWOOD SUPPORT.
4. THE PANEL SHALL BE HOISTED FROM THE STORAGE POSITION IN THE REVERSE SEQUENCE SPECIFIED ABOVE.
5. THE ARCH PANEL SHALL BE SHIPPED WITH A SUPPORT CONFIGURATION MATCHING THE "YARD STORAGE DETAIL" AND SHALL BE INSTALLED FOLLOWING THE ABOVE PROCEDURE, USING (4) 8T x 10" SL ANCHORS.



ARCH PANEL ELEV. IN FORM
3/8" = 1'-0"



YARD STORAGE DETAIL
3/16" = 1'-0"

SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

4000 PSI @ RELEASE
6500 PSI @ 28 DAYS

MIX DESIGN: 445M NO DCI

MARK: SH-AR1	QTY.: 8	WT.: 14.93 T	VOL.: 7.37 cy

MATERIAL LIST / ARCH PANEL

ITEM	MARK	DESCRIPTION	QTY.
1		#4 x 33'-2" BLACK	12
2		#4 x 32'-2" BLACK	12
3		#4 x 5'-8" BLACK	46
4			
5	SH-A401	#4 BENT BAR BLACK	5
6	SH-A402	#4 BENT BAR BLACK	6
7			
8			
9			
10		DAYTON 8T x 10" SWIFT LIFT ANCHORS (WITH RECESS PLUG)	4
11			
12			
13			
14			
15			

STATE OF VERMONT
ROY L. ERIKSSON
No. 75908
Structural
LICENSED PROFESSIONAL ENGINEER

11.21.13

APPROVAL STAMP:

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T. BUCK CONSTRUCTION
CONTRACTOR
AUBURN, MAINE

STATE OF VERMONT AGENCY OF TRANSPORTATION
COUNTY OF ADDISON

DATE: OCT. 9, 2013
SCALE: NOTED

TOWN OF MIDDLEBURY
ROUTE NO. VT 125, EAST MIDDLEBURY GORGE
BRIDGE NO.: PROJECT NO.: RS 0174(8)

CHKD: DFTM: T.D.
JOB NO:

PRECAST ARCH PANEL DETAILS

DWG. NO: AR1

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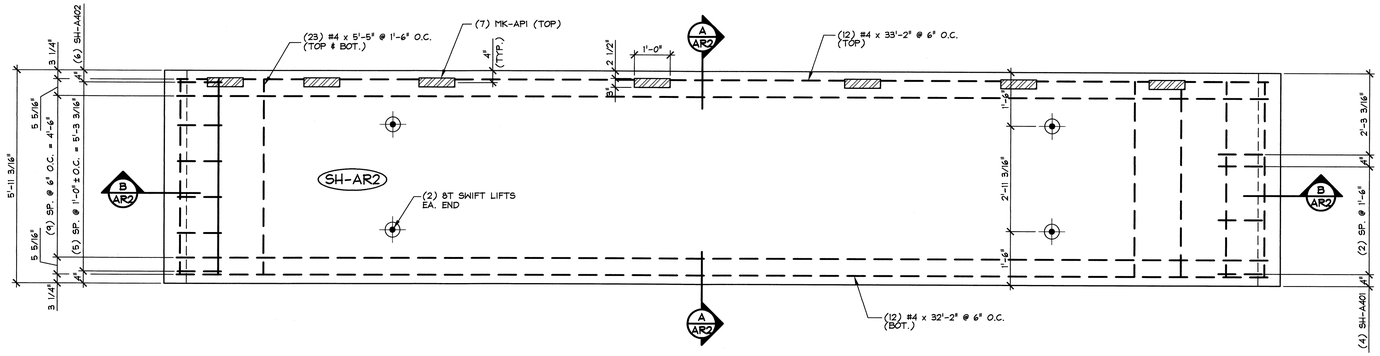
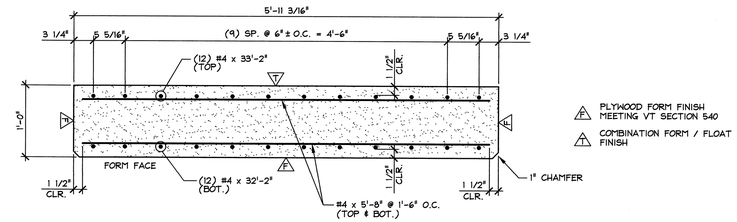
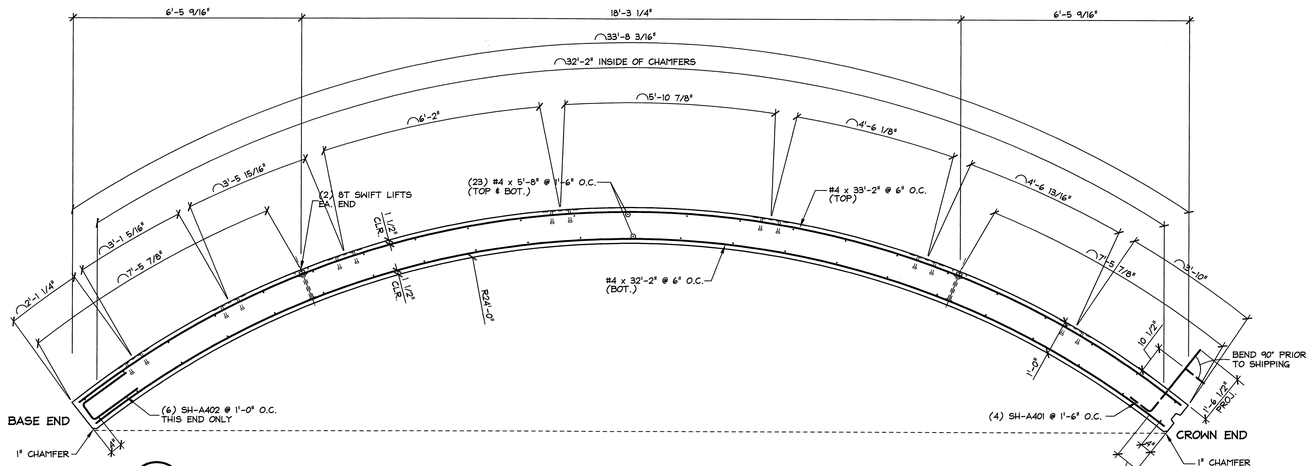


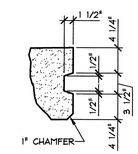
1 AR2 ARCH PANEL PLAN IN FORM W/ REINF.
1/2" = 1'-0"



A AR2 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



B AR2 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



KEYWAY DETAIL
1" = 1'-0"

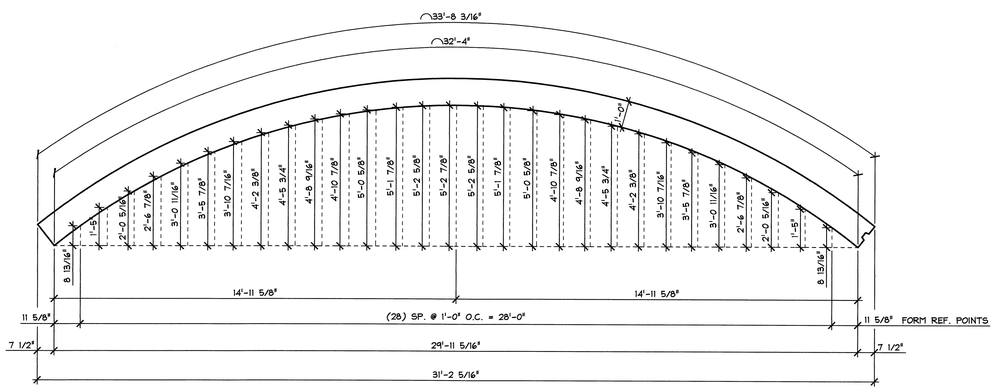
HANDLING NOTES:

1. ARCH PANEL SHALL BE HANDLED USING (4) 8T x 10" SL ANCHORS AT FIFTH POINTS.
2. ARCH PANEL SHALL BE STRIPPED USING (4) 8T x 10" SL ANCHORS.
3. FOR YARD STORAGE, ARCH PANEL SHALL BE LOWERED USING (4) 8T x 10" SL ANCHORS UNTIL PANEL CONTACTS THE STORAGE FRAME, PLACED 10'-3" FROM THE PANEL END AS SHOWN. THE BASE OF THE PANEL SHALL THEN BE LOWERED TO THE HARDWOOD SUPPORT.
4. THE PANEL SHALL BE HOISTED FROM THE STORAGE POSITION IN THE REVERSE SEQUENCE SPECIFIED ABOVE.
5. THE ARCH PANEL SHALL BE SHIPPED WITH A SUPPORT CONFIGURATION MATCHING THE "YARD STORAGE DETAIL" AND SHALL BE INSTALLED FOLLOWING THE ABOVE PROCEDURE, USING (4) 8T x 10" SL ANCHORS.

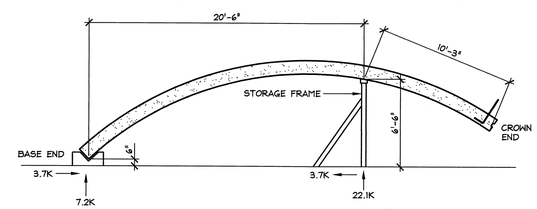
SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

4000 PSI @ RELEASE
6500 PSI @ 28 DAYS

MIX DESIGN: 445M NO DCI



ARCH PANEL ELEV. IN FORM
3/8" = 1'-0"



YARD STORAGE DETAIL
3/16" = 1'-0"

MARK: SH-AR2	QTY.: 1	WT.: 14.93 T	VOL.: 7.37 cy

MATERIAL LIST / ARCH PANEL

ITEM	MARK	DESCRIPTION	QTY.
1		#4 x 33'-2" BLACK	12
2		#4 x 32'-2" BLACK	12
3		#4 x 5'-8" BLACK	46
4			
5	SH-A401	#4 BENT BAR BLACK	4
6	SH-A402	#4 BENT BAR BLACK	6
7			
8	MK-AP1	PL 3/8" x 3" x 1'-0" W/ (2) 5/8"Φ x 3" HS (GALV.)	7
9			
10		DAYTON 8T x 10" SWIFT LIFT ANCHORS (WITH RECESS PLUG)	4
11			
12			
13			
14			
15			

STATE OF VERMONT
ROY L. ERIKSSON
No. 75908
Structural
LICENSED PROFESSIONAL ENGINEER

11.21.13

APPROVAL STAMP:

J.P. CARRARA & SONS INC.
Precast & Prestress Manufacturer
2464 CASE STR., MIDDLEBURY, VERMONT 05753 Phone:(802)388-6361 Fax:(802)388-9010

T. BUCK CONSTRUCTION
CONTRACTOR
AUBURN, MAINE

STATE OF VERMONT AGENCY OF TRANSPORTATION
COUNTY OF ADDISON

TOWN OF MIDDLEBURY
ROUTE NO. VT 125, EAST MIDDLEBURY GORGE
BRIDGE NO.: PROJECT NO.: RS 0174(8)

PRECAST ARCH PANEL DETAILS

DATE: OCT. 9, 2013
SCALE: NOTED
CHKD: DFTM: T.D.
JOB NO:
DWG. NO: AR2

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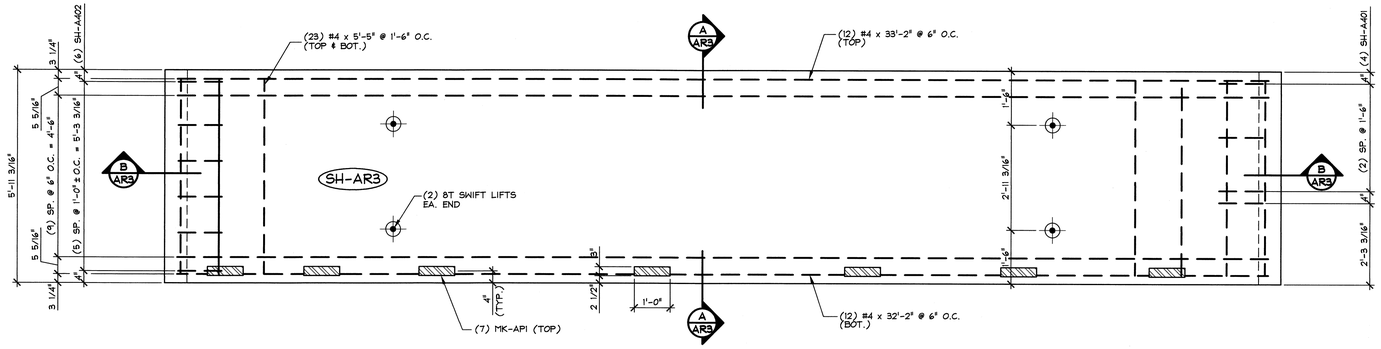
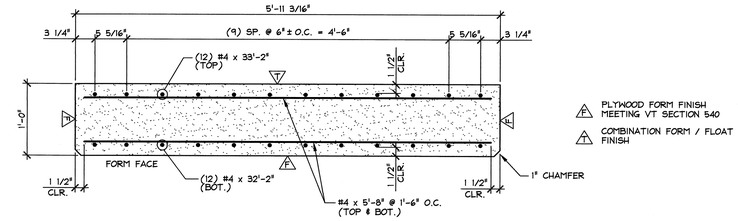
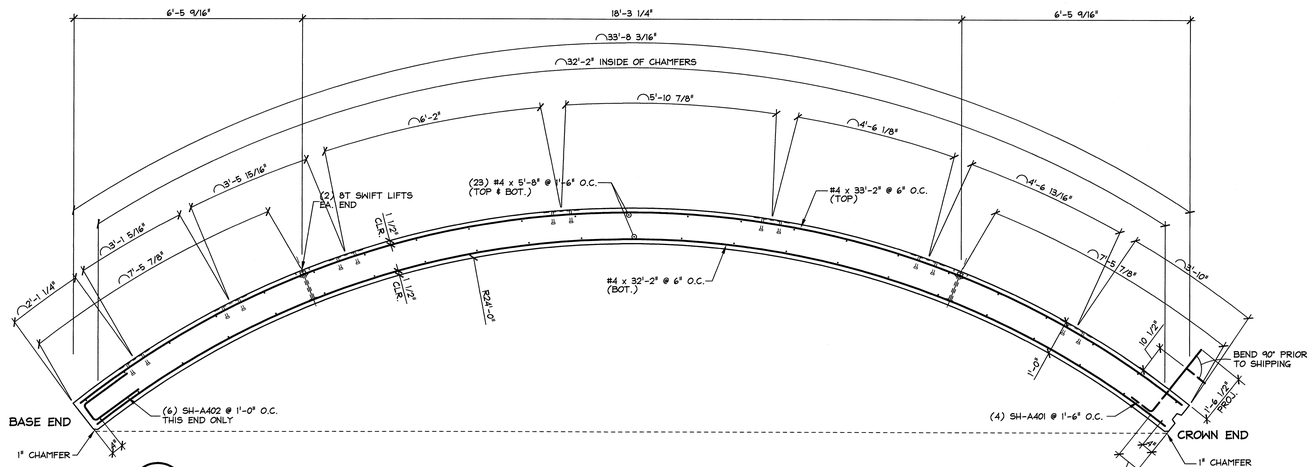


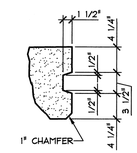
1 AR3 ARCH PANEL PLAN IN FORM W/ REINF.
1/2" = 1'-0"



A AR3 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



B AR3 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



KEYWAY DETAIL
1" = 1'-0"

HANDLING NOTES:

1. ARCH PANEL SHALL BE HANDLED USING (4) 8T x 10" SL ANCHORS AT FIFTH POINTS.
2. ARCH PANEL SHALL BE STRIPPED USING (4) 8T x 10" SL ANCHORS.
3. FOR YARD STORAGE, ARCH PANEL SHALL BE LOWERED USING (4) 8T x 10" SL ANCHORS UNTIL PANEL CONTACTS THE STORAGE FRAME, PLACED 10'-3" FROM THE PANEL END AS SHOWN. THE BASE OF THE PANEL SHALL THEN BE LOWERED TO THE HARDWOOD SUPPORT.
4. THE PANEL SHALL BE HOISTED FROM THE STORAGE POSITION IN THE REVERSE SEQUENCE SPECIFIED ABOVE.
5. THE ARCH PANEL SHALL BE SHIPPED WITH A SUPPORT CONFIGURATION MATCHING THE "YARD STORAGE DETAIL" AND SHALL BE INSTALLED FOLLOWING THE ABOVE PROCEDURE, USING (4) 8T x 10" SL ANCHORS.

SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

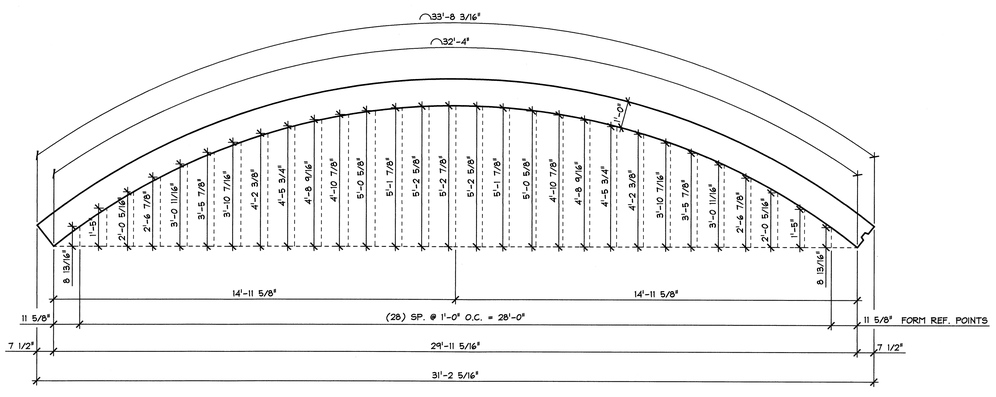
4000 PSI @ RELEASE
6500 PSI @ 28 DAYS

MIX DESIGN: 445M NO DCI

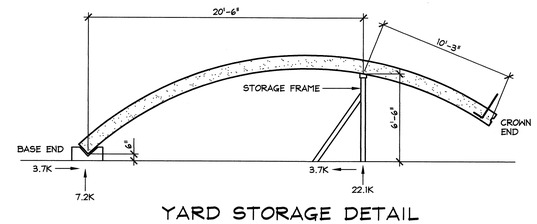
MARK: SH-AR3	QTY.: 1	WT.: 14.93 T	VOL.: 7.37 cy

MATERIAL LIST / ARCH PANEL

ITEM	MARK	DESCRIPTION	QTY.
1		#4 x 33'-2" BLACK	12
2		#4 x 32'-2" BLACK	12
3		#4 x 5'-8" BLACK	46
4			
5	SH-A401	#4 BENT BAR BLACK	4
6	SH-A402	#4 BENT BAR BLACK	6
7			
8	MK-API	PL 3/8" x 3" x 1'-0" W/ (2) 5/8"Φ x 3" HS (GALV.)	7
9			
10		DAYTON 8T x 10" SWIFT LIFT ANCHORS (WITH RECESS PLUG)	4
11			
12			
13			
14			
15			



ARCH PANEL ELEV. IN FORM
3/8" = 1'-0"



YARD STORAGE DETAIL
3/16" = 1'-0"

STATE OF VERMONT
RYAN L. ERIKSSON
No. 75908
Structural
LICENSED
PROFESSIONAL ENGINEER
11.21.13

APPROVAL STAMP:

J.P. CARRARA & SONS INC.
Precast & Prestress Manufacturer
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T. BUCK CONSTRUCTION
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AUBURN, MAINE

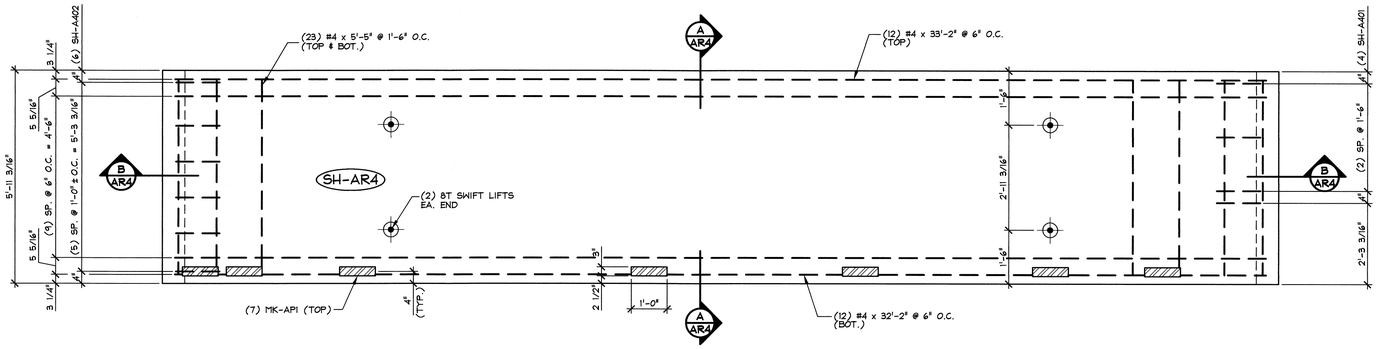
STATE OF VERMONT AGENCY OF TRANSPORTATION
COUNTY OF ADDISON

TOWN OF MIDDLEBURY
ROUTE NO. VT 125, EAST MIDDLEBURY GORGE
BRIDGE NO.: PROJECT NO.: RS 0174(8)

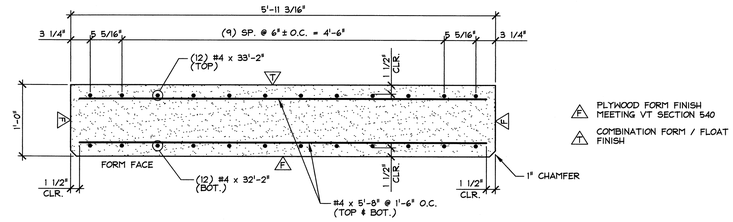
PRECAST ARCH PANEL DETAILS

DATE: OCT. 9, 2013
SCALE: NOTED
CHKD: DFTM: T.D.
JOB NO:
DWG. NO: AR3

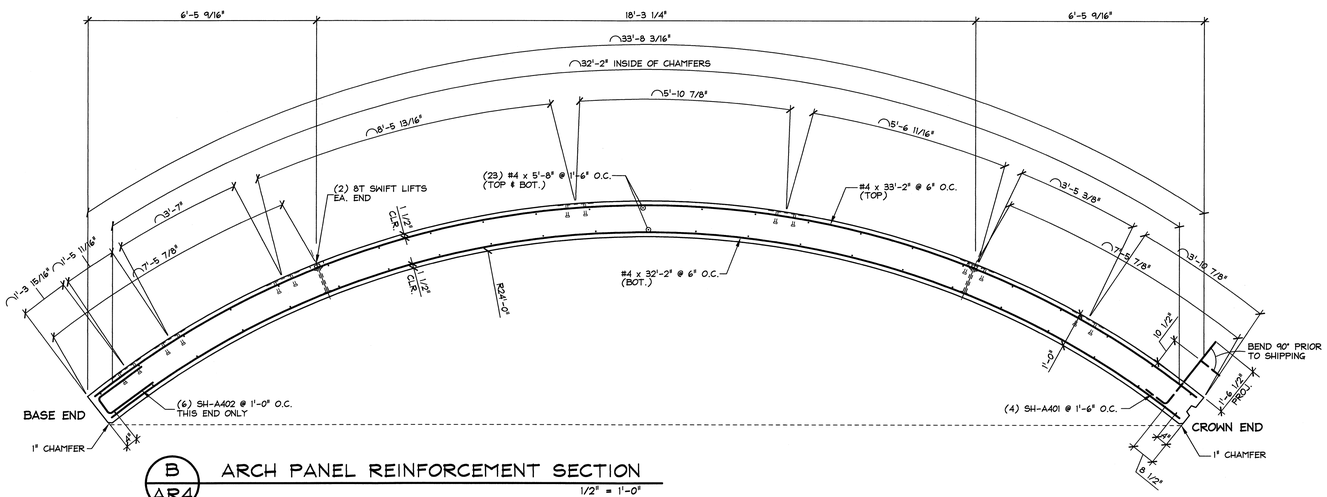
F:\VT-Bridges\East Middlebury Gorge\23411-013 AR3.dwg, 11/20/2013 2:18:49 PM



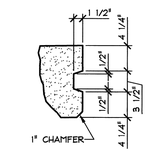
1 AR4 ARCH PANEL PLAN IN FORM W/ REINF.
1/2" = 1'-0"



A AR4 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



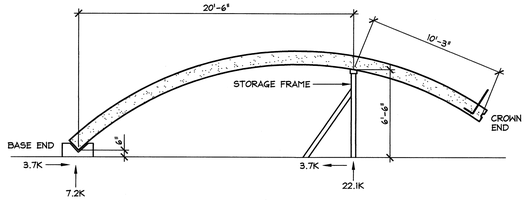
B AR4 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



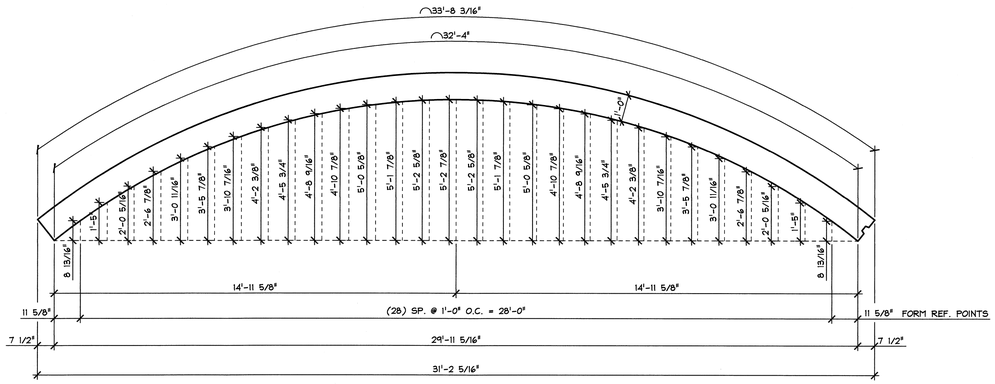
KEYWAY DETAIL
1" = 1'-0"

HANDLING NOTES:

1. ARCH PANEL SHALL BE HANDLED USING (4) 8T x 10" SL ANCHORS AT FIFTH POINTS.
2. ARCH PANEL SHALL BE STRIPPED USING (4) 8T x 10" SL ANCHORS.
3. FOR YARD STORAGE, ARCH PANEL SHALL BE LOWERED USING (4) 8T x 10" SL ANCHORS UNTIL PANEL CONTACTS THE STORAGE FRAME, PLACED 10'-3" FROM THE PANEL END AS SHOWN. THE BASE OF THE PANEL SHALL THEN BE LOWERED TO THE HARDWOOD SUPPORT.
4. THE PANEL SHALL BE HOISTED FROM THE STORAGE POSITION IN THE REVERSE SEQUENCE SPECIFIED ABOVE.
5. THE ARCH PANEL SHALL BE SHIPPED WITH A SUPPORT CONFIGURATION MATCHING THE "YARD STORAGE DETAIL" AND SHALL BE INSTALLED FOLLOWING THE ABOVE PROCEDURE, USING (4) 8T x 10" SL ANCHORS.



YARD STORAGE DETAIL
3/16" = 1'-0"



ARCH PANEL ELEV. IN FORM
3/8" = 1'-0"

SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

4000 PSI @ RELEASE
6500 PSI @ 28 DAYS

MIX DESIGN: 445M NO DCI

MARK: SH-AR4	QTY.: 1	WT.: 14.93 T	VOL.: 7.37 cy

MATERIAL LIST / ARCH PANEL

ITEM	MARK	DESCRIPTION	QTY.
1		#4 x 33'-2" BLACK	12
2		#4 x 32'-2" BLACK	12
3		#4 x 5'-8" BLACK	46
4			
5	SH-A401	#4 BENT BAR BLACK	4
6	SH-A402	#4 BENT BAR BLACK	6
7	MK-AP1	PL 3/8" x 3" x 1'-0" W/ (2) 5/8"ϕ x 3" HS (GALV.)	7
8			
9			
10		DAYTON 8T x 10" SWIFT LIFT ANCHORS (WITH RECESS PLUG)	4
11			
12			
13			
14			
15			

STATE OF VERMONT
ROY L. ERIKSSON
No. 75908
Structural
LICENSED
PROFESSIONAL ENGINEER

11.21.13

APPROVAL STAMP:

J.P. CARRARA & SONS INC.
Precast & Prestress Manufacturer
2464 CASE STR., MIDDLEBURY, VERMONT 05753 Phone:(802)388-6361 Fax:(802)388-9010

T. BUCK CONSTRUCTION
CONTRACTOR
AUBURN, MAINE

STATE OF VERMONT AGENCY OF TRANSPORTATION
COUNTY OF ADDISON

TOWN OF MIDDLEBURY
ROUTE NO. VT 125, EAST MIDDLEBURY GORGE
BRIDGE NO.: PROJECT NO.: RS 0174(8)

