USING FABRICATION & METROLOGY ADVANCES TO HELP UNITE A CANAL-DIVIDED CITY WITH A SKEWED, CURVED PRE-ERECTED MULTI-SPAN PEDESTRIAN-PARK BRIDGE

BOB CISNEROS

BIOGRAPHY

Bob has been with High Steel Structures, LLC since 1996, serving as Chief Engineer since 2004.

He developed a love for bridge building while working with a general contractor, then as a bridge inspector, a construction inspector, and also as a bridge designer. He enjoys the challenges and learning experiences that arise in bridge construction.

Bob holds a bachelor's degree in (Civil) Engineering from Cornell University, and is a professional engineer. He also holds a Welding Engineer Designation under Canadian Standard W47.1 for Division I Fabrication, an AWS Welding Supervisor Certification, and has been a certified welder.

A member of the Associated Pennsylvania Constructors Bridge Committee, the AASHTO/NSBA Task Groups for Analysis and Erection of Steel Bridges, Bob participates in various industry efforts to enhance constructability, and promote safe bridge fabrication and erection practice. He also likes to volunteer with relief organizations on church and community construction projects.

SUMMARY

The Mohawk Valley Pedestrian Overlook is a park-like, skewed, haunched and curved multi-girder bridge over the historic Erie Canal. The specifications for this project required camber verification under steel dead load. This resulted in the bridge being assembled twice – once in the fabricator's yard, and once in the field. Each erection crew employed a their own means and methods under quite different site conditions, creating a tremendous opportunity to observe the affect of erection sequence on a steel bridge's profile.

This author will review various modern engineering tools and manufacturing technologies that were used to fabricate, assemble, and measure the bridge's horizontal and vertical alignment, as preparations were made for the steel dead load check. In addition, interesting architectural details, as well as the historical significance of the Erie Canal over which this beautiful structure gracefully spans, will be discussed.

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Keywords
Fabrication, metrology, skewed, haunched girder, horizontally curved, extent of assembly needed, dead load fit, three-dimensional bridge modeling, drone.

Abstract
Advanced manufacturing and engineering tools were used to fabricate, construct and measure a rather unique structure, for which project specifications (girder dead load camber verification) necessitated special assembly at the fabricator's facility. Under near-laboratory conditions for geometric evaluation, the structure was assembled to no-load profile on falsework during the winter, then released to the steel dead load condition. In contrast, field erection sequence commenced with line girder assembly of approach spans, followed by "drop-in" installation of the closure (keystone) piece, with falsework only in the main span during the spring construction season. This provided an opportunity for the author to observe and measure the effects of erection method and season on bridge horizontal control and vertical profile, relative to recent advances in the literature regarding construction engineering of curved and skewed steel bridges, as well as the detailing of crossframes for intended fit condition.

Models and a visual tour facilitated by the erector's drone technology will hopefully inspire the reader with an appreciation of the structure's architectural details, and visually pleasing horizontal and vertical curvature. Qualitatively, this gateway bridge is seen by the author to enhance the remnants of historic infrastructure, and to aesthetically improve socio-economic access to the surrounding community.

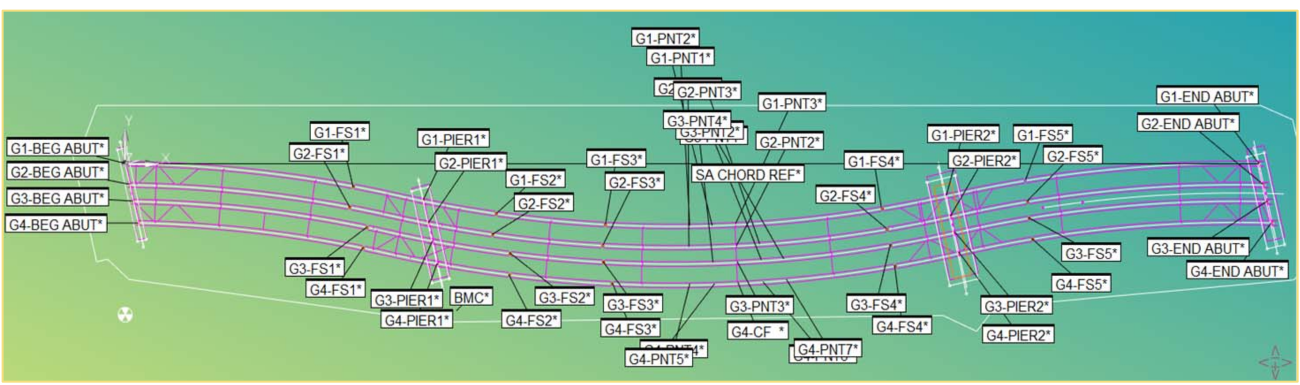

Figure 1 – Bridge Horizontal Control At Completion Of Loaded Assembly In Lancaster, Pennsylvania

Introduction
Heavier than the typical pedestrian bridge, with a lovely haunch-girder vertical profile and pronounced architectural horizontal curvature, the Mohawk Valley Gateway Overlook (MVGO) Pedestrian Bridge is a park-like structure that links both halves of the City of Amsterdam, New York.

This bridge spans the historic Erie Canal, and its architectural nature invites the passer by to reflect upon the vibrant, creative energy that engineers, architects, surveyors and bridge builders can invest toward the enrichment of society and culture. It also serves as an example of how a structure can be used to re-connect the municipal divisions that occasionally result from rivers, and infrastructure works such as canals, rail lines (the cliché "across the tracks") and urban arterials such as Boston's former Central Artery Viaduct.

