NYSDOT Case Study: 3D Design, Fabrication, and Virtual Assembly of a Steel Structure PIN: S3DF.VA Final Report

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16. Abstract

This report documents a proof of concept study determining and documenting how electronic files containing steel bridge data can be transferred from designer to detailer to fabricator under New York State Department of Transportation (NYSDOT) current design/detailing practice to first fabricate and then verify a steel bridge girder section. Information for a 114-foot girder section was provided to the fabricator in a variety of CAD data file formats (DXF files and STEP) that included flange and web sizes and stiffener locations. A three-dimensional model was also provided for reference and checking. Based solely on this information and without the use of 2-D paper drawings, a girder was fabricated at the Hirschfeld San Angelo shop in August 2016. The fabricated section was then scanned using a Faro laser scanner and was compared with the model generated by modeling software. Scan results are provided in Appendix D of this report. The laser scan provided validation that the fabricated girder was within the usual fabrication tolerances. As the first documented fabrication of a steel bridge girder based solely on the transfer of electronic data—without the use of paper drawings—the study results represent an encouraging and important milestone in the pursuit of digital steel bridge fabrication.

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Executive Summary

This report documents a proof of concept study determining and documenting how electronic files containing steel bridge data can be transferred from designer to detailer to fabricator under New York State Department of Transportation (NYSDOT) current design/detailing practice to first fabricate and then verify a steel bridge girder section. Advances in Building Information Modeling (BIM) software and three-dimensional modeling over the last quarter century offer the promise of a single source of project data from planning to design through construction and then facility management. In the case of steel fabrication, such a platform could increase efficiencies and reduce chances for error because the need to manually recreate or retype data is eliminated. This potential has, to date, been largely unrealized, and it is understood that a steel bridge has yet to be fabricated in the United States without continued reliance on 2-D paper drawings.

Information for a 114-foot girder section was provided to the fabricator in a variety of CAD data file formats (DXF files and STEP) that included flange and web sizes and stiffener locations. A three-dimensional model was also provided for reference and checking. Based solely on this information and without the use of 2-D paper drawings, a girder was fabricated at the Hirschfeld San Angelo shop in August 2016. The fabricated section was then scanned using a Faro laser scanner and was compared with the model generated by modeling software. Scan results are provided in Appendix D of this report. The laser scan provided validation that the fabricated girder was within the usual fabrication tolerances. For example, a representative report comparing top flange actual bolt hole locations to modeled locations indicates a maximum deviation of less than 1/16 inch.

The study highlighted a number of areas that will require further consideration. First, many elements required for fabrication could not be shown, such as tension and stress reversal zones, weld testing limits, Mill to Bear/Tight Fit requirements, and even simple fillet welds between components. Consequently, this study only touched on the large amounts of metadata that would need to be included in making this whole process a system that could replace current NYSDOT means and methods. Second, it was evident that electronic data transfer will require closer coordination and continued back-and-forth communication among designer, detailer, and fabricator. One example is the location of the optional shop splice locations, which is based solely on the purchaser's selection of economical locations.

As the first documented fabrication of a steel bridge girder based solely on the transfer of electronic data—without the use of paper drawings—the study results represent an encouraging and important milestone in the pursuit of digital steel bridge fabrication.

Introduction

Considerable advances have occurred over the last quarter century in building information modeling (BIM) software. Three-dimensional (3-D) models are routinely developed for visualization, for identifying spatial conflicts (such as a steel beam and an air vent), and for conventional analysis and design purposes. However, BIM's true potential is to serve as a platform for life-cycle management by offering a single source of project data from planning to design through construction and then facility management. In the case of steel fabrication, such a platform could increase efficiencies and reduce chances for error because the need to manually recreate data is eliminated. This potential has been largely unrealized in the bridge world, and it is the study team's understanding that a steel bridge has yet to be fabricated in the United States without reliance on two-dimensional (2-D) paper drawings. A number of challenges and obstacles must be overcome, including professional liability, file formatting, and data definition. One of the problems with electronic data transfer from the engineer is that the file is too rich in data and the detailer and fabricator need just a fraction of what is being generated. Accordingly, this report identifies what data are needed and demonstrates that such data can be transferred electronically from design through fabrication.