PRECAST ARCH PANEL DETAILS

DATE: OCT. 9, 2013
SCALE: NOTED
CHKD: DFTM: T.D.
JOB NO:
DWG. NO: AR4

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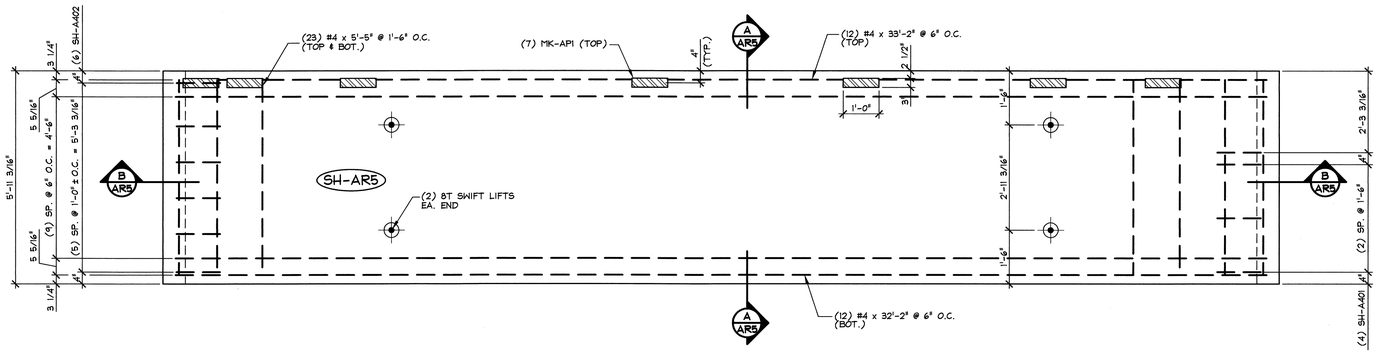
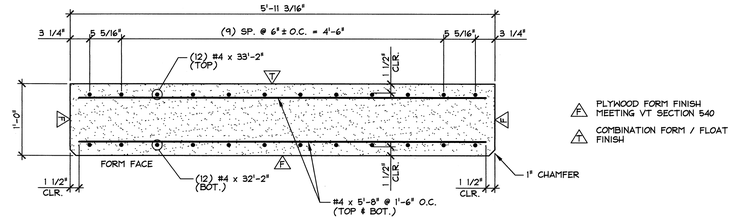
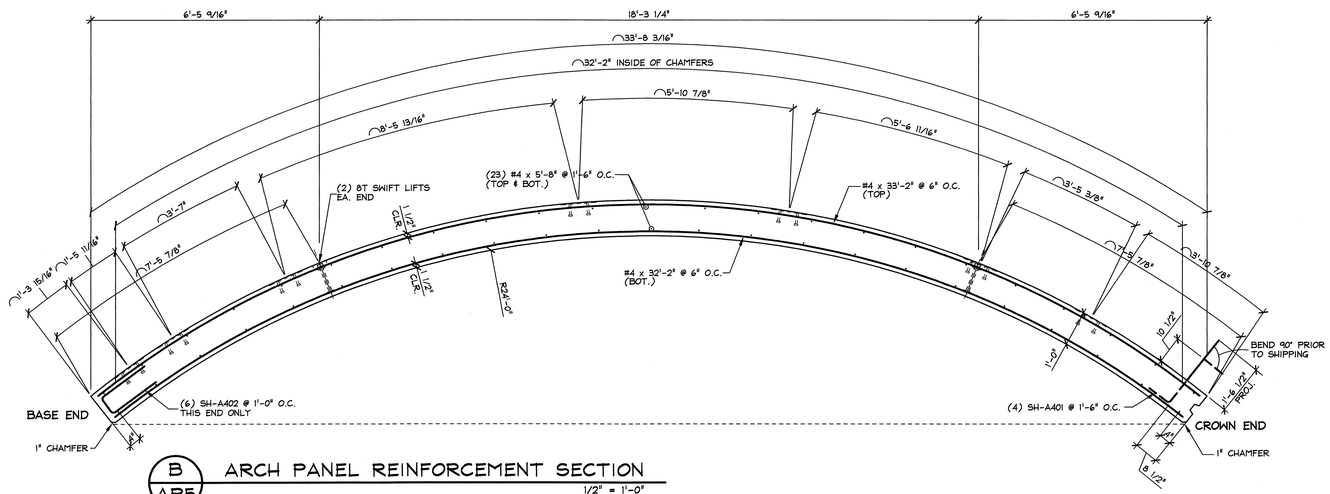


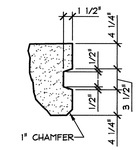
1 AR5 ARCH PANEL PLAN IN FORM W/ REINF.
1/2" = 1'-0"



A AR5 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



B AR5 ARCH PANEL REINFORCEMENT SECTION
1/2" = 1'-0"



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1" = 1'-0"

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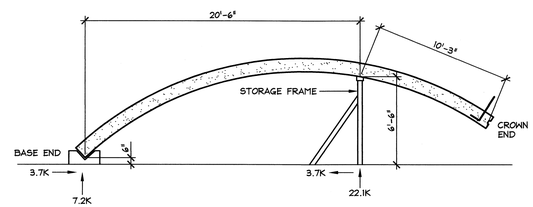
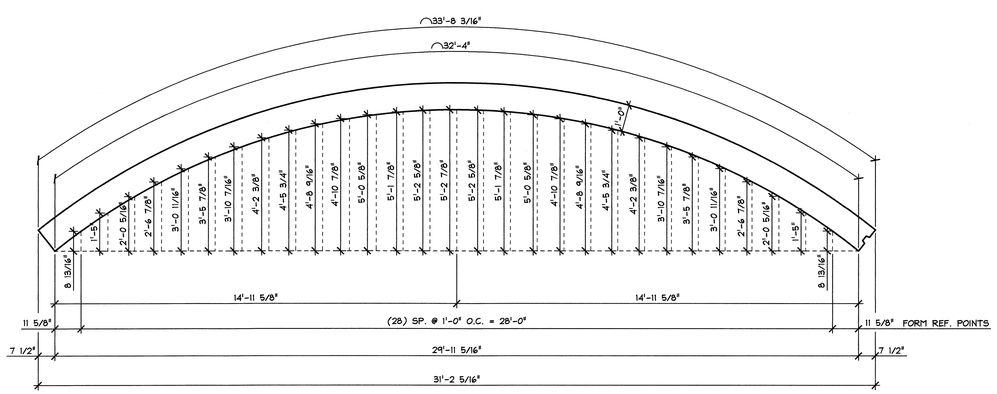


YARD STORAGE DETAIL
3/16" = 1'-0"



ARCH PANEL ELEV. IN FORM
3/8" = 1'-0"

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COUNTY OF ADDISON

TOWN OF MIDDLEBURY
ROUTE NO. VT 125, EAST MIDDLEBURY GORGE
BRIDGE NO.: PROJECT NO.: RS 0174(8)

PRECAST ARCH PANEL DETAILS

DATE: OCT. 9, 2013
SCALE: NOTED
CHKD: DFTM: T.D.
JOB NO:
DWG. NO: AR5

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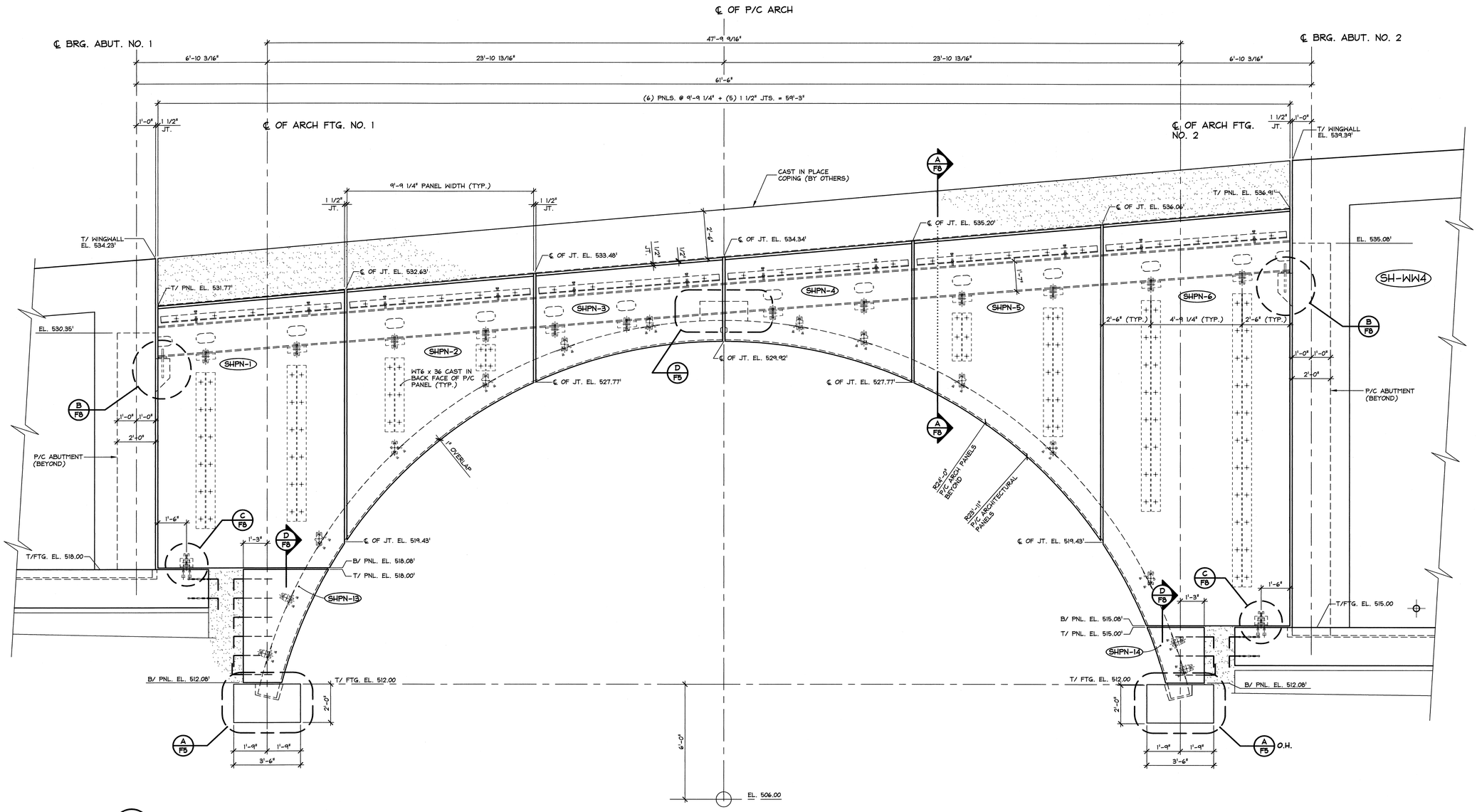

1 / F6 WEST ELEVATION OF PRECAST ARCHITECTURAL PANELS

3/8" = 1'-0"

SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

APPROVAL STAMP:	J.P. CARRARA & SONS INC. Precast & Prestress Manufacturer 2464 CASE STR., MIDDLEBURY, VERMONT 05753 Phone:(802)388-6361 Fax:(802)388-9010	T. BUCK CONSTRUCTION CONTRACTOR AUBURN, MAINE
	STATE OF VERMONT AGENCY OF TRANSPORTATION COUNTY OF ADDISON	DATE: OCT. 9, 2013 SCALE: NOTED
	TOWN OF MIDDLEBURY ROUTE NO. VT 125, EAST MIDDLEBURY GORGE BRIDGE NO.: PROJECT NO.: RS 0174(8)	CHKD: DFTM: T.D. JOB NO:
	P/C ARCHITECTURAL PANEL LAYOUT WEST ELEVATION	DWG. NO: F6

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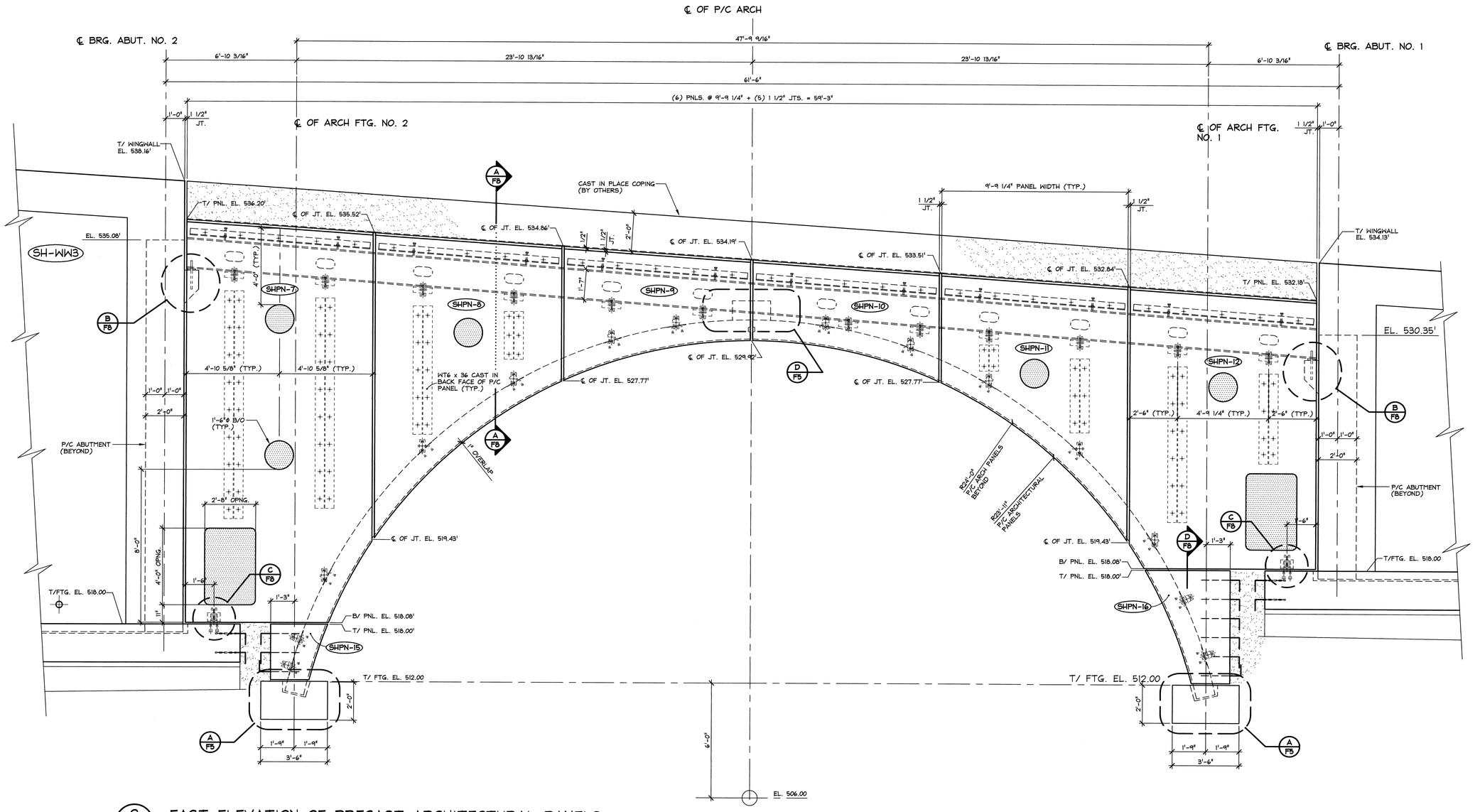

2 / F7 EAST ELEVATION OF PRECAST ARCHITECTURAL PANELS

3/8" = 1'-0"

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NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

APPROVAL STAMP:	J.P. CARRARA & SONS INC. Precast & Prestress Manufacturer 2464 CASE STR., MIDDLEBURY, VERMONT 05753 Phone:(802)388-6361 Fax:(802)388-9010	T. BUCK CONSTRUCTION CONTRACTOR AUBURN, MAINE
	STATE OF VERMONT AGENCY OF TRANSPORTATION COUNTY OF ADDISON	DATE: OCT. 9, 2013 SCALE: NOTED
	TOWN OF MIDDLEBURY ROUTE NO. VT 125, EAST MIDDLEBURY GORGE BRIDGE NO.: PROJECT NO.: RS 0174(8)	CHKD: DFTM: T.D. JOB NO:
	P/C ARCHITECTURAL PANEL LAYOUT EAST ELEVATION	DWG. NO: F7

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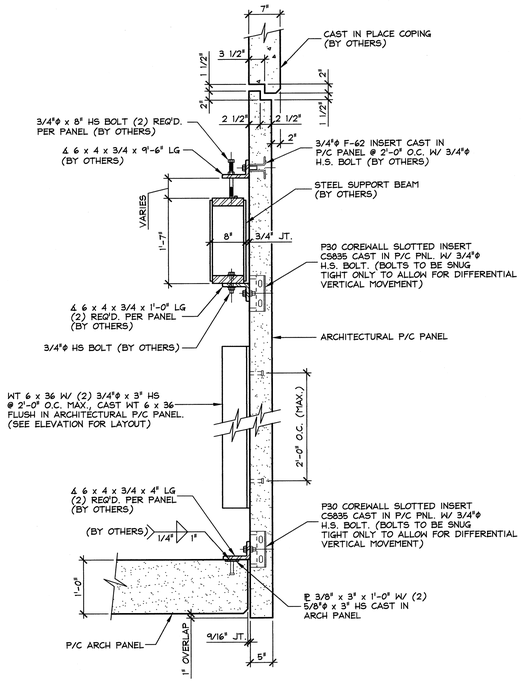

A / F8 P/C PANEL CONNECTION DETAIL

3/4" = 1'-0"

SUBMITTED
NOV 22 2013
J. P. CARRARA & SONS, INC.
MIDDLEBURY, VT 05753

APPROVAL STAMP:	J.P. CARRARA & SONS INC. Precast & Prestress Manufacturer 2464 CASE STR., MIDDLEBURY, VERMONT 05753 Phone:(802)388-6361 Fax:(802)388-9010	T. BUCK CONSTRUCTION CONTRACTOR AUBURN, MAINE
	STATE OF VERMONT AGENCY OF TRANSPORTATION COUNTY OF ADDISON	DATE: OCT. 9, 2013 SCALE: NOTED
	TOWN OF MIDDLEBURY ROUTE NO. VT 125, EAST MIDDLEBURY GORGE BRIDGE NO.: PROJECT NO.: RS 0174(8)	CHKD: DFTM: T.D. JOB NO:
	SECTIONS & DETAILS	DWG. NO: F8

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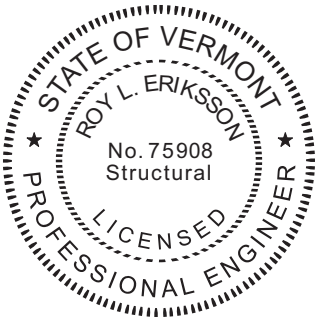
Engineering Report

JOB: Sand Hill Bridge VT Route 125 (Major Collector) Bridge No. 13
LOC: Middlebury, VT
TASK: Arch Panel Production Design

JOB NO. JPC13008
CLIENT: J.P. Carrara & Sons, Inc.

