CHALLENGES OF DESIGN AND CONSTRUCTION OF STEEL HIGHWAY BRIDGES IN NEW JERSEY

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Abstract

The NJDOT faces many challenges in building highway bridges with limitation of highway/roadway profiles, heavy traffic and water or road crossings in the crowded spaces. A few major challenges of the real projects for NJDOT may include: 1) to develop guidance for design and construction of severely skewed and/or curved steel bridges; 2) to build a lift span orthotropic deck bridge; 3) to address potential fracture critical issue for two through-girder bridges; 4) to clarify deflection requirement for high performance steel (HPS) bridges; and 5) to develop guidance for prefabricated members and systems for accelerated bridge construction (ABC).

This paper will use two ongoing steel bridge projects, Rt.3 Bridge (a highly skewed bridge) and Rt.7 Bridge (orthotropic deck lift span), to discuss part of these issues encountered by NJDOT and provide recommendations to solve the issues.

Introduction

Updating infrastructure in the modern society presents a lot of engineering challenges, ranging from how to increase capacity to how to maintain integrity in the expected service life - being bigger, longer and better. Building highway bridges is not an exception. Located in the Mid-Atlantic coast, New Jersey utilizes lots of steel materials in highway bridge construction for both new and rehabilitation/replacement projects. Due to the unique conditions in New Jersey, the most densely populated and the most highly urbanized State in the country, the NJDOT faces many challenges in building highway bridges with limitation of highway/roadway profiles, heavy traffic conditions and water or road crossings in crowded spaces. This would require bridges to be built with high skew and/or severe curvature, longer span, low vertical clearance, exposure to natural or industrial corrosive environments, light weight , innovative structure types and materials, fast construction, and so on.

For steel highway bridge constructions in New Jersey, due to a few recent problems reported in the field, new AASHTO requirements, and advancement of research studies, a few major challenges that NJDOT is currently facing include: 1) to develop guidance for design and construction of severely skewed and/or curved steel bridges; 2) to build a lift

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span orthotropic deck bridge; 3) to address potential fracture critical issue for two through-girder bridges; 4) to clarify deflection requirement for high performance steel (HPS) bridges; 5) to develop guidance for prefabricated members and systems for accelerated bridge construction (ABC), etc.

Several ongoing projects have triggered the urgent needs to investigate and address the issues for design and construction of steel bridges. For instance, Rt.3 over Passaic River/NJ Transit Bridge is highly skewed bridge (52 degree) and encountered a layover problem during construction due to the lack of understanding in erection fit and design guidance; Rt.7 Wittpenn Bridge (orthotropic deck lift span) undergoes unique design, very tight fabrication requirements and lack of domestic fabrication experience; The three-mile long Pulaski Skyway rehabilitation project is experiencing numerous issues associated with steel bridge design and construction, including replacing corroded concrete encased steel girders, retrofitting non-redundant truss structures, placing cross framing for staging, seismic retrofit (Cheng, 2013), etc. This paper will introduce the issues and challenges in design, fabrication and construction of the Rt.3 and Rt.7 bridge projects. Both of the bridges are new construction to replace the existing bridges. The paper will provide information of the bridge projects, problems encountered during construction, research study and recommended guidance.

Background: ***the Rt. 3 Skewed Bridge (Skewed Bridge)***

The Rt.3 at Passaic River Crossing Project is to replace the existing movable bridge with a fixed bridge and replace other existing bridges along the line of Rt.3 in the area. Open of these bridges is critical for the local transportation and the event of 2014 Super Bowl in north Jersey. The Rt.3 Bridge over NJ Transit is one of the bridges. The ADT is approximately 139,000 (2002 data). The layout, elevation, typical cross section, and frame plan of the bridge are shown in **Figure 1**. The bridge is of a 52 degree skew angle, single span straight hybrid I-girder with the bearing-to-bearing span of 178 feet (54.25 m). The bridge construction was divided into three phases, with Phase I on the south side, Phase II on north side, and Phase III in the middle and finally combined with Phase I and Phase II bridges to form a complete bridge. The width of the bridge is 39’-3” (12 m), 65’-9” (20 m) and 59’-6” (18 m) for Phase I, II and III, respectively, and the total width is 164’-6” (50 m). The hybrid section of 22 steel I-girders is built up of HPS 70W/HPS 50W weathering steel at a typical depth of 4’-6” (1372 mm) and the composite section at 5’-9” (Typical) (1753 mm). The cross frame layout is staggered (**Figure 1**).

Generally, horizontally curved and/or skewed bridges exhibit significant torsional displacement due to differential deflections experienced at cross frame connections. The behavior is not fully understood by the unexperienced designer, fabricator and erection/contractor. Many skewed bridges are still treated as right angle bridges and bridges with small skew, such as with less than 20 degrees skew angle. Therefore, fabrication and erection is detailed for final plumb position in the final fit.