Scope of Study

HDR was asked by the New York State Department of Transportation (NYSDOT) as a task order under its on-call engineering services agreement (PIN: S3DF.VA) to conduct a proof of concept study determining and documenting how electronic files containing steel bridge data can be transferred from designer to detailer to fabricator under NYSDOT current design/detailing practice.

HDR engaged the following firms to participate in the study effort:

MJ Engineering & Land Surveying, PC (MJ), consulting engineer
Upstate Detailing, Inc. (UDI), structural steel detailer
Hirschfeld Industries, LP, steel fabricator
High Steel Structures, Inc., steel fabricator

The original scope was limited to a review and comment by the steel fabricator on the electronic data received from the designer and detailer for the web plate of an existing steel girder. An amendment to the original contract was issued expanding the scope to include the fabrication of a steel girder based on the transfer of electronic data and verification using a laser scanner. Specifically, the fabricator would:

- Fabricate a steel bridge girder based on a DXF file(s) provided by the HDR team that included flange and web sizes, weld details, and stiffener locations.
- Scan the fabricated section and compare it with the model generated by modeling software.
- Confirm that the section had been fabricated in accordance with applicable standards and would be ready for shipping.

Background

For decades, the medium for transferring design information in the bridge industry has been paper. This design information, developed by the Engineer of Record, has been communicated by transferring it onto a set of contract documents—plans and specifications. All parties in the project, including the Owner, General Contractor, subcontractors, and material suppliers, are provided with this information via paper either in physical or electronic format. This continues to be the predominant practice in the bridge industry today, and the means by which structural steel fabricators receive the design information.

In traditional structural steel fabrication, the information shown on the contract plans is manually transferred into a fabricator's internal system and software, and is developed into a set of fabrication shop drawings on paper by a detailer. The role of the structural steel detailer is to take the information shown on the Contract Plans—including the bridge geometry, material property and size requirements, and connection details—and create a complete set of shop drawings for each piece to be produced by the fabricator. Originally, this was accomplished through manual mathematical calculations and trigonometry. With the advent of computers, some of these calculations have been automated, and rather than using manual calculations, the design information is manually typed into structural steel detailing software/ systems by the detailer. Shop drawings, though, are still the product of the detailer's work. The software systems have simply automated some of the manual processes used to calculate the necessary structure geometry, and, in certain cases, have automated some of the shop drawing generation. This continues to be the predominant practice in the industry today—that is, creation of 2-D shop drawings by a detailer using the information provided by the designer on the 2-D contract documents.

While the process of creating shop drawings has been effective and, indeed, necessary for the steel fabrication industry, it certainly has disadvantages in its current practice:

- Inefficient transfer of information – Design information/data, often available in digital format from the designer, is manually placed on contract plans by a designer, manually typed into software by the detailer, and, finally, manually placed back onto 2-D shop drawings for fabrication.
- Increased risk of error – Simply by virtue of manually transferring the design data numerous times throughout the process, the opportunity for error is great.

This process was effective in creating the shop drawings required for steel fabrication. These shop drawings were necessary because they were the communication tool used to provide direction for the manual structural steel fabrication in the shop. The 2-D shop drawings, therefore, were essential for the shop floor.

However, with the advent of computer numerically controlled (CNC) equipment, the need for shop drawings has been diminished. CNC equipment is driven by computer code. Thus, fabricators continued to create shop drawings to be submitted for Owner approval and use, but subsequently created computer code by manual programming based on the information shown on the shop drawings. While the CNC equipment created great efficiencies in steel fabrication itself, it did necessitate an additional step in translating shop drawing information into computer code. At this stage in the Industry, which is representative of most fabricators today, steel fabrication is a combination of manual fabrication processes based on the information shown on the shop drawings, and CNC processes based on code developed from the shop drawings. The current workflow process is summarized in Figure 1. Figures are included in Appendix A.