DATE: 2013-11-15

DESIGN: R. Slade, E.I.
CHECK: R. Eriksson, P.E.



11·21·13

Eriksson
technologies

Project Overview

A production design was performed for the precast concrete arch panels to be installed beneath the new Sand Hill Bridge (VT Route 125) Bridge No. 13 in Middlebury, VT. The contract drawings call for the use of six pairs of precast arch panels. These members are to be self-supporting, have an exposed-face radius of 24ft, and span approximately 47ft. Each pair of panels will be joined together at the midspan with a crown beam (pin) to transfer shear and maintain alignment.

This design presented within this report is in accordance with the current versions of the *AASHTO LRFD Bridge Design Specifications, 6th Ed. (2012),* the *VTrans Structures Design Manual (2010), ASCE 7-10 Minimum Design Loads for Buildings and Other Structures (2010)*, as well as the *ACI 318-11 Building Code Requirements for Structural Concrete (2011)*. The only design live load acting on these members is due to the presence of inspection ladders on the inside-face of the panels – and applied as 300lb point loads spaced at 10ft, per ladder. Additionally, a suction force of 30psf applied normal to the exposed-face of the panels was assumed to account for wind tunnel effects. The following AASHTO Limit States (LS) were evaluated for the in-place condition, and the design is shown to be satisfactory for each:

- **Strength I** LS – Flexural, Axial, and Shear strength of the Panels
- **Strength IV** LS – Flexural, Axial, and Shear strength of the Panels
- **Strength V** LS – Flexural, Axial, and Shear strength of the Panels
- **Service I** LS – Tensile and Compressive stress limits of the Panels

The panels were also evaluated for construction loads associated with shipping and lifting. Impact factors of ±25% and ±50% were assumed for lifting and shipping, respectively. Tensile stresses due to these loads were then checked against allowable limits. Finally, the dead weight is amplified by 25% while the dynamic effects are amplified by 50%, per section 3.4.2 of AASHTO LRFD, and the member is checked for ultimate flexural, axial, and shear strength. The design is shown to be satisfactory.

The panels shall be lifted by four P-52 Swift Lift® 8 ton x 10" anchors placed as shown on the engineering sketch. The location of these lifters was selected to minimize flexural stresses during lifting. A rigging configuration should be selected to ensure the panels remain stable during lifting and setting. During transport and storage dunnage should be placed as shown on the engineering sketch within this report. The precise orientation of the panels has been selected to minimize tensile stresses during transport.

The panels shall be lifted by the provided Swift Lift® anchors for erection. The contractor is to set the base of the arch in place, and support the “crown” end at the midspan of the structure. When all six pairs of panels are in place, the gap between each panel shall be grouted and a crown beam is to be cast as shown on the engineering sketch provided. Only after the crown beam has obtained a minimum of 4,000psi strength may the shoring be removed. This construction support shoring shall be capable of safely supporting the loads (safe working load) provided in the “Design Reactions” table within this report.

The scope of these calculations includes design of the precast arch panels and crown beam. The remainder of the superstructure, precast side panels, inspection ladders, substructure, and construction shoring were not within the scope of this design, and are therefore not evaluated in this report.

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Arch Panel Production Design Calculations

Project: Sand Hill Bridge VT Route 125 (Major Collector) Bridge No. 13

Location: Middlebury, VT

Client: J. P. Carrara & Sons

By: R. Slade, E.I. **Chk:** R. Eriksson, P.E. **Date:** 2013-11-15

References: *AASHTO LRFD Bridge Design Specifications, 6th Ed. (2012)*
VTrans Structures Design Manual (2010)
ASCE 7-10 Minimum Design Loads for Buildings and Other Structures (2010)
ACI 318-11 Building Code Requirements for Structural Concrete (2011)

1. Design Parameters

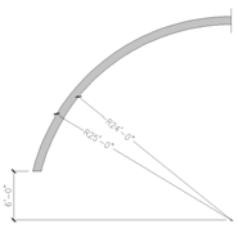
1.1 Materials:

Concrete Arches: $\gamma_{concrete} := 0.150 \cdot kcf$ $f_c := 6.5ksi$ $f_{ci} := 4ksi$

Steel Components: $\gamma_s := 0.490 \cdot kcf$ $f_{y.A36} := 36ksi$ $f_{y.rebar} := 60ksi$

1.2. Geometry:

Arch Panels: $b_{arch} := 6ft$ $th_{arch} := 1ft$ $A_{arch} := b_{arch} \cdot th_{arch} = 6\,ft^2$



$r_{i.arch} := 24ft$ $r_{o.arch} := r_{i.arch} + th_{arch} = 25\,ft$ $r_{arch} := \frac{r_{i.arch} + r_{o.arch}}{2} = 24.5\,ft$

$\Delta_{0.arch} := 6ft$ $\theta_{0.arch} := asin\left(\frac{\Delta_{0.arch}}{r_{arch}}\right) = 14.2 \cdot deg$ $\theta_{arch} := \pi - 2 \cdot \theta_{0.arch} = 151.6 \cdot deg$

$L_{i.arch} := \theta_{arch} \cdot r_{i.arch} = 63.5\,ft$ $L_{o.arch} := \theta_{arch} \cdot r_{o.arch} = 66.2\,ft$ $L_{arch} := \theta_{arch} \cdot r_{arch} = 64.8\,ft$

Loads:

Factors: $IM_{pick} := 25\%$ $IM_{ship} := 50\%$

$\gamma_{construct} := 1.25$ $\gamma_{dynamic} := 1.5$ *(AASHTO LRFD 3.4.2)*

$\phi_c := 0.9$ $\phi_v := 0.9$ *(AASHTO LRFD 5.5.4.2.1)*

$\beta_v := 2.0$ *(AASHTO LRFD 5.8.3.4.1)*

Ladder Loads: $P_{LL.ladder} := 300lbf$ $S_{LL.ladder} := 10ft$ *(ASCE 7-10)*

$LL_{ladder} := ceil\left(\frac{L_{o.arch}}{S_{LL.ladder}}\right) \cdot P_{LL.ladder} = 2.1 \cdot kip$

Wind Loads: $P_{LL.wind} := 30psf$ $LL_{wind} := P_{LL.wind} \cdot b_{arch} = 0.180 \cdot klf$ *(assumed)*

1.3. Allowable Stresses:

(at stripping) (at 28-days)

Cracking Stress: $f_{ri} := -7.5psi \cdot \sqrt{\frac{f_{ci}}{psi}} = -0.474 \cdot ksi$ $f_r := -7.5psi \cdot \sqrt{\frac{f_c}{psi}} = -0.605 \cdot ksi$

Tensile Stress Limit: $f_{allowable.Ti} := \frac{f_{ri}}{1.25} = -0.379 \cdot ksi$ $f_{allowable.T} := \frac{f_r}{1.25} = -0.484 \cdot ksi$ ($6\sqrt{f_c}$ limit)

Compressive Stress Limit: $f_{allowable.C} := 0.60 \cdot f_c = 3.9 \cdot ksi$ $f_{allowable.Ci} := 0.60 \cdot f_{ci} = 2.4 \cdot ksi$

2. In-Place Design

2.1. Design Load:

2.1.1. Load Effects

Flexure:

$M_{DC.max} := 33.49kip \cdot ft$ $\quad M_{DC.min} := -0kip \cdot ft$

$M_{LL.max} := 2.38kip \cdot ft$ $\quad M_{LL.min} := -1.65kip \cdot ft$

$M_{WS.max} := 0kip \cdot ft$ $\quad M_{WS.min} := 0kip \cdot ft$

Compression:

$N_{DC.max} := 32.311kip$ $\quad N_{DC.min} := 15.419kip$

$N_{LL.max} := 1.20kip$ $\quad N_{LL.min} := -0.004kip$

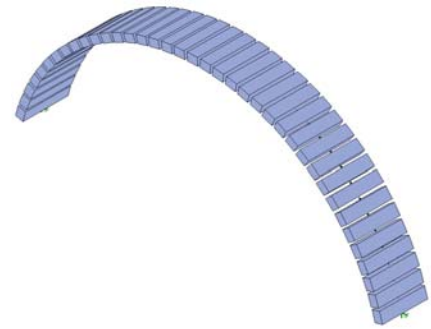
$N_{WS.max} := 4.407kip$ $\quad N_{WS.min} := 4.407kip$

Shear:

$V_{DC.max} := 7.11kip$ $\quad V_{DC.min} := -7.11kip$

$V_{LL.max} := 0.322kip$ $\quad V_{LL.min} := -0.322kip$

$V_{WS.max} := 0.154kip$ $\quad V_{WS.min} := -0.154kip$



(from RISA model)

Base Reaction:

$R_{DC.x} := 15.428kip$ $\quad R_{DC.y} := 29.165kip$ $\quad R_{DC} := \sqrt{R_{DC.x}^2 + R_{DC.y}^2} = 33.0\,kip$

$R_{LL.x} := 0.524kip$ $\quad R_{LL.y} := 1.124kip$ $\quad R_{LL} := \sqrt{R_{LL.x}^2 + R_{LL.y}^2} = 1.2\,kip$

$R_{WS.x} := 1.082kip$ $\quad R_{WS.y} := 4.275kip$ $\quad R_{WS} := \sqrt{R_{WS.x}^2 + R_{WS.y}^2} = 4.4\,kip$

2.1.2. Strength (I or IV or V)

Flexure:

$$M_{strength.p} := \max\begin{bmatrix} 1.25\cdot(M_{DC.max}) + 1.75\cdot(M_{LL.max}) + 0\cdot(M_{WS.max}) \\ 1.5\cdot(M_{DC.max}) + 0\cdot(M_{LL.max}) + 0\cdot(M_{WS.max}) \\ 1.25\cdot(M_{DC.max}) + 1.35\cdot(M_{LL.max}) + 0.4\cdot(M_{WS.max}) \end{bmatrix} = 50.235\cdot kip\cdot ft$$

$$M_{strength.n} := \min\begin{bmatrix} 1.25\cdot(M_{DC.min}) + 1.75\cdot(M_{LL.min}) + 0\cdot(M_{WS.min}) \\ 1.5\cdot(M_{DC.min}) + 0\cdot(M_{LL.min}) + 0\cdot(M_{WS.min}) \\ 1.25\cdot(M_{DC.min}) + 1.35\cdot(M_{LL.min}) + 0.4\cdot(M_{WS.min}) \end{bmatrix} = -2.887\cdot kip\cdot ft$$

Compression:

$$N_{strength.p} := \max\begin{bmatrix} 1.25\cdot(N_{DC.max}) + 1.75\cdot(N_{LL.max}) + 0\cdot(N_{WS.max}) \\ 1.5\cdot(N_{DC.max}) + 0\cdot(N_{LL.max}) + 0\cdot(N_{WS.max}) \\ 1.25\cdot(N_{DC.max}) + 1.35\cdot(N_{LL.max}) + 0.4\cdot(N_{WS.max}) \end{bmatrix} = 48.466\cdot kip$$

$$N_{strength.n} := \min\begin{bmatrix} 1.25\cdot(N_{DC.min}) + 1.75\cdot(N_{LL.min}) + 0\cdot(N_{WS.min}) \\ 1.5\cdot(N_{DC.min}) + 0\cdot(N_{LL.min}) + 0\cdot(N_{WS.min}) \\ 1.25\cdot(N_{DC.min}) + 1.35\cdot(N_{LL.min}) + 0.4\cdot(N_{WS.min}) \end{bmatrix} = 19.267\cdot kip$$

Shear:

$$V_{strength.p} := \max\begin{bmatrix} 1.25\cdot(V_{DC.max}) + 1.75\cdot(V_{LL.max}) + 0\cdot(V_{WS.max}) \\ 1.5\cdot(V_{DC.max}) + 0\cdot(V_{LL.max}) + 0\cdot(V_{WS.max}) \\ 1.25\cdot(V_{DC.max}) + 1.35\cdot(V_{LL.max}) + 0.4\cdot(V_{WS.max}) \end{bmatrix} = 10.665\cdot kip$$

$$V_{strength.n} := \min\begin{bmatrix} 1.25\cdot(V_{DC.min}) + 1.75\cdot(V_{LL.min}) + 0\cdot(V_{WS.min}) \\ 1.5\cdot(V_{DC.min}) + 0\cdot(V_{LL.min}) + 0\cdot(V_{WS.min}) \\ 1.25\cdot(V_{DC.min}) + 1.35\cdot(V_{LL.min}) + 0.4\cdot(V_{WS.min}) \end{bmatrix} = -10.665\cdot kip$$

Base Reaction: $R_{strength.max} := \max\begin{bmatrix} 1.25\cdot(R_{DC}) + 1.75\cdot(R_{LL}) + 0\cdot(R_{WS}) \\ 1.5\cdot(R_{DC}) + 0\cdot(R_{LL}) + 0\cdot(R_{WS}) \\ 1.25\cdot(R_{DC}) + 1.35\cdot(R_{LL}) + 0.4\cdot(R_{WS}) \end{bmatrix} = 49.49\cdot kip$

2.1.3. Service I

Flexure: $M_{service.max} := 1\cdot(M_{DC.max}) + 1\cdot(M_{LL.max}) + 0.3\cdot(M_{WS.max}) = 35.87\cdot kip\cdot ft$

$M_{service.min} := 1\cdot(M_{DC.min}) + 1\cdot(M_{LL.min}) + 0.3\cdot(M_{WS.min}) = -1.65\cdot kip\cdot ft$

Compression: $N_{service.max} := 1\cdot(N_{DC.max}) + 1\cdot(N_{LL.max}) + 0.3\cdot(N_{WS.max}) = 34.833\cdot kip$

$N_{service.min} := 1\cdot(N_{DC.min}) + 1\cdot(N_{LL.min}) + 0.3\cdot(N_{WS.min}) = 16.737\cdot kip$

Shear: $V_{service.max} := 1\cdot(V_{DC.max}) + 1\cdot(V_{LL.max}) + 0.3\cdot(V_{WS.max}) = 7.478\cdot kip$

$V_{service.min} := 1\cdot(V_{DC.min}) + 1\cdot(V_{LL.min}) + 0.3\cdot(V_{WS.min}) = -7.478\cdot kip$

Base Reaction: $R_{service} := 1\cdot(R_{DC}) + 1\cdot(R_{LL}) + 0.3\cdot(R_{WS}) = 35.56\,kip$