This was the case of Rt.3 over NJ Transit Bridge. During erection of the Rt.3 Phase I, excessive girder layovers and bearing rotations were observed at the girder end at the abutment locations, resulting in an excessive offset of bolt holes at the cross frame connections at the erected stage (**Figure 2**). The maximum layover at the girder end was as great as 4+ inches (~101.6 mm) which is highly unusual. Since design was based on final dead load drop/position, the excessive layover could not be accommodated by introducing external forces at erected drop/position. It was suggested the end cross frames be loosened with only one bolt left at bottom corner during the concrete pour and reinstalled after the concrete pour. This would provide more opportunity for the girders to deform more flexibly into the final intended plumb position. After the concrete pouring, the measurement of girder layover showed an improvement with most girders returned the position closer to the intended plumb position under the total dead load. However, the layover of all girders on one abutment was still significant compared with the intended plumb position. New cross frame connection details and new holes were suggested, and bearings were reset and leveled for final alignment. Eventually, the layover was measured for the most girders within the tolerance of deviation from intended position (1/8" x 4.5' (girder depth) = 0.56" (14.3 mm) or 0.6 degrees of rotation). Bearing sole plate rotation was also in the allowable rotation capacity of 0.06 radians (3.43 degrees). However, the locked-in forces in the girders and cross frames was not clear although an analysis showed the stresses did not appear to exceed estimated member capacities. It was an intensive procedure to approximately reach the final girder geometrical position as designed, and should be avoided as much as practical.

To prevent the situation of Phase I construction from reoccurring and to better understand the layover behavior, the NJDOT had established a research study with Rutgers University during Rt.3 Bridge Phase II construction to model, instrument and analyze the construction procedure and bridge behavior (Szary et. al, 2014). The study addressed the issues and made recommendations to address the issues on constructability during skewed bridge erection due to lack of regulations and contractor experience; concrete deck placement sequence; unknown locked-in stresses; bearings block or tie down; etc. The detail will be presented in the later Section.

<u>Fundamental of Skewed Steel I-Girder Bridge Fit</u>

Two issues are present in skewed and/or curved bridges that are negligible in traditional straight girder bridges with right supports: 1) differential deflection between adjacent girders occurs and causes loads to be transferred between girders through the cross frames and the deck; that is, cross frames are connected at locations with differential deflection; it causes the maximum girder layover (or referred to as twist, rotation, torsion displacement, etc.) at the girder ends with more constraint when rotation of end cross frame are parallel to the skew; 2) Non-uniform torsion is created by the differential deflections and by curvature at cross frame connection locations. **Figure 3** shows typical differential deflections between adjacent girders in a skewed bridge from a line girder analysis. These two issues lead to a number of issues that need to be addressed during design, fabrication and erection so that the bridge can be built without difficulty and function properly. The extent of the issues can be quantified with proper analysis. Normally simple span highly skewed and curved girder are often problematic.

<u>Girder Position and Conditions</u> When the planned bridge is severely skewed, the Designer should specify the intended girder web position and condition during erection and final completion per AASHTO LRFD requirement. Intended positions are either 1) *Plumb/vertical*; or 2) *Out of plumb*, whereas conditions include:

1) *No load* (NL) – girders are erected under a zero stress condition where they are supported (such as with shoring);

2) *Steel dead load* (SDL) – after steel girder erection is completed; and

3) *Total/Full dead load* (TDL) – after full construction is complete with loads of steel structure, deck, over lay, barriers and so on.

Figure 4 illustrates the stages of the three conditions during the bridge construction.

<u>Detailing Fit Methods</u> When cross frames are detailed to fit in the condition of girder web plumb at no-load condition, it is called "*no-load fit*" (NLF, fully cambered fit) and girder webs will be out-of-plumb under the steel dead load (SDL) and total dead load (TDL) conditions. This condition may result in out of plumb at the bearings so the reaction at skewed supports may not rest squarely on bearings unless sole plates are beveled, especially for elastomeric bearing. Therefore bearings will rotate, and the bearing and bearing stiffener on one side of web may be overloaded. In addition, the deck and barriers may not be lined up with the approach slab. AASHTO LRFD requires the computed bearing rotation be accumulated over the assumed construction sequence and not exceed the bearing rotational capacity for each construction stage. This is the simplest detailing method, but girders will be out of plumb under SDL and TDL conditions, and causes the largest cross frame forces compared with other options. NLF is common for complex bridges with lots of shoring.