Furthermore, its rare assembly (and re-assembly) hold history lessons for the present day bridge erection engineer, the project having specified pre-assembly to verify Total Dead Load Fit (TDLF) geometry at the fabrication facility prior to field erection. This requirement shed some light upon the effect of erection sequence upon a curved, skewed & haunched (variable web depth) steel multi-girder bridge.

With a bridge length of five hundred twenty feet, the six hundred ton steel superstructure was fabricated using innovative (computer) numerically controlled (CNC), full-sized hole (FSH) practice but using 3/16" sub-sized diameter holes (for reaming) then assembled at the High Steel Structures, LLC (HSSL) Lancaster Yard facility. Figure 2 (below) shows primary member sub-assemblies at the fabrication stage.

During assembly, metrology/shop survey tools such as a robotic total station were used to control bridge geometry at the No-Load (NL) position, and observe deflections at Steel Dead Load (SDL) position (shown in Figure 1, above).

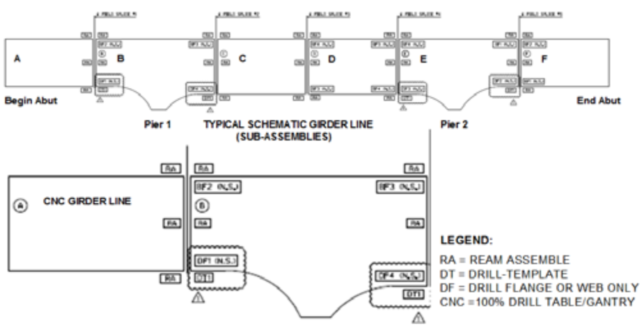

Figure 2 – Schematic Girder Elevation. Girder Fabrication Methods Utilized For Field Sections.

Canal Site Historical Significance

Located a few hundred feet west of the mainline Route 30 Bridge over Amtrak, the Erie Canal and Front Street in Downtown Amsterdam, New York, an architectural rendering of the completed MVGO structure is shown in Figure 3.

The Erie Canal holds a special significance to American History, as well as to the civil engineering and surveying professions. Most mid-nineteenth century American civil engineers (and also surveyors) had either been trained by Erie Canal Chief Engineer Benjamin Wright, or by someone who had worked for him during the construction of "Clinton's Ditch", which extended from Lake Erie to the Hudson River.

Figure 3 – Architectural Rendering of the MVGO

The visitor to the Erie Canal Museum in Syracuse, New York (Figure 4) will observe that settlers, up to the early 1800's, would find that their westward journey began with a long, meandering and arduous trek across the breadth of New York State, lasting several weeks along bumpy corduroy roads.

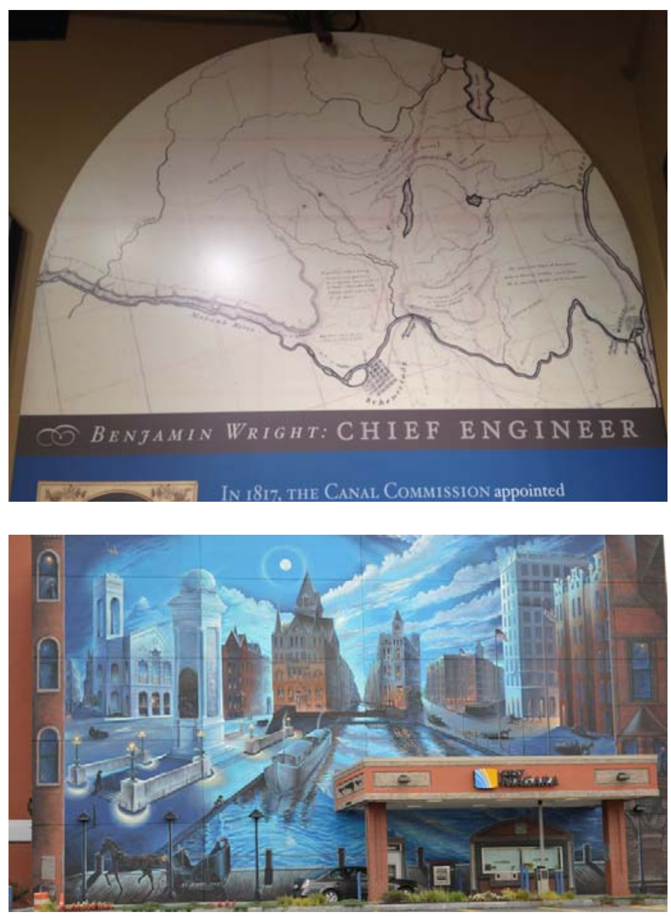

Figure 4 Clinton's Ditch, an eighth world wonder.
Top – exhibit near entrance to Erie Canal Museum
Bottom – nearby mural, downtown Syracuse, NY.

Upon completion of the Erie Canal, one of our nation's first super highways, large commodity and passenger boats could be hauled alongside towpaths across the state in as little as eleven days (1).

Looking at the mural of the Erie Canal that once ran through the heart of the City of Syracuse, one can imagine the wondrous sense of adventure in that exciting time. Today, the weigh-lock, an early toll booth, remains as the heart of the museum, with a canal boat in the lock which visitors may explore.

The new MVGO Pedestrian Bridge follows a similar gracefully meandering horizontal curvature reminiscent of the winding Canal over which it spans. Considering the innovation exhibited by the nineteenth century canal builders, engineers and surveyors, it is appropriate that, in the twenty-first century, fairly state-of-the-art civil engineering and surveying technologies were used for the MVGO structure overlooking the canal that was once considered an eighth wonder of the world.