2.2. Stress Check:

Gross Section Modulus: $S_{arch} := \frac{b_{arch}\cdot th_{arch}^2}{6} = 1728\cdot in^3$

Gross Area: $A_{arch} = 864\cdot in^2$

Max Tension: $f_{max.T} := \frac{M_{service.max}}{-S_{arch}} = -0.249\cdot ksi$

$\text{if}(f_{allowable.T} \le f_{max.T}, \text{"OK"}, \text{"NoGood"}) = \text{"OK"}$

Max Compression: $f_{max.C} := \frac{M_{service.max}}{S_{arch}} + \frac{N_{service.max}}{A_{arch}} = 0.289\cdot ksi$

$\text{if}(f_{allowable.C} \ge f_{max.C}, \text{"OK"}, \text{"NoGood"}) = \text{"OK"}$

2.3. Flexural Design:

Design Moment: $M_{design} := \max(M_{strength.p}, |M_{strength.n}|) = 50.235\cdot kip\cdot ft$

Try #4 bars at 6" o/c

$A_s := \frac{0.20in^2}{6in} = 0.4\cdot\frac{in^2}{ft}$

$a := \frac{A_s\cdot f_{y.rebar}}{0.85\cdot f_c} = 0.362\cdot in$

$d_{use} := th_{arch} - 3.25in = 8.75\cdot in$ *(depth to top bars for negative bending)*

Moment Capacity: $\phi M_n := \phi_c\cdot A_s\cdot f_{y.rebar}\cdot\left(d_{use} - \frac{a}{2}\right)\cdot b_{arch} = 92.5\cdot kip\cdot ft$

$\text{if}(M_{design} \le \phi M_n, \text{"OK"}, \text{"NoGood"}) = \text{"OK"}$

Temperature Steel Required:

$$A_{s.T.req} := \frac{1.3 \cdot b_{arch} \cdot th_{arch}}{2 \cdot (b_{arch} + th_{arch}) \cdot f_{y.rebar}} \cdot \left(\frac{ksi \cdot in}{in^2}\right) \cdot \frac{in^2}{ft} = 0.111 \cdot \frac{in^2}{ft}$$ *(AASHTO LRFD 5.10.8-1)*

$$A_{s.T.req} := \max\left(\min\left(A_{s.T.req}, 0.6 \cdot \frac{in^2}{ft}\right), 0.11 \cdot \frac{in^2}{ft}\right) = 0.111 \cdot \frac{in^2}{ft}$$ *(AASHTO LRFD 5.10.8-2)*

Try #4 bars at 18" o/c

$$A_{s.T} := \frac{0.2in^2}{18in} = 0.133 \cdot \frac{in^2}{ft}$$

$$if\left(A_{s.T.req} \le A_{s.T}, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$

2.4. Axial Design:

Design Compression:

$$N_{des} := \max\left(N_{strength.p}, \left|N_{strength.n}\right|\right) = 48.5 \cdot kip$$

Long Steel:

$$A_{s.long} := 2 \cdot A_s \cdot b_{arch} = 4.8 \cdot in^2$$

$$if\left(\frac{A_{s.long}}{A_{arch}} \le 0.08, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$ *(AASHTO LRFD 5.7.4.2-1)*

Axial Capacity:

$$\phi P_n := \phi_c \cdot 0.8 \cdot \left[0.85 \cdot f_c \cdot \left(A_{arch} - A_{s.long}\right) + f_{y.rebar} \cdot A_{s.long}\right] = 3625 \cdot kip$$ *(AASHTO LRFD 5.7.4.4-2)*

$$if\left(\phi P_n \ge N_{des}, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$

2.5. Shear Design:

Design Shear:

$$V_{des} := \max\left(V_{strength.p}, \left|V_{strength.n}\right|\right) = 10.7 \cdot kip$$

Concrete Capacity:

$$V_c := 0.0316ksi \cdot \beta_v \cdot \sqrt{\frac{f_c}{ksi}} \cdot b_{arch} \cdot d_{use} = 101.5 \cdot kip$$ *(AASHTO LRFD 5.8.3.3-3)*

$$\phi V_c := \phi_v \cdot \min\left(V_c, 0.18 \cdot f_c \cdot b_{arch} \cdot d_{use}\right) = 91.4 \cdot kip$$

$$if\left(\frac{\phi V_c}{2} \ge V_{des}, \text{"No Shear Steel Required"}, \text{"Shear Steel Required"}\right) = \text{"No Shear Steel Required"}$$

3. Shipping Design

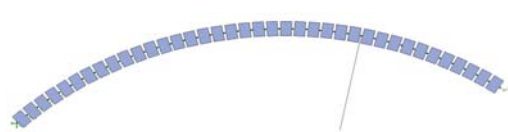
3.1. Design Load:

3.1.1. Load Effects

Flexure: $M_{DC.max} := 45.130kip \cdot ft$ $M_{DC.min} := -40.303kip \cdot ft$

Compression: $N_{DC.max} := 2.022kip$ $N_{DC.min} := -4.655kip$

Shear: $V_{DC.max} := 13.256kip$ $V_{DC.min} := -9.098kip$



(from RISA model)

Reactions: $R_{y.1} := 7.19kip$ $R_{y.2} := 22.110kip$

$R_{x.1} := -3.69kip$ $R_{x.2} := 3.69kip$

3.1.2. Strength
(per AASHTO LRFD 3.4.2.1)

Flexure: $M_{strength.max.ship} := \max(M_{DC.max}, |M_{DC.min}|)\cdot(\gamma_{construct} + IM_{ship}\cdot\gamma_{dynamic}) = 90.26\cdot kip\cdot ft$

Compression: $N_{strength.max.ship} := \max(N_{DC.max}, |N_{DC.min}|)\cdot(\gamma_{construct} + IM_{ship}\cdot\gamma_{dynamic}) = 9.31\cdot kip$

Shear: $V_{strength.max.ship} := \max(V_{DC.max}, |V_{DC.min}|)\cdot(\gamma_{construct} + IM_{ship}\cdot\gamma_{dynamic}) = 26.51\cdot kip$

3.1.3. Stress

Flexure: $M_{stress.max.ship} := \max(M_{DC.max}, |M_{DC.min}|)\cdot(1 + IM_{ship}) = 67.69\cdot kip\cdot ft$

Axial Load: $N_{stress.max.ship} := \min(N_{DC.max}, N_{DC.min})\cdot(1 + IM_{ship}) = -6.98\cdot kip$ (tension)

Shear: $V_{stress.max.ship} := \max(V_{DC.max}, |V_{DC.min}|)\cdot(1 + IM_{ship}) = 19.88\cdot kip$

3.2. Strength Check:

Flexural Capacity: $A_s = 0.4\cdot\frac{in^2}{ft}$ $\quad d_{use} = 8.75\cdot in$

$$a := \frac{A_s\cdot f_{y.rebar}}{0.85\cdot f_{ci}} = 0.588\cdot in$$

$$\phi M_n := \phi_c\cdot A_s\cdot f_{y.rebar}\cdot\left(d_{use} - \frac{a}{2}\right)\cdot b_{arch} = 91.3\cdot kip\cdot ft$$

$$\text{if}(M_{strength.max.ship} \le \phi M_n, \text{"OK"}, \text{"NoGood"}) = \text{"OK"}$$

Axial Capacity: $\phi P_n := \phi_c\cdot 0.8\cdot\left[0.85\cdot f_{ci}\cdot(A_{arch} - A_{s.long}) + f_{y.rebar}\cdot A_{s.long}\right] = 2311\cdot kip$ *(AASHTO LRFD 5.7.4.4-2)*

$$\text{if}(N_{strength.max.ship} \le \phi P_n, \text{"OK"}, \text{"NoGood"}) = \text{"OK"}$$

Shear Capacity: $V_c := 0.0316ksi\cdot\beta_v\cdot\sqrt{\frac{f_{ci}}{ksi}}\cdot b_{arch}\cdot d_{use} = 79.6\cdot kip$ *(AASHTO LRFD 5.8.3.3-3)*

$$\phi V_c := \phi_v\cdot\min(V_c, 0.18\cdot f_{ci}\cdot b_{arch}\cdot d_{use}) = 71.7\cdot kip$$

$$\text{if}\left(V_{stress.max.ship} \le \frac{\phi V_c}{2}, \text{"No Steel Required"}, \text{"Shear Steel Required"}\right) = \text{"No Steel Required"}$$

3.3. Stress Check:

Allowable Stress: $f_{allowable.T} = -0.484\cdot ksi$

Section Modulus: $S_x := \frac{b_{arch}\cdot th_{arch}^2}{6} = 1728\cdot in^3$

Maximum Stress: $f_{max.ship} := \frac{N_{stress.max.ship}}{A_{arch}} - \frac{M_{stress.max.ship}}{S_x} = -0.478\cdot ksi$ (tension)

$$\text{if}(f_{max.ship} \ge f_{allowable.T}, \text{"OK"}, \text{"NoGood"}) = \text{"OK"}$$

4. Lifting Design

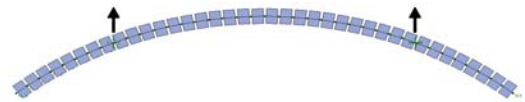
4.1. Design Load:

4.1.1. Load Effects

Flexure: $M_{DC.max} := 17.712kip \cdot ft$ $M_{DC.min} := -19.438kip \cdot ft$

Compression: $N_{DC.max} := 3.043kip$ $N_{DC.min} := -2.413kip$

Shear: $V_{DC.max} := 5.675kip$ $V_{DC.min} := -7.914kip$



(from RISA model)

Reactions: $R_{y.1} := 14.65kip$ $R_{y.2} := 14.65kip$

$R_{x.1} := 0kip$ $R_{x.2} := 0kip$

4.1.2. Strength

(per AASHTO LRFD 3.4.2.1)

Flexure: $M_{strength.max.pick} := \max(M_{DC.max}, |M_{DC.min}|) \cdot (\gamma_{construct} + IM_{pick} \cdot \gamma_{dynamic}) = 31.59 \cdot kip \cdot ft$

Compression: $N_{strength.max.pick} := \max(N_{DC.max}, |N_{DC.min}|) \cdot (\gamma_{construct} + IM_{pick} \cdot \gamma_{dynamic}) = 4.94 \cdot kip$

Shear: $V_{strength.max.pick} := \max(V_{DC.max}, |V_{DC.min}|) \cdot (\gamma_{construct} + IM_{pick} \cdot \gamma_{dynamic}) = 12.86 \cdot kip$

4.2.3. Stress

Flexure: $M_{stress.max.pick} := \max(M_{DC.max}, |M_{DC.min}|) \cdot (1 + IM_{pick}) = 24.30 \cdot kip \cdot ft$

Axial Load: $N_{stress.max.pick} := \min(N_{DC.max}, N_{DC.min}) \cdot (1 + IM_{pick}) = -3.02 \cdot kip$ (tension)

Shear: $V_{stress.max.pick} := \max(V_{DC.max}, |V_{DC.min}|) \cdot (1 + IM_{pick}) = 9.89 \cdot kip$

4.2. Strength Check:

Flexural Capacity: $A_s = 0.4 \cdot \frac{in^2}{ft}$ $d_{use} = 8.75 \cdot in$

$$a := \frac{A_s \cdot f_{y.rebar}}{0.85 \cdot f_{ci}} = 0.588 \cdot in$$

$$\phi M_n := \phi_c \cdot A_s \cdot f_{y.rebar} \cdot \left(d_{use} - \frac{a}{2}\right) \cdot b_{arch} = 91.3 \cdot kip \cdot ft$$

$$if(M_{strength.max.pick} \le \phi M_n, "OK", "NoGood") = "OK"$$

Axial Capacity: $\phi P_n := \phi_c \cdot 0.8 \cdot \left[0.85 \cdot f_{ci} \cdot (A_{arch} - A_{s.long}) + f_{y.rebar} \cdot A_{s.long}\right] = 2311 \cdot kip$ *(AASHTO LRFD 5.7.4.4-2)*

$$if(N_{strength.max.pick} \le \phi P_n, "OK", "NoGood") = "OK"$$

Shear Capacity: $V_c := 0.0316ksi \cdot \beta_v \cdot \sqrt{\frac{f_{ci}}{ksi}} \cdot b_{arch} \cdot d_{use} = 79.6 \cdot kip$ *(AASHTO LRFD 5.8.3.3-3)*

$$\phi V_c := \phi_v \cdot \min(V_c, 0.18 \cdot f_{ci} \cdot b_{arch} \cdot d_{use}) = 71.7 \cdot kip$$

$$if\left(V_{strength.max.pick} \le \frac{\phi V_c}{2}, "No\ Steel\ Required", "Shear\ Steel\ Required"\right) = "No\ Steel\ Required"$$

4.3. Stress Check:

Allowable Stress: $f_{allowable.Ti} = -0.379 \cdot ksi$

Section Modulus: $S_x = 1728 \cdot in^3$

Maximum Stress: $f_{max.pick} := \frac{N_{stress.max.pick}}{A_{arch}} - \frac{M_{stress.max.pick}}{S_x} = -0.172 \cdot ksi$ (tension)

$\text{if}\left(f_{max.pick} \geq f_{allowable.Ti}, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$

4.4. Lifter Selection:

Panel Weight: $SW_{arch} := A_{arch} \cdot \left(\frac{L_{arch}}{2}\right) \cdot \gamma_{concrete} = 29.2 \cdot kip$

$P_{lifting} := SW_{arch} \cdot \left(1 + IM_{pick}\right) = 36.5 \cdot kip$

$No_{pick} := 4$

Lifting Load: $P_{pick.flat} := \frac{P_{lifting}}{No_{pick}} = 9.1 \cdot kip$ *(vertical pick)*

Try (4) P-52 Swift Lift® 8 ton x 10" Anchors

$SWL := 16000lbf = 16 \cdot kip$

$f_{c.min} := 3500psi = 3.5 \cdot ksi$

$edge_{min} := 19in$

$\text{if}\left(edge_{min} \leq \frac{b_{arch}}{4}, \text{"Spacing OK"}, \text{"Check Spacing"}\right) = \text{"Check Spacing"}$

Theoretical reduction in lifter capacity due to spacing & edge effects (per ACI-318 Appendix D):

$A_0 := \left(2 \cdot edge_{min}\right)^2 = 1444 \cdot in^2$

$A_{effective} := \left(edge_{min} \cdot b_{arch}\right) = 1368 \cdot in^2$

$\Psi_{edge.spacing} := \min\left(1, \frac{A_{effective}}{A_0}\right) = 94.7 \cdot \%$

Theoretical increase in lifter capacity due to concrete strength:

$\Psi_{concrete.strength} := \sqrt{\frac{f_{ci}}{f_{c.min}}} = 106.9 \cdot \%$

Adjusted lifter capacity:

$SWL_{adjusted} := (SWL) \cdot \Psi_{edge.spacing} \cdot \Psi_{concrete.strength} = 16.204 \cdot kip$

$\text{if}\left(P_{pick.flat} \leq SWL_{adjusted}, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$

5. Crown Beam Design

5.1. Geometry:

Bar Development: $d_b := \frac{4}{8}in = 0.5 \cdot in$ *(assume #4 bars)*

$$L_{dh} := \max\left(8 \cdot d_b, 6in, \frac{38.0 \cdot d_b}{\sqrt{\frac{f_{ci}}{ksi}}}\right) = 9.5 \cdot in$$

$$L_{hook} := (4 + 12) \cdot d_b = 8 \cdot in$$

Crown Geometry: $cover_{crown} := 3in$

$$h_{crown} := \min\left(L_{dh} + cover_{crown} + \frac{d_b}{2}, 12in\right) = 12 \cdot in$$ say $h_{crown} := 12in$

$$b_{crown} := 2 \cdot \left(L_{hook} + cover_{crown} + \frac{d_b}{2}\right) = 22.5 \cdot in$$ say $b_{crown} := 24in$

$$L_{crown} := \left(b_{arch} - 2ft\right) = 4\,ft$$ *(minimum)*

5.2. Hanger Steel:

Transfer Load: $P_{crown} := 2 \cdot V_{des} = 21.3 \cdot kip$

$$A_{s.hanger.req} := \frac{P_{crown}}{f_{y.rebar} \cdot L_{crown}} = 0.089 \cdot \frac{in^2}{ft}$$