When straight skewed girders are desired to be plumb after either SDL or TDL is applied, the cross frames and their connections must be detailed so the location of the bolt holes on the connection plates is such that the girders will be plumb after cross frames are installed and SDL or TDL is applied. This is referred to as "*steel dead load fit*" (SDLF; Erected Fit) or "*total/full dead load fit*" (TDLF; Final Fit), respectively. The cross frames design should be detailed inconsistently with (not normal to) the girders and fit-up forces are required into the system to force the girders into the cross frames during erection. The force effect will remove as SDL or TDL is applied. However, forces required to accommodate lack-of-fit can be excessive and unconstructable in some cases (such as longer span, sharply curved) thus other fit options need to be selected. As a result the girders will rotate into the final web plumb position under the dead load. If girder web is made plumb under SDL, the webs will not be plumb under NL and TDL conditions. Similarly, if design makes girder webs plumb under TDL, the webs will not be plumb under NL and SDL conditions. Although this fit method is relatively difficult, it provides web plumb position under dead load as the bridge is originally designed or construction planned for the girders and bearings. TDLF (final fit) method would result in significant locked-in force with small or without geometry change due to forces needed to pull girders and cross frames together. SDLF is common for curved bridges and highly skewed bridges, whereas TDLF is common for right/square bridges and less skewed bridges. For each bridge, the fit condition must be elected to effectively manage the structure geometry and internal forces during construction and to facilitate the construction.

In addition, an alternative detailing method "*Lean-on Bracing*" is sometimes used to minimize or eliminate intermediate cross frame effects. Some cross frames are replaced with top and bottom struts only during deck placement. Lean-on braces allow differential vertical deflection to occur between the girders without inducing twist. In in internal lean-on system, cross frame locations can be selected strategically to minimize twist in the system, but the strength and stiffness should be ensured to be adequate. Lean-on bracing provides a more cost benefit than an all cross frame system, but could cause a concern over the long term. In particular, in redecking or widening, lean-on bracing would require special analysis and perhaps temporary bracing to ensure stability.

Cross frames sometimes are detailed with vertical slotted holes which permits for web plumb at no load (NL) condition to minimize the twist of girders and reduce cross frame forces. The analysis assumptions for loosening and tightening, and sizes and locations should be reflected on Designer's Construction plans. It is note that oversized/slotted hole in cross frame connections could also result in potential fit-up problem due relative displacement between the girders, and the system geometry is not under control. Therefore oversized hole/slotted holes actually prove to be a disadvantage instead of help in the fit-up.

Selection of Fit Methods AASHTO LRFD requires Designer identify the intended girder web position (plumb or out of plumb) and condition (ND, SDL, FDL) under which the position is to be achieved. Designer should also identify how the end rotations (layover) are to be accounted for in the anticipated magnitudes, as well as determine if bearings can accommodate the girder end rotations within the capacity.

The NCHRP Report 725 (White et al., 2012) demonstrated that skew angle alone is not the best characterization of the effect of skew for straight skewed girder bridges. This study and the NSBA (NSBA, 2014) recommended a term of skew index, *Is*, characterizing skew effects better, and further recommended analysis and fit methods depending on the skew index, Is=Wg•tgθ/Ls; where Wg is the bridge width measured between fascia girders, θ is the maximum skew angle measured from a line perpendicular to the tangent of the bridge centerline, and Ls is the bearing-to-bearing span length at the bridge centerline. It can be seen that *Is* is sort of relative skew accounting for the aspect ratio of bridge span length and width along with skew angle. The greater the skew, the greater the differential deflection across the width of the bridge will be. For a same skew angle, a longer and narrower bridge may has a smaller *Is*, whereas a shorter span and wider bridge has a higher *Is*. Strong correlation was found between this skew index and general magnitude of the cross frame forces caused by skew. During development of the NSBA guidance for selection of fit methods, different sets of methods have been recommended for straight skewed bridges depending on the value of skew index, due to different perspectives since there are trade-offs between the approaches of SDLF and TDLF methods. The latest recommendations are shown in **Table 1**. The industry practices and engineering judgments have a big weight in determining the recommendations.

Most bridge owners have not specified who should specify fit requirements and conditions, and contractors are lacking experience in this matter. Often experienced fabricators may make the decision and provide valuable experience in the field, but the fabricator do not know forces associated with their decision. AASHTO LRFD 6.7.2 requires designer to specify plumb position and condition as discussed above. Accordingly designer understand the forces and deflections but they don't have benefit of fabricator/erector knowledge and experience. Therefore, the owner, designer, fabricator, erector and contractor have to coordinate and work together to achieve a successful project.

The NSBA (NSBA, 2014) also suggests other details associated with the fit detailing be included but not limited to: 1) Keep the first intermediate cross frame at least 1.5 times web depth away from the support to facilitate construction at the abutments and piers; 2) Tighten bolts before concrete deck pouring; 3) Be cautious using oversized/slot holes; 4) Shop assembly of cross frames; 5) Phased construction, 6) When TDLF method is used, note the expected layover at erection load in design plans and shop drawings to avoid construction delay; 7) Uplift of bearings due to exceeded deformation, 7) Stability of the system, and 8) deck placement sequence. Ignorance of any of these may result in significant problem in the field and should be addressed prior to the construction. Consideration of all the issues may significantly change the steel bridge construction and will be challenging for all parties involved in the projects of skewed steel bridges.