Project Development and Description

A signature architectural bridge bearing a city park can link a city at its heart. Such a project often takes much up front design effort, inter-agency coordination and community engagement. The process of selecting the final MVPO design involved winnowing out several alternatives through public input, project sponsor and permitting agency requirements, and budget.

Open public meetings were held where design alternative pros and cons were presented through renderings, construction and cost estimates; one example, a lovely early cable-stayed alternate structure rendering with architecturally twisted piers (2), is seen in Figure 5. Voting, conducted via ballot boxes at the meeting site and City Hall, reduced the number of potential alternatives; preliminary engineering further eliminated alternatives with large in-water substructures, due to floodway permitting. During the design and permitting process, the bridge's north end was also relocated about 50 ft east in order to avoid an archaeologically sensitive area.

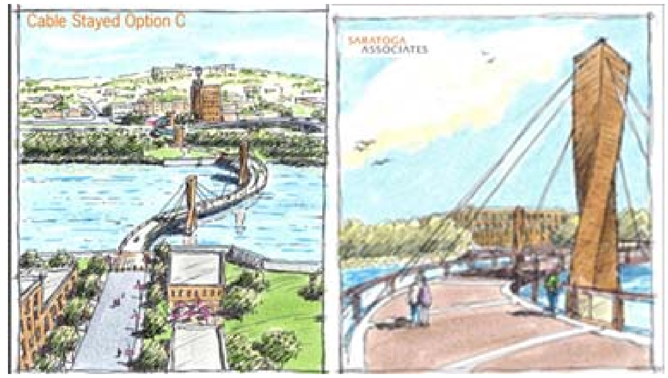

Figure 5 Early Concept Structure Option.

The final structure is a tree-lined, meandering, park-like pedestrian thoroughfare with provision for emergency vehicle crossing. It progresses horizontally thru (W-shaped) S-curve reversals and is supported by skewed, parallel piers. The three spans measure 135 ft, 235 ft and 141 ft along the bridge centerline (station line), with steel plate girders at 9'-0" maximum spacing. Beyond each pier a fifteen foot long cantilevered, westward facing belvedere (overlook) extends in a sleek semicircle, offering a stunning view of the Erie Canal.

The project owner specified steel dead load deflection checks during fabrication, in addition to the usual field erection and slab formwork checks. This requirement (3) provided an opportunity to evaluate and observe three-dimensional geometry and (crossframe) detailing for intended erected position, relative to recent industry advances regarding construction engineering for bridge curvature and skew, such as (4) NCHRP's Report 725, (5) the AASHTO/NSBA Guidelines G13.1 (Bridge Analysis), and (6) AISC's "Skewed and Curved Steel I-Girder Bridge Fit", etc.

Skewed-Curved Bridge Terminology

The industry resources listed do a fine job of explaining in-depth the twisting and un-twisting that a curved, skewed bridge undergoes as steel and slab concrete dead load accumulates, and structural camber dissipates. (The reader is directed these treatises for additional information that is not reproduced in this paper.) That being said, this structure was detailed to the Total Dead Load Fit (TDLF) condition, so that the crossframes' diagonal, top and bottom strut connections reflect final super-elevation and cross-slope of the bridge, as seen in the section below (Figure 6).

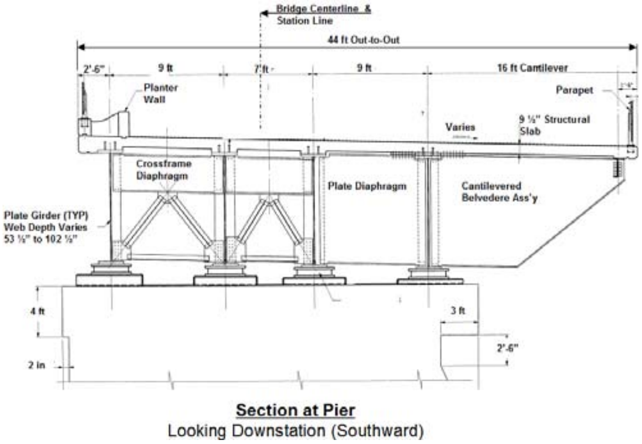

Figure 6 – Superelevation along Bridge Pier

Determining Extent of Assembly Needed

Structural steel is a well-understood structural material to the extent that AASHTO permits a constant Young's Modulus assumption for all grades (7), and NL Profile camber checks are often considered adequate to achieve bridge alignment within AASHTO/AWS D1.5 Bridge Welding Code and New York State Steel Construction Manual fabrication and assembly tolerances. Consequently, a multi-girder bridge will typically be assembled as follows:

- straight (horizontal tangent), constant web-depth bridge girder field section camber is checked in the no-load position. When SDL profile check is required by contract, the piece deflection can be measured while supported at/very near the ends (statically determinate).
- Horizontally (gently) curved, constant web-depth girders are checked supported at/near the quarter points (for torsional stability). (8)
- Sharply curved, haunched (variable web depth), skewed or especially stiff units may warrant partial assembly, to ensure lateral bracing and plate diaphragms fit.
- Especially complex or stiff structure types, such as the merging trapezoidal box (tub) spans or dense transfer frames shown in Figure 15, may warrant a complete structure assembly.

For this project, with rigid overlook belvederes, skewed pier plate diaphragms and steel DL deflection verification requirement, it was felt that the skewed, reversed curvatures warranted unit assembly, with those crossframes needed for lateral and torsional stability (about 60% of final frames and braces).