Try #4 bars @ 18"

$$A_{s.hanger} := \frac{0.2in^2}{18in} = 0.133 \cdot \frac{in^2}{ft}$$

$$A_{s.hanger.developed} := \frac{A_{s.hanger}}{L_{dh}} \cdot \left(h_{crown} - cover_{crown} - \frac{d_b}{2}\right) = 0.123 \cdot \frac{in^2}{ft}$$

$$\text{if}\left(A_{s.hanger.developed} \geq A_{s.hanger.req}, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$

5.3. Moment Steel:

Transfer Moment: $$M_{crown} := P_{crown} \cdot \left(\frac{b_{crown}}{2} - cover_{crown} - \frac{d_b}{2}\right) = 15.6 \cdot kip \cdot ft$$

Try #4 bars @ 18"

$$A_{s.crown} := \frac{0.2in^2}{18in} = 0.133 \cdot \frac{in^2}{ft}$$

$$A_{s.crown.developed} := \frac{A_{s.crown}}{L_{dh}} \cdot \left(\frac{b_{crown}}{2} - cover_{crown} - \frac{d_b}{2}\right) = 0.123 \cdot \frac{in^2}{ft}$$

$$a := \frac{A_s \cdot f_{y.rebar}}{0.85 \cdot f_{ci}} = 0.588 \cdot in$$

$$d_{use} := h_{crown} - cover_{crown} - \frac{d_b}{2} = 8.75 \cdot in$$

Moment Capacity: $$\phi M_n := \phi_c \cdot A_{s.crown.developed} \cdot f_{y.rebar} \cdot \left(d_{use} - \frac{a}{2}\right) \cdot b_{arch} = 28.0 \cdot kip \cdot ft$$

$$\text{if}\left(M_{crown} \leq \phi M_n, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$

Temperature Steel Required:

$$A_{s.T.req} := \frac{1.3 \cdot h_{crown} \cdot b_{crown}}{2 \cdot (h_{crown} + b_{crown}) \cdot f_{y.rebar}} \cdot \left(\frac{ksi \cdot in}{in^2}\right) \cdot \frac{in^2}{ft} = 0.087 \cdot \frac{in^2}{ft}$$ *(AASHTO LRFD 5.10.8-1)*

$$A_{s.T.req} := \max\left(\min\left(A_{s.T.req}, 0.6 \cdot \frac{in^2}{ft}\right), 0.11 \cdot \frac{in^2}{ft}\right) \cdot b_{crown} = 0.22 \cdot in^2$$ *(AASHTO LRFD 5.10.8-2)*

Try (2) #3 bars in each face

$$A_{s.T} := (2) \cdot 0.11 in^2 = 0.22 \cdot in^2$$

$$\text{if}\left(A_{s.T.req} \le A_{s.T}, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$

5.4. Crown Shear:

Transfer Shear:

$$V_{crown} := P_{crown} = 21.33 \cdot kip$$

Concrete Shear Capacity:

$$V_c := 0.0316 ksi \cdot \sqrt{\frac{f_{ci}}{ksi}} \cdot d_{use} \cdot L_{crown} = 26.5 \cdot kip$$ *(AASHTO LRFD 5.8.3.3-3)*

$$\phi V_c := \phi_v \cdot \min\left(V_c, 0.18 \cdot f_{ci} \cdot d_{use} \cdot L_{crown}\right) = 23.9 \cdot kip$$

$$\text{if}\left(V_{crown} \le \phi V_c, \text{"OK"}, \text{"NoGood"}\right) = \text{"OK"}$$

6. Shoring Load

The contractor is to support the "crown end" of each panel at the midspan of the structure. This support structure shall be capable of safely supporting arch panels during erection. The **unfactored** design vertical load due to the arch panels acting on the support is provided below:

6.1. Component Loads

Panel Selfweight: $SW_{arch} = 29.181 \cdot kip$

Panel Reactions: $CG_x := r_{arch} - \left(\frac{2}{\pi} \cdot r_{arch}\right) = 8.903\,ft$

$R_{panel.y} := SW_{arch} \cdot \left(\frac{CG_x}{r_{arch}}\right) = 10.6 \cdot kip$

$R_{panel.x} := \left(SW_{arch} - R_{panel.y}\right) \cdot \tan\left(\theta_{0.arch}\right) = 4.692\,kip$

Panel Load: $w_{panel.y} := \frac{R_{panel.y}}{b_{arch}} = 1.77 \cdot klf$

$w_{panel.x} := \frac{R_{panel.x}}{b_{arch}} = 0.782\,klf$

Wind Suction Load: $w_{wind.y} := 0klf$

$w_{wind.x} := \frac{L_{i.arch}}{2} \cdot P_{LL.wind} = 0.953 \cdot klf$

Crown Load: $w_{crown.y} := \gamma_{concrete} \cdot \left(h_{crown} \cdot b_{crown}\right) = 0.3 \cdot klf$

$w_{crown.x} := 0klf$

Construction LL: $LL_{construct} := 50psf$ *(assumed)*

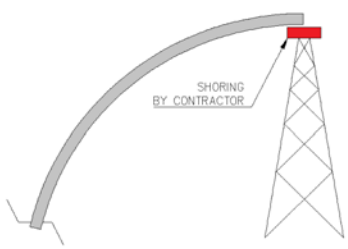
$w_{construct.y} := \frac{r_{i.arch}}{2} \cdot LL_{construct} = 0.6 \cdot klf$

$w_{construct.x} := 0klf$

6.2. Total Design Loads

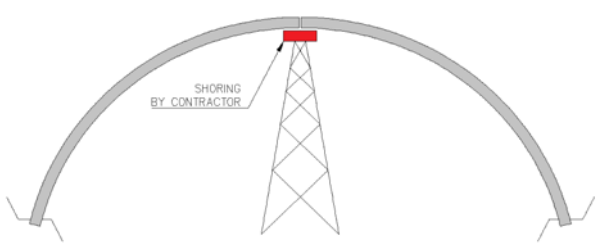
Half-Arch Loads: $w_{shoring.y1} := w_{panel.y} + w_{wind.y} + w_{construct.y}$ $\boxed{w_{shoring.y1} = 2.37\,klf}$

$w_{shoring.x1} := w_{panel.x} + w_{wind.x} + w_{construct.x}$ $\boxed{w_{shoring.x1} = 1.73\,klf}$

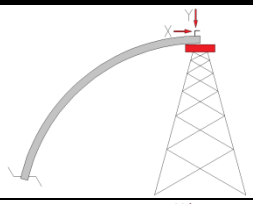
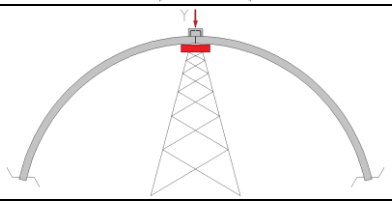


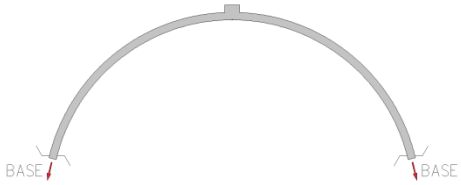
Complete Arch Loads: $w_{shoring.y2} := 2 \cdot \left(w_{panel.y} + w_{wind.y} + w_{construct.y}\right) + w_{crown.y}$ $\boxed{w_{shoring.y2} = 5.03\,klf}$

$w_{shoring.x2} := 0 \cdot \left(w_{panel.x} + w_{wind.x} + w_{construct.x}\right) + w_{crown.x}$ $\boxed{w_{shoring.x2} = 0\,klf}$



Design Reactions

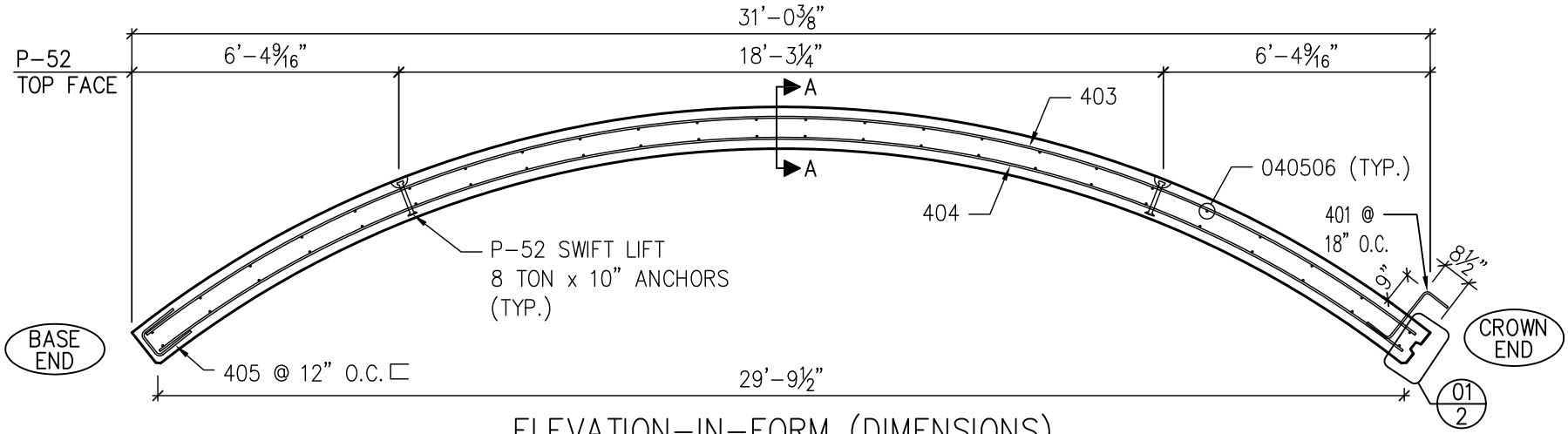
Loading Condition	Direction	Safe Working Load
	X	1,800 plf
	Y	2,400 plf
	Y	5,100 plf

Loading Condition	Direction	Maximum Factored Load
	BASE	8,300 plf

Analysis Program Output Data
(RISA-3D)