Rt. 3 Bridge Research Study on Field Measurement and Response Analysis

The Rt.3 Bridge was detailed for the girder webs to be plumb at TDL regardless of the skew angle or skew index. The research study was conducted on the Rt.3 Bridge Phase II construction (Szary et al., 2014). A 3D FEM modeling and analysis was utilized and a field measurement was conducted to better understand the forces, rotations, layover, and displacements developed during different stage of the highly skewed steel bridge. Each bearing was modeled according to allowed translation/rotation specified in the contract drawings. The girder erection procedure was simulated using contractor's procedure, and the results from the analysis and the field measurement are compared.

Based on the NSBA definition, the skew index of the Phase II bridge is *Is* = 0.473 and SDLF should be recommended (Is>0.30). The layover measured in the field appeared exceeding the specified tolerance (1/8 inch x web depth in feet). This may be due to the use of oversize holes, finger tightened bolts until after the deck pour, which was in contrast to the NSBA recommendations for standard holes fully tightened prior to the deck pour, concrete pouring sequence and other identified behaviors. The study reported that when cross frames are fabricated with oversized holes, geometric control is lost during construction, and the web plumbness and bearing positions cannot be assured. This was evident in the observation of variability in the girder layover of the Rt.3 Bridge at SDL stage, and it illustrates an oversized hole effect. To implement web plumb tolerance, it is necessary for the geometry to be predictable at SDL and TDL. Predicting layover at different stages of construction assumes no additional deflection due to oversize holes and holes and finger tight. Without knowing these mechanisms in the prediction, the use of a strict tolerance to judge the acceptability of web plumb at the intended fit position is not practical.

The bridge is characterized by a large initial camber and vertical curve due to approach profile and the required clearance over the transit lines. The bridge girder depth is 54 inches (1.37m) over the span of 178 feet. Use of high performance steel (HPS) unpainted weathering steel was because of lower girder depth for underclearance requirement. The girders are supported on multi-rotational pot bearings. The skew index *Is* for Phase I bridge (6 girders) is 0.282 which can be classified as a moderate skewed bridge, whereas *Is* for this Phase II bridge (8 girders) is 0.473 which is a severely skewed bridge.

Field Measurement Observations The field measurement/instrumentation was conducted to find out the primary bending stresses in the girders and layover of the girders during erection/construction stages. The strain gages and sensors (32 in total) were attached to the bridge members prior to any erection action, and connected to a remote data acquisition system and monitored for a period of 160 days. **Figure 5** shows the strain gage and sensor locations. Typical strain readings and girder end stresses at Final Condition (TDL) are given in **Figure 6.** It suggested low stresses for out of plane bending, and top and bottom flange bending (Szary et. al, 2014).

Girder layover, or the relative deformation between the top flange and bottom flange of the girder at the bearing lines, was measured before and after the concrete deck pour to provide an indication of the layover in each girder at the SDL and FDL conditions. **Table 2** shows a summary of the layover measurements. For girder depth of 54 inches (1372mm), the 1/8" (3.175mm) per feet (304.8mm) tolerance would be corresponding to a tolerance of 0.5625 inches (14.3mm). In **Table 2** it appears that for TDL condition, the majority of west bearing line rotations are within the specified tolerance, while the majority of the east bearing line rotations exceed the plumb tolerance at the TDL condition (final condition). This can be explained with the fact that concrete pour started from the west end and proceeded linearly across the structure to the east end. There was a period of time when a pour was stopped due to an accident on Rt.3 which made the poured concrete quickly gain strength within hours and restrained the girder from the west end, reducing the ability of the east end to rotate fully into final plumb condition (Szary et. al, 2014).

The comparison between modeling prediction and field measurement indicated that there are errors. It is because that the analysis did not take into account for special actions during erection, such as blocking bearings and oversized holes. Therefore it is reasonable to expect the difference between model prediction and field measurement of layover.

Recommendations The use of oversized holes and concrete pour sequence may have caused variable measurement results, being difficult to maintain system geometry during the construction. Based on FEM analysis and field measurements, following good practices are recommended for skewed steel bridge construction in New Jersey:

- The skew index be used to select the appropriate fit/detailing method;
- A simplified fit conditions be used based on skew index (**Table 3**);
- Concrete deck pouring sequence be carefully developed to permit even distribution of wet concrete dead load. A linear pouring sequence aligned with the skew angle be recommended for severely skewed bridges, providing more even dead load distribution to the girders than perpendicular to the girders for TDLF for even rotation towards plumb;
- Out of tolerance plumb at the final dead load stage appears no significant impact on the strength of the system, Rather, investigation be focus on out of plumb impact on other identified performance or serviceability issues;
- Measured compressive axial stresses are much higher than analytical stresses which may be due to the blocked bearings introducing more axial stresses due to bearing restraint. Fabricator/erector/contractor should perform an analysis of erection procedure to assure no detrimental stresses, rotations, deflections are introduced.
- The NSBA tolerance (1/8" per feet) deviated from the theoretical position (plumb or not) be adopted without use of oversized/slot holes and finger tight.