Today, the industry is on the cusp of an evolution, or revolution, in structural steel fabrication. With the software and data model developments associated with Bridge Information Models (BrIMs), the opportunity now exists to use the data inherent in these models directly for bridge fabrication. This BrIM technology and associated software packages provide opportunities to create any 2-D shop drawings necessary for fabrication, while, at the same time, creating CNC code to drive fabrication equipment. Software packages such as Tekla and SDS/2 have such capabilities. With this technology, it is now feasible to take bridge design information directly from the designer in data format, rather than paper format, and import it into detailing/modeling software. This eliminates the need to manually transfer information from 2-D contract plans into the detailing software. Thus, it is a means to capitalize on a new data flow process in the industry and on data sharing between project stakeholders. This is possible because of a convergence of the evolution and increasing use of CNC fabrication, and the evolution and

development of data-driven software feeding the CNC equipment. Data sharing from the designer to fabricator further enhances and streamlines this process. The potential, preferred workflow process is summarized in Figure 2.

Benefits

The advantages of this data sharing for the steel fabrication industry include:

- Increased efficiency – The need to manually recreate/retype design information from contract plans for use by the detailer and fabricator is eliminated; redundant handling of project data is eliminated.
- Increased accuracy – The potential for error in manually recreating/retyping information is significantly reduced, if not eliminated.
- Single source of project data – With this data flow and data sharing, it is now possible to generate a single data model of the project, with each subsequent stakeholder adding project data relative to his or her portion of the overall project. This data model can then serve as the Owner's asset management tool.

Challenges/Obstacles

The challenges of implementing this data sharing and full utilization of BrIM in the industry include:

- Professional liability – Processes of determining who is responsible for what portions of a project have been well-established and are readily apparent when dealing with paper. It is relatively easy to determine and define the documents of record on a paper-based project. New processes for establishing electronic documents of record and data of record will need to be created for a data-based system.
- File formats – Sharing information on paper is simple; ensuring file compatibility for data sharing is more complex and will require an open file format (for example, XML or IFC) such that all parties can access and use the information. The file format shared among members of a team cannot be in native software formats because each designer, Owner, General Contractor, fabricator, etc. may have different software packages. The key is to define an "open" file format that can be imported by each team member into his or her specific software. Each team member will need to develop the "translator" necessary to read the data file, and import it into his or her software package for the specific purpose.
- Definition of needed data – The data needed by each stakeholder in the process, from upstream stakeholders, will need to be defined. In essence, the essential information shown on the contract plans will need to be replicated in the data file.
- Quality control/quality assurance (QC/QA) – QC/QA processes have been developed based on paper and are relatively easy to complete, confirm, and verify on paper. New processes for QC/QA control of data-based systems will need to be developed.
- Industry inertia – The bridge industry can be generally characterized as a conservative industry—a necessary and desirable characteristic when public safety is at stake. However, this can be challenging when striving to implement change. In general, the industry is accustomed to working with paper documents. Transitioning to a data-based process, which may include checking of data vs. checking of drawings, or submission of data vs. submission of drawings, will be challenging.
- Risk transfer – Data sharing could essentially result in transfer of risk from the Contractor/fabricator to Engineer/Owner since current practice provides an independent check and identifies errors or omissions in the paper design.