Modern Fabrication Methods Used

Referring again to Figure 2, had steel DL camber checks not been required (i.e., only the usual NL profile girder camber checks), the girder assemblies would have simply been drilled as follows:

1. A, C, D and F girders (field sections) would be CNC drill-line gantry prepared, using full-sized (FSH) methods, then heat curved to final radius
2. B and E girder webs, being parabolically haunched and curved with skewed supports, would have been drilled FSH at both web ends. Flanges would be drilled FSH at one end, then aligned to the webs and drilled at the other end.
3. Girder line(s) would have been check-fit for cambered field splice alignment, for a minimum of three-continuous pieces or 150 ft length, minimum.
4. Line G1 and G2 B & E sections would have been partially assembled to verify PD and belvedere alignment, then reamed in place.
5. Except for the PD's used in the belvedere check assembly, all crossframes, diaphragms and planter/utility supports would be fabricated via FSH practiced, with no assembly necessary.
6. Lateral Braces (LB) would be FSH drilled (typically OSH used at one connection ply).

Since, however, SDL profile checks were required, a hybrid fabrication method was utilized, combining the above but with 1/4" sub-sized holes which were reamed at assembly, both at the girder field splices and also at the belvedere PD assemblies. See Figure 7.

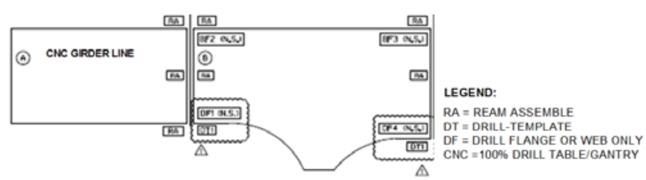

Figure 7 – Typical Hole Preparations

Benefits Realized Via Assembly

Due to the dead load profile verification requirement, skew, curvature plus variable web-depth, the author decided that the nearly complete assembly shown was needed. In hindsight, this special, nearly complete structure assembly brought certain items to light for ready resolution:

1. Belvedere constructability. Several connections in Figure 8 were quite tight (limited drill access), the observation of which determined sequence of piece installation.
2. Bearing stiffener alignment. The pedestrian structure's pronounced vertical and horizontal S-curve geometry is visually pleasing, but certain detail geometries proved contrary to builder expectations. At Pier 1, the complex confluence of skew, superelevation, variable web depth, vertical and horizontal curvature reversal was downright non-intuitive at Pier 1, to the extent that the G1 (belvedere) fascia girder's outboard bearing stiffener was canted oppositely (downstation) to its interior twin (adjacent G2 through G4 bearing stiffeners were also canted upstation at NL profile). G1's end-rotation was, in fact, misinterpreted as a detail error by a well-intended builder, who then installed and welded it parallel to its neighbors. The misfit was fortunately caught during PD installation, proving a nuisance rather than a major jobsite delay (had this portion of the structure not been trial assembled).
3. Lateral bracing (LB) alignment verifications. For a variable depth girder, LBs will require two-way tapered fill plates, since each end of each brace intersects a girder along a different point in the parabola (Figure 8, lower left).

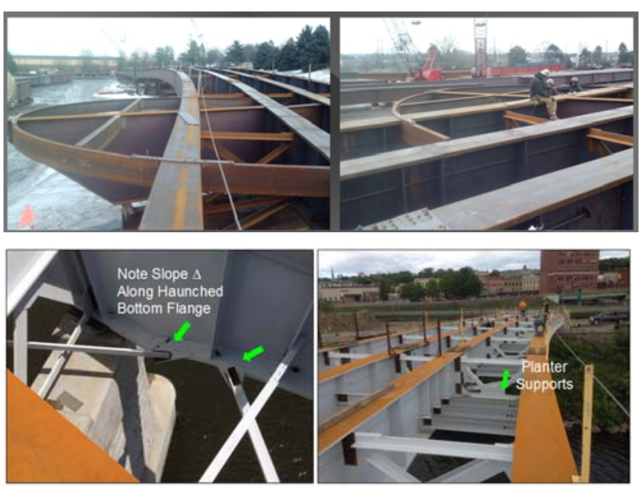

Figure 8 – Belvedere, Haunch LB and Planters

Yard and Field Assembly

Falsework. Temporary substructures were selected to emulate the abutments and piers. Steel dead loads were computed, and a 3D, stiffness based model was created. Parabolic haunches were approximated using tapered sections (as shown in Figure 9, the program selected uses a symmetrical taper), and deemed sufficiently accurate to size the temporary footings using a conservative $p_A \sim 1$ tsf (compacted gravel). See Table 1.

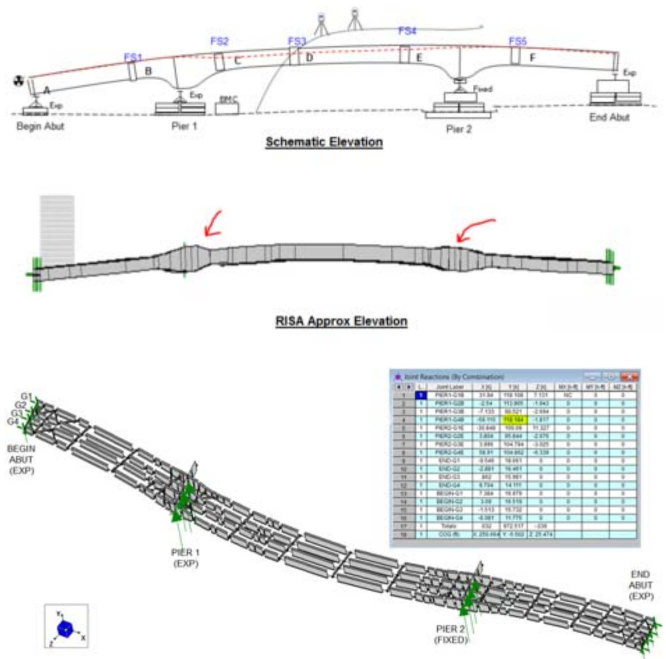

Figure 9 – Approximate Steel DL Model

Joint Reactions (By Combination)