Background: *the Rt. 7 Wittpenn Bridge (Orthotropic Deck)*

Rt.7 Bridge orthotropic deck is a completely different challenge from the Rt.3. The Route 7 Wittpenn Bridge lift span project is located in Hudson County over Hackensack River. It serves as a major connector between Rt.139 and Rt.1&9T to the east (Holland Tunnel), and the NJ turnpike and Newark-Jersey City Turnpike to the west. Rt.7, located next to the Pulaski Skyway, is a key component of NJDOT's Portway Corridor, allowing traffic from the west to gain access to the Holland Tunnel and New York City, as well as within Jersey City. The facilities and their access routes are the front door to global and domestic commerce in New Jersey and the greater metropolitan New York region.

The existing Wittpenn Bridge (**Figure 7a**) is a vertical bridge that was built in 1930 with 209-foot (63.7m) vertical lift span. The bridge is both functionally obsolete and structurally deficient, and will be replaced with a new moveable bridge including a vertical lift span of 325 feet (99m) and four steel towers (**Figure 7b**), and deck-girder approach spans on both ends of the lift span.

Challenges of Rt.7 Bridge Construction

The new bridge will provide for a minimum vertical clearance of 70 feet above the Mean High Water (MHW) EL 2.19 in the close position as compared to current 35-feet for the existing life bridge. The bridge replacement has been designed to address the major needs and goals of the project:

- Replace the structurally deficient bridge for 100 year design life;
- Meet current AASHTO and NJDOT design criteria for bridge safety and to improve traffic operation and safety;
- Increase vertical clearance over the Heckensack River to improve marine traffic flow and reduce interruptions from bridge openings (from 35' to 70' in the close position and retain 136' clearance in the fully open position; bridge openings reduced ~75%);
- Improve ship collision resistance of bridge substructures;
- Meet mechanical and electrical requirement for lift capacity with weight limitation;
- Carry design ADTT of 5,500 and meet fatigue design for infinite life; and so on.

The structural design of the vertical lift bridge structure consists of three steel box girders (**Figure 8**) with an integrated orthotropic steel deck and steel rigid frame towers. The consideration of orthotropic deck design was mainly because of the advantage of relatively light weight. Due to the complexity of the bridge design, long term durability requirement, shipping difficulty with the designed structure height, and extremely tight requirement for the fabrication, the project is full of challenges in design, fabrication and field erection, The issues included but not limited to the following:

- Fatigue strength of the unique rib-to-deck welded detail intended to achieve cost-effectiveness;
- Tight tolerance throughout the fabrication process;
- Tight flatness requirement for larger and thicker panels;
- Field setup and filed weld splice;
- Fabrication inspection and acceptance;
- Lack of fabrication capacity and experience for fabricators; and so on

Research study is being conducted to simulate fabrication of Rt.7 orthotropic deck design and investigate fatigue resistance. The further information associated with this bridge and research will be briefly presented at the meeting.

Acknowledgments

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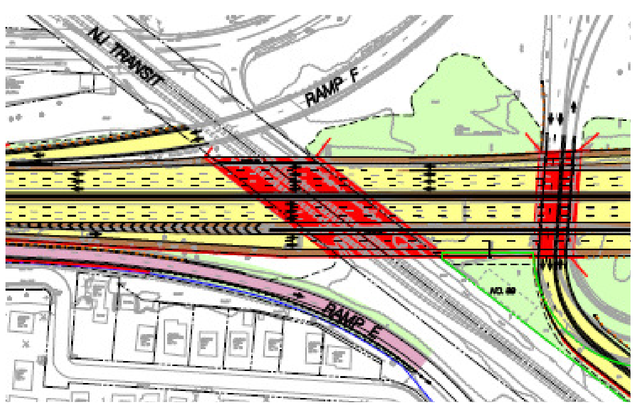