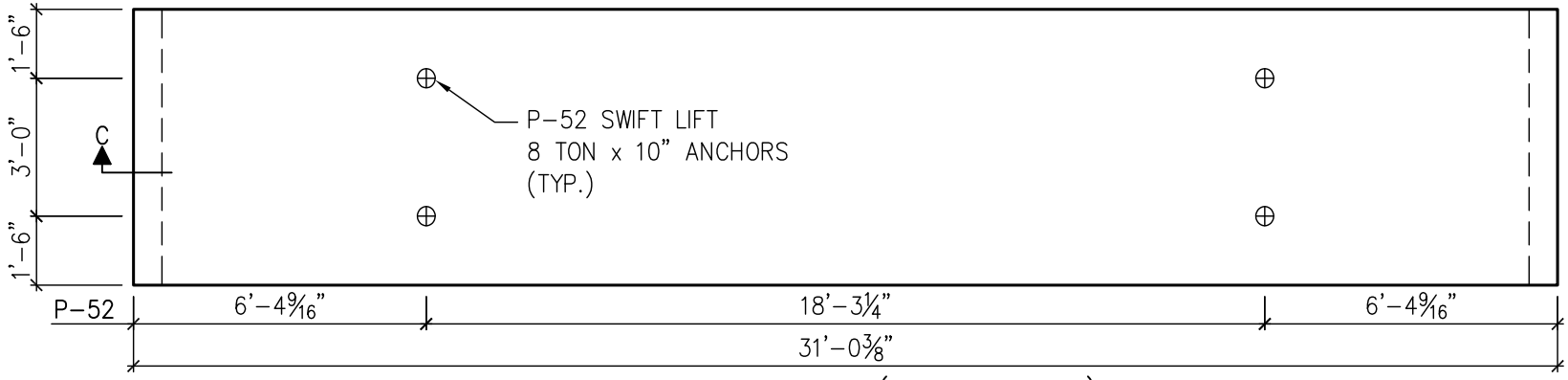
Member Label	LIFTING				SHIPPING				IN-PLACE			
	Sec	Axial[k]	y Shear[k]	z-z Moment[k-ft]	Sec	Axial[k]	y Shear[k]	z-z Moment[k-ft]	Sec	Axial[k]	y Shear[k]	z-z Moment[k-ft]
M1	1	0.000	0.000	0.000	1	0.000	0.000	0.000	1	48.466	-10.022	0.000
	2	-0.116	-0.154	0.016	2	-0.103	-0.163	0.017	2	47.914	-10.183	4.308
	3	-0.232	-0.308	0.066	3	-0.207	-0.325	0.070	3	47.361	-10.343	8.684
	4	-0.348	-0.461	0.148	4	-0.310	-0.488	0.157	4	46.808	-10.504	13.128
	5	-0.464	-0.615	0.263	5	-0.413	-0.651	0.279	5	46.255	-10.664	17.641
M2	1	-0.443	-0.631	0.263	1	-0.390	-0.665	0.279	1	46.885	-7.420	17.641
	2	-0.553	-0.789	0.415	2	-0.488	-0.831	0.439	2	46.345	-7.619	20.848
	3	-0.664	-0.946	0.601	3	-0.585	-0.997	0.634	3	45.805	-7.818	24.139
	4	-0.775	-1.104	0.821	4	-0.683	-1.163	0.866	4	45.264	-8.016	27.514
	5	-0.885	-1.262	1.074	5	-0.780	-1.329	1.133	5	44.724	-8.215	30.975
M3	1	-0.841	-1.292	1.074	1	-0.734	-1.356	1.133	1	45.187	-5.083	30.975
	2	-0.946	-1.454	1.368	2	-0.825	-1.525	1.441	2	44.662	-5.319	33.192
	3	-1.051	-1.615	1.697	3	-0.917	-1.695	1.786	3	44.137	-5.555	35.511
	4	-1.156	-1.777	2.060	4	-1.009	-1.864	2.167	4	43.612	-5.790	37.929
	5	-1.261	-1.938	2.457	5	-1.100	-2.034	2.584	5	43.087	-6.026	40.449
M4	1	-1.193	-1.981	2.457	1	-1.029	-2.071	2.584	1	43.401	-3.014	40.449
	2	-1.292	-2.146	2.899	2	-1.114	-2.244	3.046	2	42.894	-3.286	41.792
	3	-1.391	-2.311	3.376	3	-1.200	-2.416	3.545	3	42.386	-3.557	43.251
	4	-1.491	-2.476	3.889	4	-1.286	-2.589	4.081	4	41.879	-3.829	44.825
	5	-1.590	-2.642	4.437	5	-1.371	-2.761	4.653	5	41.371	-4.101	46.516
M5	1	-1.497	-2.695	4.437	1	-1.274	-2.808	4.653	1	41.557	-1.212	46.516
	2	-1.590	-2.864	5.032	2	-1.354	-2.983	5.273	2	41.069	-1.519	47.098
	3	-1.684	-3.032	5.663	3	-1.433	-3.159	5.931	3	40.582	-1.825	47.811
	4	-1.777	-3.201	6.331	4	-1.513	-3.334	6.626	4	40.094	-2.131	48.655
	5	-1.871	-3.369	7.034	5	-1.593	-3.510	7.359	5	39.607	-2.438	49.629
M6	1	-1.752	-3.433	7.034	1	-1.469	-3.563	7.359	1	39.681	0.324	49.629
	2	-1.840	-3.604	7.787	2	-1.542	-3.741	8.141	2	39.216	-0.016	49.563
	3	-1.927	-3.776	8.577	3	-1.616	-3.919	8.961	3	38.751	-0.355	49.642
	4	-2.015	-3.948	9.404	4	-1.689	-4.098	9.819	4	38.286	-0.695	49.866
	5	-2.102	-4.119	10.268	5	-1.763	-4.276	10.715	5	37.821	-1.034	50.235
M7	1	-1.957	-4.190	10.268	1	-1.612	-4.335	10.715	1	37.802	1.600	50.235
	2	-2.039	-4.365	11.184	2	-1.679	-4.515	11.663	2	37.362	1.229	49.632
	3	-2.120	-4.539	12.137	3	-1.747	-4.696	12.649	3	36.921	0.858	49.187
	4	-2.202	-4.714	13.128	4	-1.814	-4.876	13.674	4	36.481	0.487	48.901
	5	-2.283	-4.889	14.156	5	-1.881	-5.057	14.737	5	36.041	0.115	48.772
M8	1	-2.111	-4.965	14.156	1	-1.703	-5.120	14.737	1	35.946	2.623	48.772
	2	-2.187	-5.143	15.238	2	-1.764	-5.303	15.853	2	35.533	2.222	47.739
	3	-2.262	-5.320	16.358	3	-1.825	-5.485	17.008	3	35.119	1.821	46.877
	4	-2.337	-5.497	17.516	4	-1.885	-5.668	18.202	4	34.706	1.420	46.186
	5	-2.413	-5.675	18.712	5	-1.946	-5.851	19.435	5	34.293	1.020	45.666
M9	1	3.043	7.914	18.712	1	-1.741	-5.916	19.435	1	34.139	3.403	45.666
	2	2.974	7.734	17.037	2	-1.795	-6.100	20.721	2	33.755	2.975	44.306
	3	2.905	7.554	15.400	3	-1.849	-6.285	22.047	3	33.370	2.546	43.129
	4	2.835	7.374	13.802	4	-1.904	-6.470	23.413	4	32.986	2.118	42.135
	5	2.766	7.194	12.242	5	-1.958	-6.655	24.818	5	32.602	1.689	41.323
M10	1	2.513	7.287	12.242	1	-1.724	-6.719	24.818	1	32.405	3.953	41.323
	2	2.450	7.105	10.701	2	-1.772	-6.906	26.277	2	32.051	3.499	39.735
	3	2.387	6.922	9.200	3	-1.820	-7.093	27.775	3	31.698	3.045	38.340
	4	2.325	6.740	7.737	4	-1.868	-7.279	29.314	4	31.344	2.591	37.138
	5	2.262	6.558	6.313	5	-1.916	-7.466	30.892	5	30.991	2.136	36.130
M11	1	2.031	6.633	6.313	1	-1.654	-7.528	30.892	1	30.767	4.287	36.130
	2	1.975	6.449	4.913	2	-1.695	-7.717	32.524	2	30.446	3.809	34.404
	3	1.918	6.265	3.552	3	-1.737	-7.905	34.197	3	30.125	3.332	32.882
	4	1.862	6.080	2.230	4	-1.778	-8.093	35.909	4	29.803	2.854	31.563
	5	1.805	5.896	0.948	5	-1.819	-8.281	37.662	5	29.482	2.376	30.448
M12	1	1.598	5.956	0.948	1	-1.529	-8.340	37.662	1	29.246	4.422	30.448
	2	1.548	5.770	-0.307	2	-1.563	-8.529	39.468	2	28.958	3.923	28.669
	3	1.498	5.583	-1.522	3	-1.598	-8.719	41.315	3	28.671	3.424	27.102
	4	1.448	5.397	-2.698	4	-1.633	-8.908	43.202	4	28.384	2.925	25.749
	5	1.399	5.211	-3.834	5	-1.668	-9.098	45.130	5	28.097	2.426	24.608
M13	1	1.216	5.257	-3.834	1	-1.778	13.256	45.130	1	27.860	4.375	24.608
	2	1.172	5.069	-4.939	2	-1.806	13.065	42.312	2	27.608	3.857	22.853
	3	1.129	4.881	-6.004	3	-1.834	12.874	39.535	3	27.357	3.340	21.318
	4	1.085	4.694	-7.029	4	-1.862	12.684	36.799	4	27.105	2.822	20.005
	5	1.042	4.506	-8.014	5	-1.891	12.493	34.103	5	26.853	2.304	18.912
M14	1	0.884	4.540	-8.014	1	-2.326	12.420	34.103	1	26.628	4.167	18.912
	2	0.847	4.350	-8.966	2	-2.348	12.228	31.465	2	26.413	3.633	17.249
	3	0.810	4.161	-9.877	3	-2.369	12.036	28.867	3	26.198	3.099	15.814
	4	0.773	3.972	-10.748	4	-2.390	11.845	26.310	4	25.983	2.565	14.606
	5	0.736	3.783	-11.578	5	-2.412	11.653	23.795	5	25.767	2.031	13.626
M15	1	0.604	3.806	-11.578	1	-2.818	11.562	23.795	1	25.564	3.819	13.626
	2	0.574	3.616	-12.373	2	-2.832	11.370	21.340	2	25.386	3.271	12.114
	3	0.543	3.426	-13.127	3	-2.847	11.178	18.926	3	25.209	2.724	10.836
	4	0.513	3.235	-13.840	4	-2.862	10.986	16.553	4	25.031	2.176	9.792
	5	0.483	3.045	-14.512	5	-2.876	10.794	14.222	5	24.854	1.629	8.980
M16	1	0.376	3.060	-14.512	1	-3.252	10.686	14.222	1	24.680	3.354	8.980
	2	0.353	2.869	-15.147	2	-3.260	10.494	11.954	2	24.542	2.795	7.669
	3	0.329	2.678	-15.741	3	-3.268	10.301	9.728	3	24.403	2.237	6.597
	4	0.306	2.486	-16.293	4	-3.276	10.109	7.543	4	24.264	1.678	5.762
	5	0.282	2.295	-16.805	5	-3.284	9.916	5.399	5	24.125	1.119	5.166
M17	1	0.202	2.304	-16.805	1	-3.628	9.795	5.399	1	23.989	2.795	5.166
	2	0.185	2.112	-17.278	2	-3.630	9.603	3.323	2	23.889	2.228	4.095
	3	0.168	1.920	-17.709	3	-3.631	9.410	1.287	3	23.789	1.661	3.265
	4	0.151	1.728	-18.100	4	-3.632	9.217	-0.707	4	23.689	1.094	2.678
	5	0.135	1.536	-18.449	5	-3.633	9.025	-2.660	5	23.590	0.527	2.332
M18	1	0.081	1.539	-18.449	1	-3.947	8.892	-2.660	1	23.496	2.167	2.332
	2	0.071	1.347	-18.758	2	-3.941	8.700	-4.543	2	23.436	1.595	1.530
	3	0.061	1.155	-19.026	3	-3.936	8.507	-6.385	3	23.376	1.022	0.972
	4	0.051	0.962	-19.253	4	-3.930	8.314	-8.186	4	23.316	0.450	0.658
	5	0.040	0.770	-19.438	5	-3.925	8.122	-9.946	5	23.256	-0.123	0.589
M19	1	0.013	0.771	-19.438	1	-4.206	7.980	-9.946	1	23.208	1.496	0.589
	2	0.010	0.578	-19.583	2	-4.194	7.787	-11.633	2	23.188	0.920	0.073
	3	0.007	0.385	-19.686	3	-4.182	7.595	-13.280	3	23.168	0.345	-0.196
	4	0.003	0.193	-19.748	4	-4.170	7.403	-14.886	4	23.148	-0.230	-0.221
	5	0.000	0.000	-19.768	5	-4.157	7.210	-16.450	5	23.128	-0.806	0.000
M20	1	0.000	0.000	-19.768	1	-4.407	7.061	-16.450	1	23.128	0.806	0.000
	2	0.003	-0.193	-19.748	2	-4.388	6.869	-17.941	2	23.148	0.230	-0.221
	3	0.007	-0.385	-19.686	3	-4.369	6.677	-19.391	3	23.168	-0.345	-0.196
	4	0.010	-0.578	-19.583	4	-4.350	6.485	-20.801	4	23.188	-0.920	0.073
	5	0.013	-0.771	-19.438	5	-4.331	6.294	-22.169	5	23.208	-1.496	0.589

Member Label	LIFTING				SHIPPING				IN-PLACE			
	Sec	Axial[k]	y Shear[k]	z-z Moment[k-ft]	Sec	Axial[k]	y Shear[k]	z-z Moment[k-ft]	Sec	Axial[k]	y Shear[k]	z-z Moment[k-ft]
M21	1	0.040	-0.770	-19.438	1	-4.548	6.138	-22.169	1	23.256	0.123	0.589
	2	0.051	-0.962	-19.253	2	-4.523	5.947	-23.462	2	23.316	-0.450	0.658
	3	0.061	-1.155	-19.026	3	-4.497	5.756	-24.715	3	23.376	-1.022	0.972
	4	0.071	-1.347	-18.758	4	-4.472	5.565	-25.927	4	23.436	-1.595	1.530
	5	0.081	-1.539	-18.449	5	-4.446	5.374	-27.099	5	23.496	-2.167	2.332
M22	1	0.135	-1.536	-18.449	1	-4.631	5.216	-27.099	1	23.590	-0.527	2.332
	2	0.151	-1.728	-18.100	2	-4.599	5.026	-28.195	2	23.689	-1.094	2.678
	3	0.168	-1.920	-17.709	3	-4.566	4.836	-29.251	3	23.789	-1.661	3.265
	4	0.185	-2.112	-17.278	4	-4.534	4.646	-30.266	4	23.889	-2.228	4.095
	5	0.202	-2.304	-16.805	5	-4.502	4.456	-31.240	5	23.989	-2.795	5.166
M23	1	0.282	-2.295	-16.805	1	-4.655	4.296	-31.240	1	24.125	-1.119	5.166
	2	0.306	-2.486	-16.293	2	-4.616	4.107	-32.140	2	24.264	-1.678	5.762
	3	0.329	-2.678	-15.741	3	-4.577	3.918	-32.999	3	24.403	-2.237	6.597
	4	0.353	-2.869	-15.147	4	-4.538	3.729	-33.817	4	24.542	-2.795	7.669
	5	0.376	-3.060	-14.512	5	-4.499	3.541	-34.596	5	24.680	-3.354	8.980
M24	1	0.483	-3.045	-14.512	1	-4.620	3.381	-34.596	1	24.854	-1.629	8.980
	2	0.513	-3.235	-13.840	2	-4.575	3.194	-35.300	2	25.031	-2.176	9.792
	3	0.543	-3.426	-13.127	3	-4.529	3.007	-35.964	3	25.209	-2.724	10.836
	4	0.574	-3.616	-12.373	4	-4.484	2.820	-36.587	4	25.386	-3.271	12.114
	5	0.604	-3.806	-11.578	5	-4.438	2.632	-37.171	5	25.564	-3.819	13.626
M25	1	0.736	-3.783	-11.578	1	-4.528	2.476	-37.171	1	25.767	-2.031	13.626
	2	0.773	-3.972	-10.748	2	-4.476	2.290	-37.681	2	25.983	-2.565	14.606
	3	0.810	-4.161	-9.877	3	-4.424	2.104	-38.152	3	26.198	-3.099	15.814
	4	0.847	-4.350	-8.966	4	-4.372	1.919	-38.582	4	26.413	-3.633	17.249
	5	0.884	-4.540	-8.014	5	-4.320	1.733	-38.973	5	26.628	-4.167	18.912
M26	1	1.042	-4.506	-8.014	1	-4.378	1.581	-38.973	1	26.853	-2.304	18.912
	2	1.085	-4.694	-7.029	2	-4.319	1.398	-39.292	2	27.105	-2.822	20.005
	3	1.129	-4.881	-6.004	3	-4.261	1.214	-39.572	3	27.357	-3.340	21.318
	4	1.172	-5.069	-4.939	4	-4.202	1.030	-39.812	4	27.608	-3.857	22.853
	5	1.216	-5.257	-3.834	5	-4.144	0.847	-40.013	5	27.860	-4.375	24.608
M27	1	1.399	-5.211	-3.834	1	-4.171	0.701	-40.013	1	28.097	-2.426	24.608
	2	1.448	-5.397	-2.698	2	-4.106	0.520	-40.144	2	28.384	-2.925	25.749
	3	1.498	-5.583	-1.522	3	-4.041	0.339	-40.236	3	28.671	-3.424	27.102
	4	1.548	-5.770	-0.307	4	-3.977	0.157	-40.289	4	28.958	-3.923	28.669
	5	1.598	-5.956	0.948	5	-3.912	-0.024	-40.303	5	29.246	-4.422	30.448
M28	1	1.805	-5.896	0.948	1	-3.908	-0.161	-40.303	1	29.482	-2.376	30.448
	2	1.862	-6.080	2.230	2	-3.837	-0.340	-40.249	2	29.803	-2.854	31.563
	3	1.918	-6.265	3.552	3	-3.766	-0.519	-40.157	3	30.125	-3.332	32.882
	4	1.975	-6.449	4.913	4	-3.695	-0.698	-40.027	4	30.446	-3.809	34.404
	5	2.031	-6.633	6.313	5	-3.624	-0.877	-39.858	5	30.767	-4.287	36.130
M29	1	2.262	-6.558	6.313	1	-3.591	-1.004	-39.858	1	30.991	-2.136	36.130
	2	2.325	-6.740	7.737	2	-3.514	-1.180	-39.625	2	31.344	-2.591	37.138
	3	2.387	-6.922	9.200	3	-3.436	-1.357	-39.353	3	31.698	-3.045	38.340
	4	2.450	-7.105	10.701	4	-3.359	-1.533	-39.044	4	32.051	-3.499	39.735
	5	2.513	-7.287	12.242	5	-3.282	-1.710	-38.696	5	32.405	-3.953	41.323
M30	1	2.766	-7.194	12.242	1	-3.220	-1.823	-38.696	1	32.602	-1.689	41.323
	2	2.835	-7.374	13.802	2	-3.136	-1.997	-38.288	2	32.986	-2.118	42.135
	3	2.905	-7.554	15.400	3	-3.053	-2.171	-37.841	3	33.370	-2.546	43.129
	4	2.974	-7.734	17.037	4	-2.970	-2.344	-37.358	4	33.755	-2.975	44.306
	5	3.043	-7.914	18.712	5	-2.886	-2.518	-36.837	5	34.139	-3.403	45.666
M31	1	-2.413	5.675	18.712	1	-2.796	-2.617	-36.837	1	34.293	-1.020	45.666
	2	-2.337	5.497	17.516	2	-2.707	-2.788	-36.259	2	34.706	-1.420	46.186
	3	-2.262	5.320	16.358	3	-2.617	-2.959	-35.644	3	35.119	-1.821	46.877
	4	-2.187	5.143	15.238	4	-2.528	-3.129	-34.992	4	35.533	-2.222	47.739
	5	-2.111	4.965	14.156	5	-2.438	-3.300	-34.304	5	35.946	-2.623	48.772
M32	1	-2.283	4.889	14.156	1	-2.322	-3.383	-34.304	1	36.041	-0.115	48.772
	2	-2.202	4.714	13.128	2	-2.226	-3.551	-33.561	2	36.481	-0.487	48.901
	3	-2.120	4.539	12.137	3	-2.131	-3.718	-32.783	3	36.921	-0.858	49.187
	4	-2.039	4.365	11.184	4	-2.035	-3.885	-31.969	4	37.362	-1.229	49.632
	5	-1.957	4.190	10.268	5	-1.940	-4.053	-31.119	5	37.802	-1.600	50.235
M33	1	-2.102	4.119	10.268	1	-1.797	-4.118	-31.119	1	37.821	1.034	50.235
	2	-2.015	3.948	9.404	2	-1.696	-4.282	-30.220	2	38.286	0.695	49.866
	3	-1.927	3.776	8.577	3	-1.595	-4.446	-29.286	3	38.751	0.355	49.642
	4	-1.840	3.604	7.787	4	-1.494	-4.610	-28.316	4	39.216	0.016	49.563
	5	-1.752	3.433	7.034	5	-1.392	-4.774	-27.312	5	39.681	-0.324	49.629
M34	1	-1.871	3.369	7.034	1	-1.225	-4.820	-27.312	1	39.607	2.438	49.629
	2	-1.777	3.201	6.331	2	-1.118	-4.980	-26.262	2	40.094	2.131	48.655
	3	-1.684	3.032	5.663	3	-1.011	-5.141	-25.179	3	40.582	1.825	47.811
	4	-1.590	2.864	5.032	4	-0.904	-5.301	-24.061	4	41.069	1.519	47.098
	5	-1.497	2.695	4.437	5	-0.797	-5.461	-22.909	5	41.557	1.212	46.516
M35	1	-1.590	2.642	4.437	1	-0.606	-5.486	-22.909	1	41.371	4.101	46.516
	2	-1.491	2.476	3.889	2	-0.493	-5.642	-21.718	2	41.879	3.829	44.825
	3	-1.391	2.311	3.376	3	-0.381	-5.799	-20.493	3	42.386	3.557	43.251
	4	-1.292	2.146	2.899	4	-0.269	-5.955	-19.234	4	42.894	3.286	41.792
	5	-1.193	1.981	2.457	5	-0.156	-6.112	-17.942	5	43.401	3.014	40.449
M36	1	-1.261	1.938	2.457	1	0.057	-6.114	-17.942	1	43.087	6.026	40.449
	2	-1.156	1.777	2.060	2	0.175	-6.266	-16.617	2	43.612	5.790	37.929
	3	-1.051	1.615	1.697	3	0.293	-6.419	-15.259	3	44.137	5.555	35.511
	4	-0.946	1.454	1.368	4	0.411	-6.571	-13.869	4	44.662	5.319	33.192
	5	-0.841	1.292	1.074	5	0.529	-6.724	-12.445	5	45.187	5.083	30.975
M37	1	-0.885	1.262	1.074	1	0.763	-6.701	-12.445	1	44.724	8.215	30.975
	2	-0.775	1.104	0.821	2	0.886	-6.849	-10.995	2	45.264	8.016	27.514
	3	-0.664	0.946	0.601	3	1.009	-6.998	-9.512	3	45.805	7.818	24.139
	4	-0.553	0.789	0.415	4	1.132	-7.146	-7.998	4	46.345	7.619	20.848
	5	-0.443	0.631	0.263	5	1.256	-7.294	-6.452	5	46.885	7.420	17.641
M38	1	-0.464	0.615	0.263	1	1.510	-7.246	-6.452	1	46.255	10.664	17.641
	2	-0.348	0.461	0.148	2	1.638	-7.390	-4.885	2	46.808	10.504	13.128
	3	-0.232	0.308	0.066	3	1.766	-7.534	-3.288	3	47.361	10.343	8.684
	4	-0.116	0.154	0.016	4	1.894	-7.678	-1.659	4	47.914	10.183	4.308
	5	0.000	0.000	0.000	5	2.022	-7.822	0.000	5	48.466	10.022	0.000
			Due To Unfactored Selfweight				*Due To Unfactored Selfweight*				*Due To Factored Load (per Strength IV LS)*	
MAX		3.04	7.91	18.71		2.02	13.26	45.13		48.47	10.66	50.24
MIN		-2.41	-7.91	-19.77		-4.66	-9.10	-40.30		23.13	-10.66	-0.22