	L...	Joint Label	X [k]	Y [k]	Z [k]	MX [k-ft]	MY [k-ft]	MZ [k-ft]
1	1	PIER1-G1B	31.94	118.108	7.131	NC	0	0
2	1	PIER1-G2B	-2.54	113.905	-1.943	0	0	0
3	1	PIER1-G3B	-7.133	90.521	-2.694	0	0	0
4	1	PIER1-G4B	-59.115	118.184	-1.817	0	0	0
5	1	PIER2-G1E	-30.848	100.09	11.327	0	0	0
6	1	PIER2-G2E	3.804	95.844	-2.676	0	0	0
7	1	PIER2-G3E	3.996	104.784	-3.025	0	0	0
8	1	PIER2-G4E	58.91	104.862	-6.339	0	0	0
9	1	END-G1	-9.546	18.661	0	0	0	0
10	1	END-G2	-2.881	16.461	0	0	0	0
11	1	END-G3	.862	15.981	0	0	0	0
12	1	END-G4	9.704	14.111	0	0	0	0
13	1	BEGIN-G1	7.384	16.979	0	0	0	0
14	1	BEGIN-G2	3.09	16.519	0	0	0	0
15	1	BEGIN-G3	-1.513	15.732	0	0	0	0
16	1	BEGIN-G4	-6.081	11.775	0	0	0	0
17	1	Totals:	.032	972.517	-.036			
18	1	COG (ft):	X: 250.664	Y: -5.502	Z: 25.474			

Table 1 – Superstructure DL Reactions, kips

Temporary Bearings. Following the Contract Plan Design bearing alignment was developed during the yard assembly as follows:

- both abutments, being expansion and supporting short spans, were at grade footings (grade beam, with crane mat on stone dust atop yard compacted gravel, in turn above a "hardpan" stratum)
- Pier 1 was sized for the larger expansion reactions.
- Pier 2 was fixed. In order to control the snake-like, reversed S-curve, an excavated key was filled with crushed stone bedding to develop passive resistance in event of thermal ratcheting (short-term). Temporary steel bearings were clamped to the girder bottom flanges. The Fixed Pier and bearings are shown in Figure 10.

Figure 10 – Temporary Fixed Pier, Bearing

The field sections were then sequentially erected on intermediate towers to the steel NL (fully cambered) vertical profile & horizontal alignment; from Figure 11, the reader may visualize the dramatic camber at this condition, as well as the extensive falsework needed to shore the superstructure in the no-load position.

Figure 11 – Intermediate Falseworks

Yard Assembly Sequence. The erection sequence simply progressed from A through F girders, lifted via a pair of yard truck cranes and supported along span quarter points via intermediate falseworks composed of High Steel's modular shoring atop one-inch road plates.

Temporary Field Splices and Reaming. Bolting of field splices was a challenge and required careful staging to permit the reaming operation, since the holes were subsized to 11/16" (vs. the usual 15/16" diameter). From erection analysis, it was determined that approximately 50% of bolts evenly distributed should allow for steel gravity load plus moderate erection stresses. The Project subsequently accepted reaming at no-load profile, which was considered safer than reaming under steel DL. This meant, however, that the closest feasible no-load profile be established, to validate predicted dead load behavior. So with 50% of the 5/8" diameter bolts installed to hold profile, remaining holes were reamed to FSH and 7/8" Diameter, A325 bolts installed for maximum connection effectiveness; the temporary web bolt pattern is shown in Figure 12.

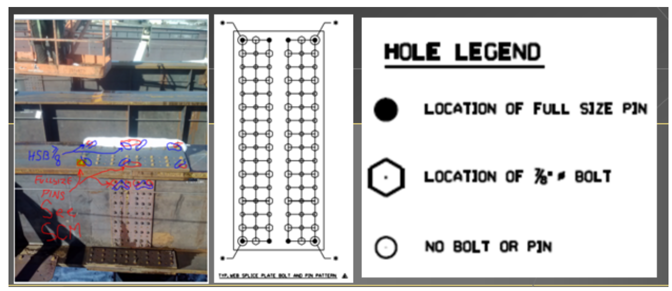

Figure 12 – Staged bolting sequence

Upon assembly, and with temporary LB's at key locations (see Figure 1), load was then transferred from intermediate falsework to the temporary substructures intended to simulate short-term final bridge abutment and pier geometry, bearing alignment and fixity.

Yard Assembly Measurement Methods.

A robotic total station was used that permitted a useful combination of survey and metrology (shop survey) techniques in the construction of the temporary substructures, the setting of field splices to NL profile, and the checking of steel DL deflection & alignment of the structure. Key steps in this process follow:

1. **Footprint.** A portion of High Steel's assembly yard was cordoned off to allow the 65 ft wide by 540 ft long assembly, as well as a suitable perimeter for crane, trailer (girder delivery), boom truck and lift access (Figures 1 and 13).
2. **Contouring.** Within the designated yard assembly area, a bridge alignment was chosen to take advantage of slight grade for drainage and, given the pronounced vertical curvature, to minimize overall falsework height (optimal worker safety via fall exposure limit).