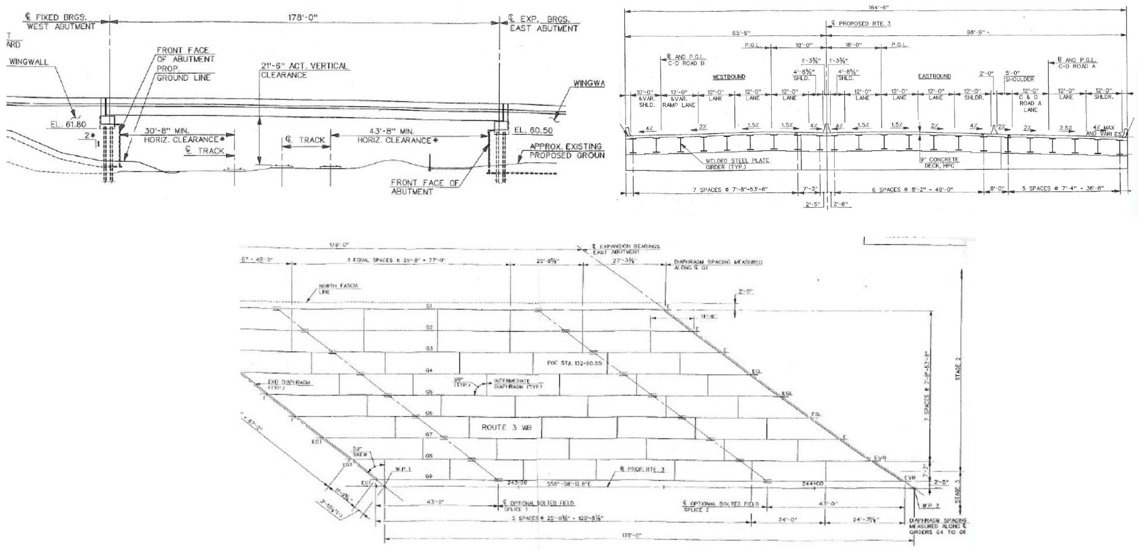


Figure 1 Rt. 3 Bridge Layout and Frame Plan

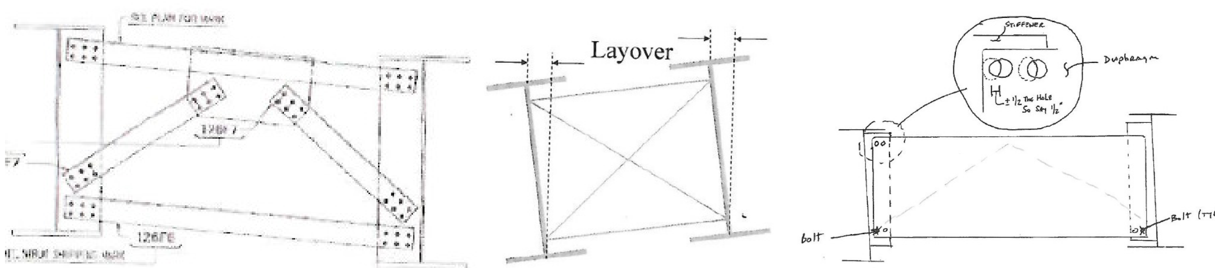
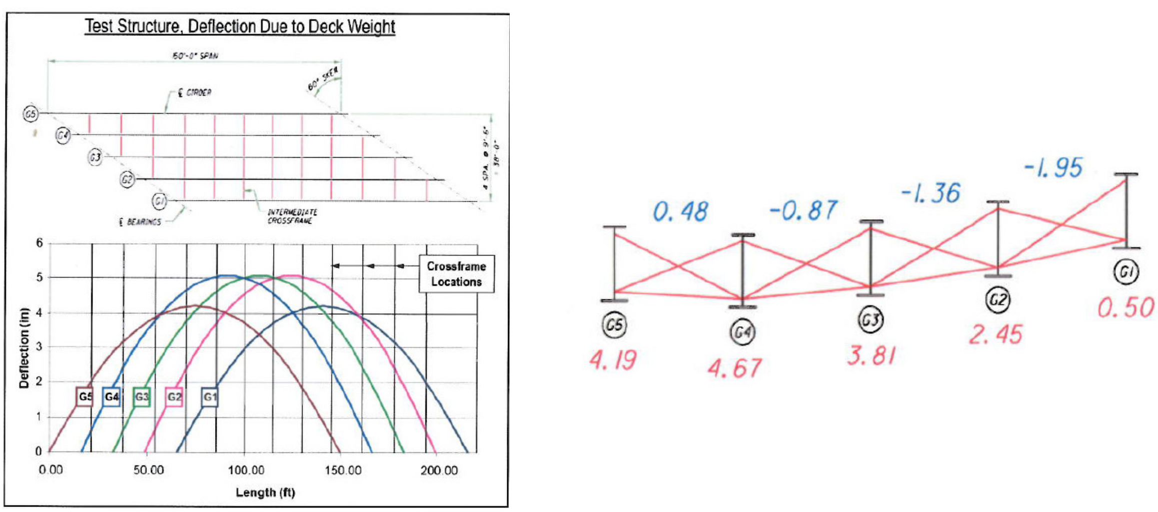


Figure 2 Girder Layover and Unbolted Cross Frame Connection



(a) Exterior Girder vs. Interior Girder (b) in the Same Cross Section

Figure 3 Typical Large Differential Deflections in a Straight Skewed I-Girder Bridge (1D Line Girder Analysis; cross frame effect ignored) (Butz, 2012)