ELEVATION-IN-FORM (DIMENSIONS)

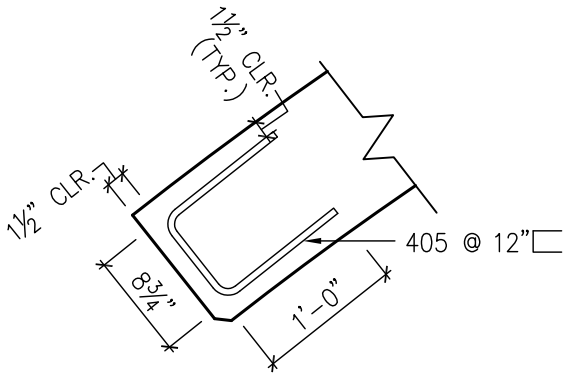
SCALE: 1/4" =1'-0"



PLAN-IN-FORM (DIMENSIONS)

SCALE: 1/4" =1'-0"

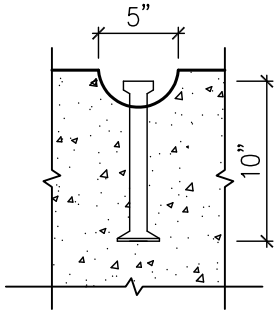
NOTE: REINF. NOT SHOWN FOR CLARITY.



SECTION C

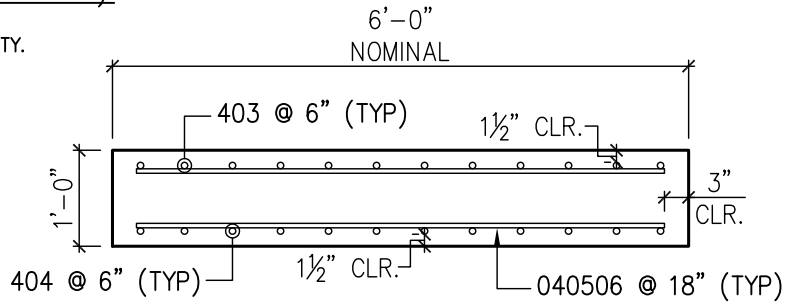
SCALE: 3/4" = 1'-0"

NOTE: PRIMARY REINFORCEMENT NOT SHOWN FOR CLARITY



SWIFT LIFT ANCHOR DETAIL

SCALE: 1" = 1'-0"



SECTION A-A

SCALE: 1/2" =1'-0"

NOTE: VERIFY 1.5" CLEAR COVER WITH E.O.R.

DRAWN BY	AAT	Eriksson technologies	DWG TITLE: ARCH PANEL DETAIL	
DATE	11/13/2013			
CHECKED BY	RAS	TAMPA, FL ■ 813.989.3317 ■ LRFD.COM	CLIENT: J.P. CARRARA	PROJECT: SAND HILL BRIDGE / SHEET NO: 1 OF 3
DATE	11/13/2013			

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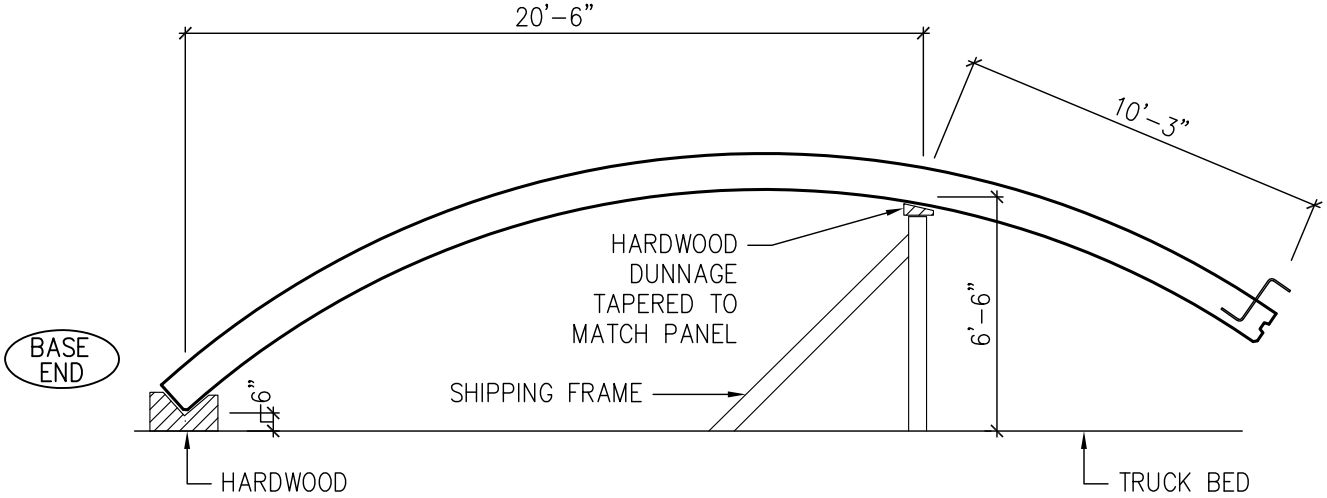
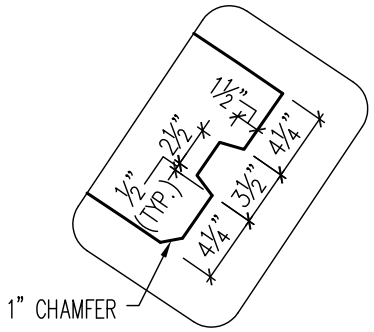


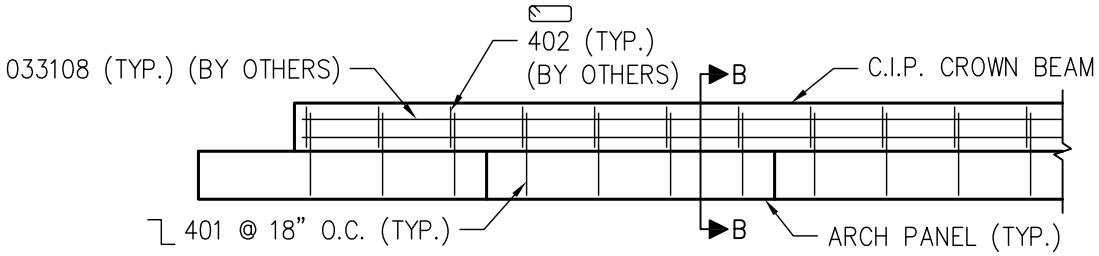
ASSUMED SHIPPING CONFIGURATION

SCALE: 3/16" =1'-0"
NOTE: REINF. NOT SHOWN FOR CLARITY.



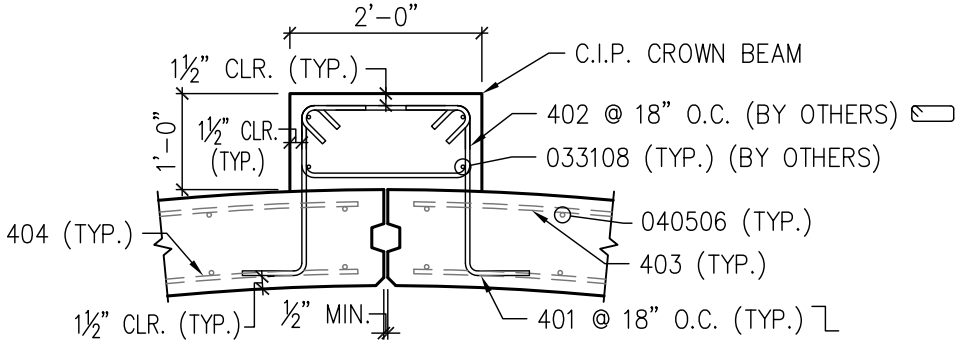
01/1 DETAIL 01

SCALE: 1"=1'-0"



C.I.P. CROWN BEAM DETAIL

SCALE: ¼" =1'-0"



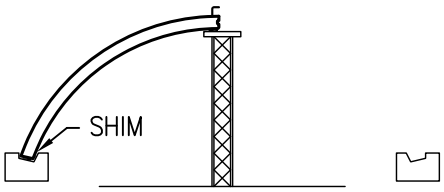
SECTION B-B

SCALE: 1/2" = 1'-0"

MATERIAL SPECIFICATIONS	
TYPE	*DESCRIPTION*
PRECAST CONCRETE	STRIPPING STRENGTH: 4,000 PSI
	28 DAY STRENGTH: 6,500 PSI
C.I.P. CONCRETE	MINIMUM STRENGTH AT REMOVAL OF SHORING 4,000 PSI

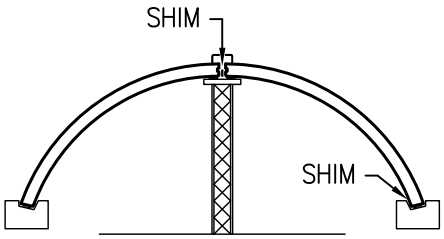
DRAWN BY	AAT	Eriksson technologies	DWG TITLE: CROWN BEAM DETAIL		
DATE	11/13/2013				
CHECKED BY	RAS	TAMPA, FL ■ 813.989.3317 ■ LRFD.COM	CLIENT:	PROJECT:	SHEET NO:
DATE	11/13/2013	© 2013 ERIKSSON TECHNOLOGIES, INC. ALL RIGHTS RESERVED	J.P. CARRARA	SAND HILL BRIDGE	2 OF 3

ARCH ERECTION SEQUENCE



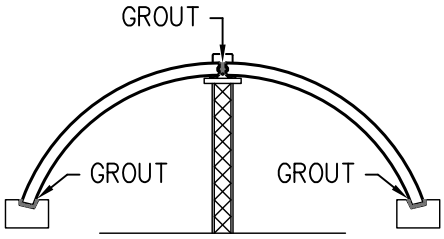
STAGE 1
N.T.S.

STAGE 1
a. PLACE BEARING END OF PANEL ON FOUNDATION AND SHIM SUPPORT.
b. LOWER CROWN END OF PANEL ONTO SHORING AND ADJUST TO PROPER ELEVATION.



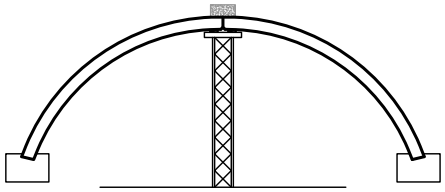
STAGE 2
N.T.S.

STAGE 2
a. REPEAT STAGE 1 FOR OPPOSITE PANEL.
b. PLACE SHIMS BETWEEN PANELS AT CROWN.



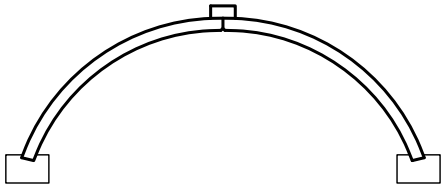
STAGE 3
N.T.S.

STAGE 3
a. REPEAT STAGES 1 AND 2 FOR ALL ARCH PANELS.
b. PLACE BACKER ROD AT BOTTOM OF SHEAR KEY.
c. FILL SHEAR KEY AND BASE CONNECTIONS WITH APPROVED NON-SHRINK GROUT.
d. ALLOW GROUT TO OBTAIN MINIMUM OF 6,500 PSI STRENGTH.



STAGE 4
N.T.S.

STAGE 4
a. FORM AND CAST CROWN BEAM AS SHOWN.
b. ALLOW CROWN BEAM TO OBTAIN MINIMUM OF 4,000 PSI STRENGTH.



STAGE 5
N.T.S.

STAGE 5
a. REMOVE SHORING

DRAWN BY	AAT	Eriksson technologies	DWG TITLE: ASSUMED ARCH ERECTION SEQUENCE		
DATE	11/18/2013				
CHECKED BY	RAS	TAMPA, FL ■ 813.989.3317 ■ LRFD.COM	CLIENT:	PROJECT:	SHEET NO:
DATE	11/19/2013		J.P. CARRARA	MIDDLEBURY	3 OF 3

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