3. **Footing Stakeout.** Control points were established for centerline bearings at each substructure; corners were laid out for footing cut (Pier 2 excavation depth) and fill (both Abutments and Pier 1 bottom of footing).

4. **Falsework placement**. The intersection of centerline bearing and centerline girders serves as bearing points, which were laid out GPS-style via 360 degree prism, directed by the total station operator and aligned to a theoretical control model.

5. **Girder Profiles and Horizontal Control**. As erection progressed, no-load profile was monitored and girder workpoints transferred from bearing point to top of steel (allowing for girder end rotations). See Figure 14.

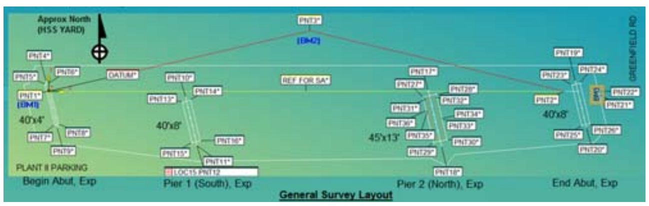

Figure 13 – Footprint of Temporary Substructures

Figure 14 – Steel DL Profile Verification

Yard Erection Observations

The structure was progressively assembled and reamed in the yard during winter. At times, the ground was frozen and iced over (see Figure 11). Trial loading occurred during the early spring (Figure 14), and final profile was accepted in April. At times, operations were suspended due to high wind, or until snow melted, was swept from the steel (or simply blew away) sufficiently to permit safe work access for bolting/alignment operations to continue (Figure 12).

At no-load profile, the structure was approximately 1/4" low in the mainspan, despite additional shimming to maximum feasible positive profile. A summary of final no-load variance is shown in Table 2 (prior to reaming).

Surveys 2/17/15 & 2/18/15 (between squalls)

Location	G1	G2	G3	G4
Begin Abutment	- 1/8	3/8	1/4	Datum 0
FS #1	- 1/8	- 1/8	-0	1/4
Pier 1	1/2	1/8	1/8	3/8
FS #2	1/4	- 1/8	-1/4 - ~~1/2~~	- 3/8
FS #3	-0	-1/8 - ~~3/8~~	-1/8 - ~~3/8~~	- 1/4
FS #4	1/8	- 1/4	- 1/4	- 1/8
Pier 2	0	0	1/8	1/8
FS #5	- 1/4	-1/8 - ~~1/2~~	- 1/8	1/8
End Abutment	- 1/4	- 1/8	1/8	- 1/4

Profile: Approx No-load

Table 2 – Shop Assembly I (No-Load Profile) Best-Fit Measurements; variance shown in inches

Load transfer from intermediate falsework coincided with spring thaws, and Piers 1 & 2 were seen to elastically displace approximately ½". Torsional (horizontal curve) effect was observed, along with slight main span relaxation and corresponding re-cambering of side spans. Over the course of three weeks, the structure settled into the profile shown in Table 3.

Control Point Survey 3/31/2015

Location	G1	G2	G3	G4
Begin Abutment	0	1/2	0	0
FS #1	-0	1/4	1/2	3/4
Pier 1	1	- 3/8	- 1/4	1/4
FS #2	- 1/2	-1	-1	-1
FS #3	- 1/2	-1	-1	- 3/4
FS #4	- 1/4	-0	- 1/2	- 5/8
Pier 2	- 1/8	1/4	- 1/8	-0
FS #5	- 1/4	1	1/2	1 1/4
End Abutment	1/4	1/8	0	- 1/8

Profile: Steel Dead Load (50% CF Load)

Tolerance: Abutments, Piers: +/- 1/8"
Field Splices: +3/4, -0

References: NYS SCM Sections 1104 excl FS, & 1214
Contract Plan Sheet GN-02, Camber Notes 1,11

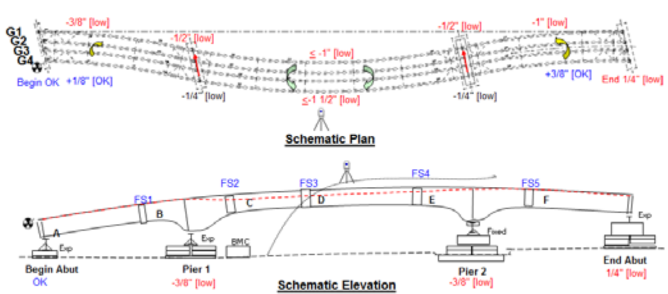

Table 3 – Steel DL Profile Summary

During this time, it was noted that:

1. fairly uniform ½" elastic settlement remained at both piers after transfer of steel DL from intermediate falsework.
2. Spring thaw resulted in ½" additional settlement.
3. upon transfer of steel dead load, the structure was seen to relax, abutment ends being in slightly expanded positions during late winter/early spring temperatures.

It is believed that the temporary piers on yard "hardpan" simply could not compete with the robustness of a fully-designed and well-founded permanent pier or footing. That being said, most fabricators simply do not have provision for indoor, room temperature deflected bridge superstructures (on customized concrete foundations) and so, given the practical limitations of building a bridge on short-term, re-usable site strata, the author is overall quite pleased with the results, fabricators generally not being set up for indoor assembly except for smaller structure footprints (Figure 15).

Figure 15 – Indoor/Pre-loaded Assembly (usually only feasible for smaller-footprint bridge structures)

Field Erection

In the field, approach spans were built first, followed by "drop-in" installation of the closure (keystone) piece using a falsework within the canal for the main span during the field construction season. See Figure 16.