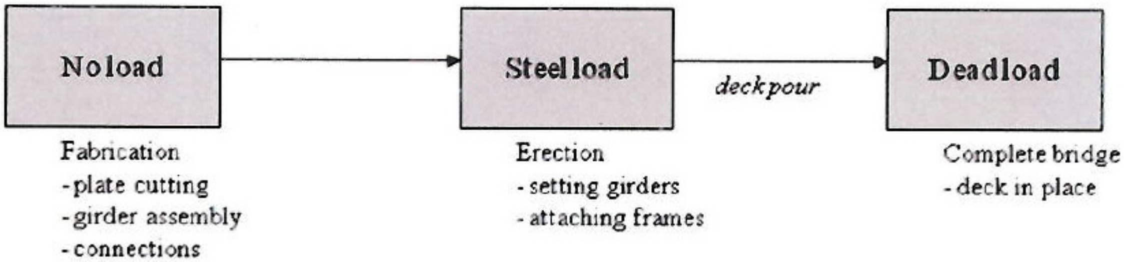


Figure 4 Three Conditions from Start of fabrication to Completion of Bridge (NSBA, 2014)

Table 1 Recommended Fit Conditions for Straight Skewed Girder Bridges (NSBA, 2014)

Square Bridges and Skewed Bridges up to 20 deg +/- Skew			
	Recommended	***Acceptable***	***Avoid***
Any span length	Any		None
Skewed Bridges with skew > 20 deg +/- and $I_s \leq 0.30$ +/-			
	Recommended	***Acceptable***	***Avoid***
Any span length	TDLF or SDLF		NLF
Skewed Bridges with skew > 20 deg +/- and $I_s > 0.30$ +/-			
	Recommended	***Acceptable***	***Avoid***
Span lengths up to 200' +/-	SDLF	TDLF	NLF
Span lengths greater than 200' +/-	SDLF		TDLF & NLF

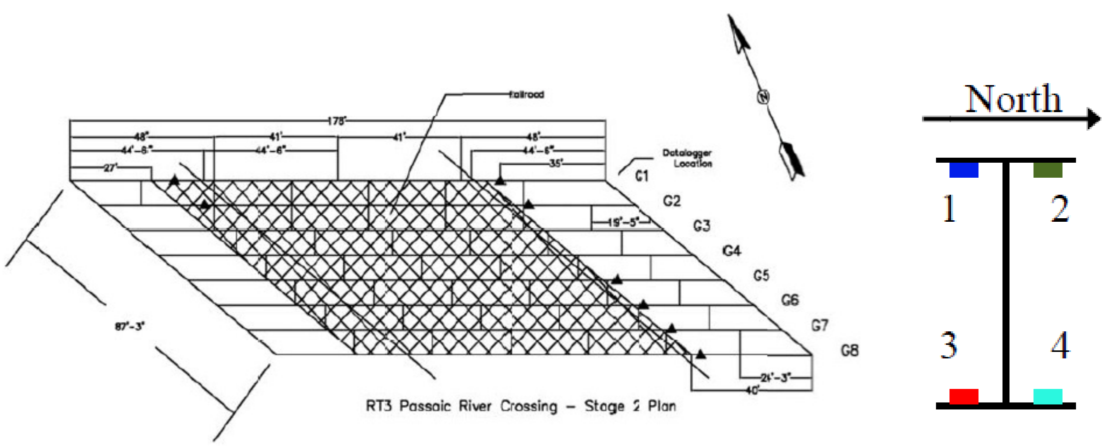
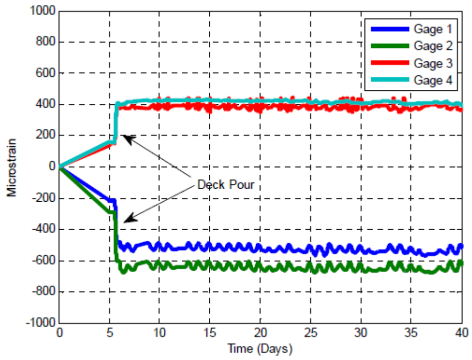


Figure 5 Strain Gage Instrumentation on the Rt.3 Phase II Bridge



	Field Measured Stresses				
	Axial (ksi)	In plane Bending (ksi)	Out of plane Bending (ksi)	Top Flange Bending (ksi)	Bottom Flange Bending (ksi)
G8 East	-2.1	12.5	0.7	1.5	-0.8
G7 East	-5.9	15.0	-1.2	-1.0	-0.2
G6 East	-3.2	13.7	-2.3	-2.5	0.2
G5 East	-1.6	12.2	-0.9	-0.4	-0.5
G2 East	-6.8	15.6		-0.7	
G1 East	-4.7	17.4			0.2
G2 West	-3.5	16.1	4.6	3.1	1.5
G1 West	-2.2	13.6	-1.2	-1.7	0.5

Figure 6 Field Measurement of Girder Stresses at Final Condition (left: time history)

Table 2 Girder Layover from Field Measurement

	Field Measured Stresses				
	Axial (ksi)	In plane Bending (ksi)	Out of plane Bending (ksi)	Top Flange Bending (ksi)	Bottom Flange Bending (ksi)
G8 East	-2.1	12.5	0.7	1.5	-0.8
G7 East	-5.9	15.0	-1.2	-1.0	-0.2
G6 East	-3.2	13.7	-2.3	-2.5	0.2
G5 East	-1.6	12.2	-0.9	-0.4	-0.5
G2 East	-6.8	15.6		-0.7	
G1 East	-4.7	17.4			0.2
G2 West	-3.5	16.1	4.6	3.1	1.5
G1 West	-2.2	13.6	-1.2	-1.7	0.5

Table 3 Fit Conditions and Intended Positions Recommended to NJDOT

Bridge Configuration	Crossframe Fit	Web Position
straight, moderately skewed bridges ($I_s \leq 0.30$)	TDLF	plumb in final constructed position
straight, severely skewed bridges ($I_s > 0.30$)	SDLF	plumb after erection

Figure 7 Rt.7 Wittpenn Lift Span Bridge (left: existing; right: new)

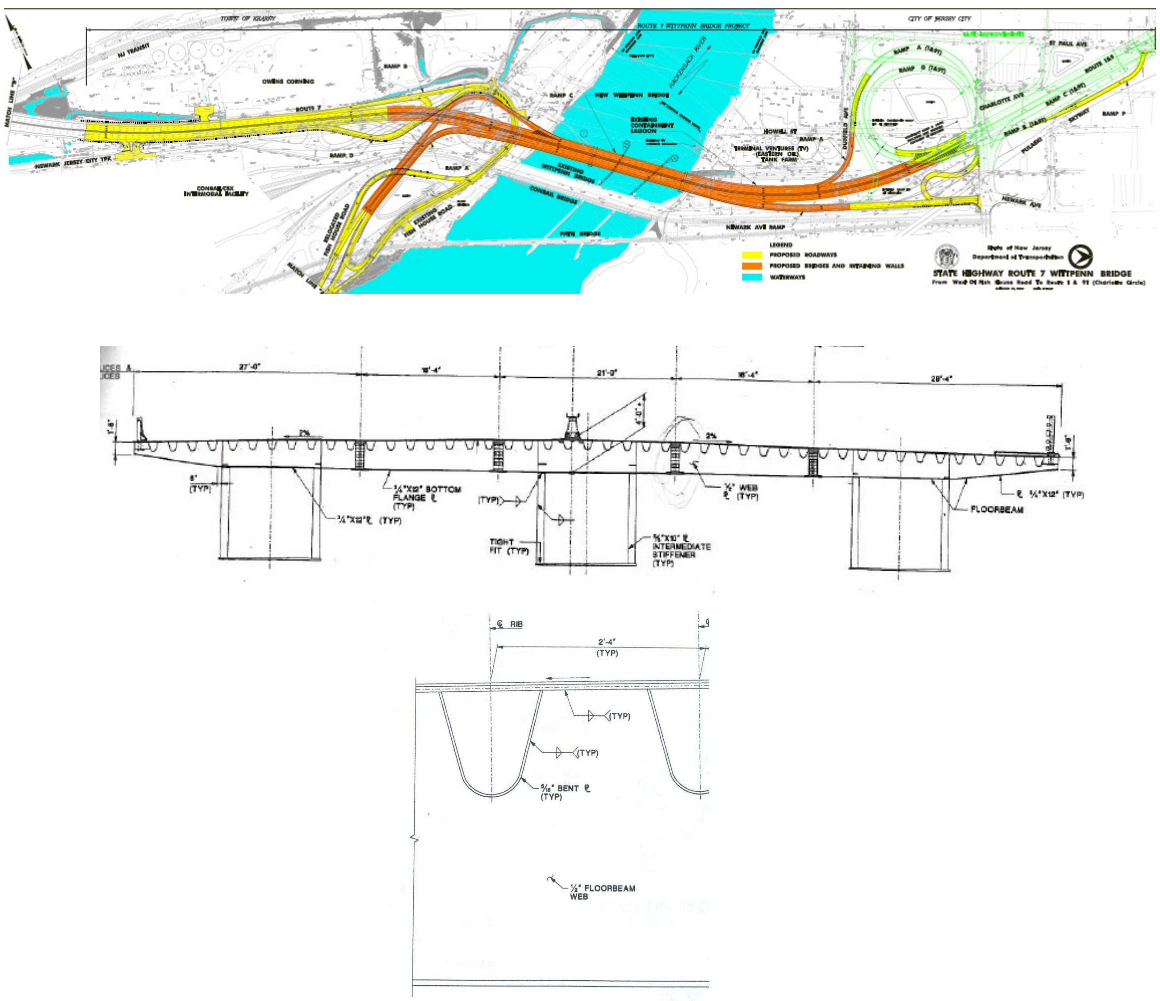


Figure 8 Wittpenn Bridge Location, Typical Cross Section and Rib Welded Detail