Figure 16 – Field Erection Sequence

The structure was erected by May, 2015, providing a long-sought opportunity for the author to observe the effects of erection method and season on bridge horizontal control and vertical profile (inspired by earlier works on the subject by Linzell et al, Cozy etc).

Comparison: Field To Shop Erection

Figure 17 illustrates the parallel Shop Assembly and Field Erection sequences. The upper sketches show how the bridge was erected, abutment to abutment, upon regularly spaced intermediate falseworks. The lower sketches illustrate the approach spans being erected first, followed by the main span on a canal falsework tower, and completed via drop-in closure. Side by side comparison of the Steel Dead Load (DL) profile achieved in the Shop and Field (derived from slab haunch computations), is shown in Table 4.

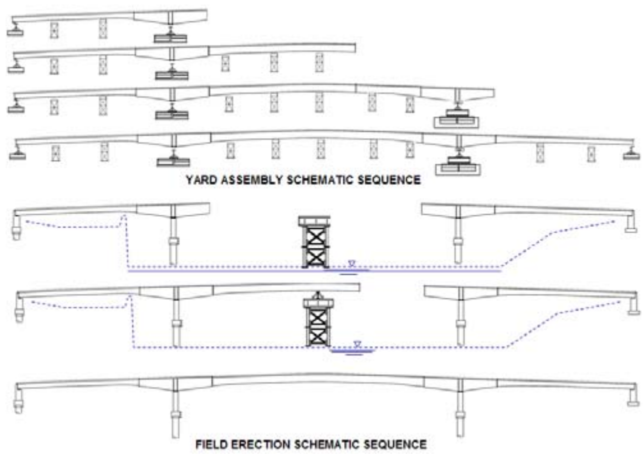

Figure 17 – Shop (upper) **& Field** (lower) **Sequences**

	Yard Steel DL Profile Δ, inches				Field DL Profile Δ, inches			
Location	G1	G2	G3	G4	G1	G2	G3	G4
Beg Abut	(0.066)	**0.316**	0.051	-	(0.220)	0.020	(0.100)	-
0.4L1	(0.391)	(0.155)	0.158	0.148	(0.810)	(0.158)	0.246	**0.272**
Pier 1	(0.518)	(0.495)	(0.404)	(0.200)	0.097	**0.258**	0.138	0.097
0.5L2	(0.378)	(0.646)	(0.853)	(1.354)	0.124	0.044	(0.452)	(1.890)
Pier 2	(0.458)	(0.617)	(0.234)	(0.193)	(0.343)	(0.393)	(0.393)	(0.423)
0.6L3	(0.765)	(0.593)	(0.128)	0.346	(1.606)	(0.570)	(0.073)	**0.279**
End Abut	(0.229)	0.018	(0.168)	(0.347)	(0.428)	(0.417)	(0.057)	(0.068)
	April 2015, Lancaster PA				May 2015, Amsterdam NY			

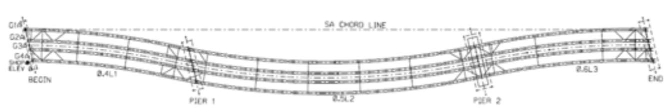

Table 4 – Shop (left) **& Field** (right) **Assembled Girder Profile Variances** (relative to theoretical data)

Each case resulted in elegant taper and skew, with clean horizontal and vertical curvatures (Figure 18, below).

Overall, the author was quite satisfied to observe the structure's ability to be aligned by two separate erectors under quite different site conditions, yielding reproducibly similar results generally within the typical industry dimensional, alignment and assembly tolerances.

Figure 18 Assemblies: (left) **Yard;** (right) **Field**

Steel DL Assembly Observations

From this experience and the information collected, the following observations are made by the author:

1. a "corkscrew" torsional effect is seen, whereby the outboard (outside of the curve) fascia girder is lower than theoretical elevation at 0.4L1, 0.5L2 and 0.6L3; the inboard fascia is correspondingly either higher than the theoretical, or only slightly negative.
2. only bracing deemed necessary needed for stability was installed at Yard Assembly. In the field, bracing was installed in the approach spans prior to erecting the drop-in "keystones". It may be deduced that torsional system stiffness will fully engage once the bridge is completely erected, with field splices and LB connections fully tightened. The variances seen between theoretical and the (two) actual assemblies, are consistent with the traditional multi-girder bridge design assumption that "the structural steel is completely erected before it is allowed to deflect under its own dead load…the actual erection methods and sequences employed by the contractor may have a substantial effect on the final steel profile." (3)

Slab Placement

The deck was cast during summer of 2015. It appears that, as composite action developed, the main span essentially maintained the two inch negative variance observed at steel DL profile. Fortunately, the bridge's crest vertical curve design provides adequate reserve vertical clearance at the navigation channel, as well as pleasing visual positive camber.

In Figure 19, the stay-in-place (SIP) formwork gleams in the sunshine; massive barge footprints, from which the main span superstructure was staged and erected by the contractor, are also seen. In Figure 20, with the slab placed and curing, the outlines of the park at each approach to the bridge can be seen taking shape.

Figure 19 Forming the Deck

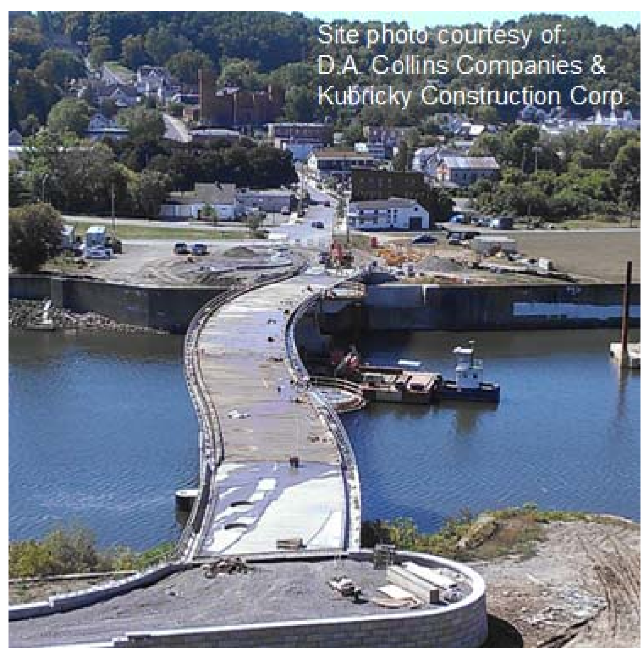

Figure 20 Slab placed and curing (viewed from NE)

A once-desolate waterfront area so common in cities retaining functionally obsolete factory shells, etc, is now in the process of becoming a vibrant community linked by a welcoming gateway that so naturally fits into the surrounding neighborhoods, infrastructure and terrain.

Deck appurtenances are scheduled to be installed in spring of 2016. See Figure 21. The author is inspired by how this park-like structure will enhance, and not merely link, the surrounding community.

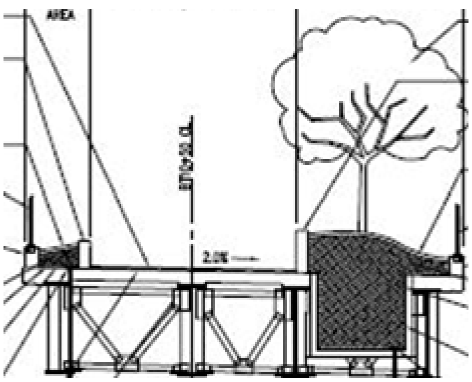

Figure 21 – Future insulated tree plantings

Summary and Concluding Observations

This project illustrates some advantages and challenges that may be encountered in erecting (and re-erecting) a curved, skewed, haunch-girder bridge.

Erectors use different means and methods to achieve bridge construction and, provided structural stability as well as vertical and horizontal control are maintained within applicable fabrication and erection tolerances, the above shows that there is usually more than one way to build a bridge successfully. (The bridge erection engineer may find this observation reassuring).

This project has also given the author a long-sought opportunity to observe (free of the usual hurried activity in field assembling a bridge) the general concepts of allowing certain crossframes, lateral bracing (hand-tight) and field splices snug tight (vs fully torqued), so that a continuous structure can settle into an overall best fit while the cranes move on to subsequent span erection (bolting crews typically following on with final tightening to specification).

Finally, the author finds it historically fitting that this graceful structure invites the passer by to stop at the pier overlooks, and reflect on the engineering/survey accomplishments of the past, as well as the complimentary beauty displayed by the MVGO Pedestrian Bridge over the Barge Canal.

Acknowledgements

The author would like to thank the following individuals and organizations, without whose efforts this technical paper would not have been possible: Richard Karis of the New York State Thruway & Canal Authority; the firm Amman & Whitney for their design innovation in developing such a magnificent structure that enriches the local community (along with the various architectural design alternates along the way); Volker Burkowski of Kubricky Construction Corporation for their open sharing of technical information; Michael Whittam of the D.A. Collins Companies for the outstanding drone-generated aerial photography and his artistic eye in obtaining brilliant photos; Jeff Wampler, Charles Lowe and Michael Bresch II of High Steel Structures, LLC (HSSL) as well as Jaimon Jacob and Omar Ramos-Lopez of Drexel University (HSSL Engineering Co-Op Students) for their combined efforts in measuring the structure; and Gregory DeMascola of High Structural Erectors LLC (HSEL) for his patient crew leadership, in constructing the temporary substructures for this bridge. Finally, appreciation is expressed to Ronnie Medlock of HSSL, for his mentorship and skill in finding common ground on major bridge construction endeavors.

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Project Team

Owner/designer: New York State Thruway and Canal Authority (Architectural Drawings by Saratoga Associates)

Contractor: Kubricky Construction Corporation

Erector: D.A. Collins Companies

Fabricator: High Steel Structures, LLC

Structural Steel Detailer: Lancaster Country Drafting Services.

About the Author

Bob Cisneros is Chief Engineer for High Steel Structures, LLC where he has had opportunity to specialize in project management, shop drawing preparation, fabrication, transportation (shipping) and erection engineering, surveying and metrology. Prior to his career with High, Bob worked in New York State as a construction manager, general contractor, construction inspector, bridge inspector, design engineer and rigging/scaffolding engineer for the construction of temporary structures. He has a Bachelors Degree in (Civil) Engineering from Cornell University, holds (Canadian) Welding Engineer Designation and an American Welding Society Welding Supervisor Certification, and has been an AWS certified welder.

Experiences learned in the course of an enjoyable bridge building career have facilitated occasional (disaster relief) volunteer work in Mississippi, Alaska and Pennsylvania, occasionally serving as demolition, steel erection supervisor or Engineer of Record for church and community design/construction projects.

In closing, this project has reinforced the author's belief, developed during the course of a career, that bridge construction projects are a team achievement, optimizing overall quality when the skills that each member brings to the overall effort are fully engaged in synergistic, professional camaraderie.