Summary of Current Practice

- During the typical design process, vertical and horizontal alignments are created in InRoads and are transferred to the bridge group in 2-D data sets.
- Design is completed using software that either analyzes the structure using a Line/Girder Analysis or Grillage Analysis.
- From that model/analysis, haunch tables, camber tables, shear/moment tables, and the contract plans for the superstructure are developed. The detailing of connections for cross bracing/diaphragms is not completely designed. For example, the bolt patterns and some gusset plates sizes for the cross bracing connections are not provided. This information is developed by the detailer. The member sizes and number of H.S. bolts are usually provided only in the contract plans.
- The contract plans include all the above-listed tables, as well as the girder's section properties, loading information, elevation, framing, etc.
- Working from the hard copy 2-D plans, the detailer will typically use the roadway profile and horizontal geometry to develop the roadway surface and place the working points for the structural steel underneath. This serves as a check on the design. From the contract plans, the detailer has to remodel the superstructure, adding in bolt patterns and other miscellaneous details not included from the designer, to develop a data file for the fabricator to cut and assemble the steel for the structure. This is where redeveloping the model is extra work.
- Detailer creates 2-D shop drawings for submittal to the fabricator.
- Fabricators will generally require different information in a particular format. For example, in addition to hard-copy 2-D plans, certain fabricators request DXF files for plate members. Others, such as High Steel Structures, maintain a proprietary Coordinate Geometry (COGO) system.
- With the advent of CNC equipment, the need for shop drawings has been diminished. CNC equipment is driven by computer code. Thus, while fabricators continue to create shop drawings to be submitted for Owner approval and use, they also create computer code by manual programming based on the information shown on the shop drawings. While the CNC equipment created great efficiencies in steel fabrication itself, it did necessitate an additional step in translating shop drawing information into computer code. At this stage in the Industry, representative of most fabricators today, steel fabrication is a combination of manual fabrication processes based on the information shown on the shop drawings and CNC processes based on code developed from the shop drawings.

Research Method

Overview

- The study involved data gathered from two girders (G5 and G6) of a two-span, continuous steel multiplate girder bridge, carrying NY RT. 5/8/12 over Oriskany Blvd. The girders are 316'- 8" in length (Figure 3). The design provides for two field splices, so each girder line consists of three pieces that are 114'-0", 106'-6" (over the intermediate support), and 96'-2" in length. The test section girder for fabrication is the 114'-0" piece. The Top and Bottom flanges are both 1.5" × 16" and the Web plate is 0.5625" thick and 60" deep. Bearing stiffeners (two required) are 1" × 7" and intermediate connection plates (three required) are all 0.5" × 7".

The study was conducted in two parts. The objective of the first part was to verify that a graphical representation of a bridge member is a viable means of data transmission. The second part involved the actual fabrication of the steel girder and verification using a laser scanner.

Part 1: Feasibility of Data Transmission

The study team initially assumed that NYSDOT had a 3-D model of the girder alignment. However, NYSDOT does not develop the 3-D geometry for the girders as part of its design effort and does not typically fully model girders in 3-D. NYSDOT has a deck surface and alignment file, and it copied the LAG file into a separate directory. This represented the starting point for the electronic data transfer process.

Based on the information received, MJ (in the role of designer) developed 3-D graphic models for two of the girders, specifically girders G5 and G6. These girders were modeled in 3-D in preparation for a coordination meeting to understand what information the detailer, UDI, needed.

The main goals of the meeting were to coordinate the relevant information needed by UDI and to understand what format UDI needed to develop information to produce shop drawings and coordinate with the fabricator. MJ displayed the model that had been developed based on the NYSDOT's project files. The 3-D graphic representations of the girders were created using the Bentley InRoads program. The 3-D girders were positioned according to the contract plans and were based on the provided alignment (.alg) and digital terrain model (.dtm) files, using the top of the web at the centerline of the girder as the control point.

It was agreed that, initially, MJ would submit the centerline of bearing and tenth point data to make sure they transferred successfully, and then add the additional data points required once the process and data submission format were established. This way, the beam's basic information would be established and the rest could build off of that. Camber, haunch, moment, and shear tables were formulated from the design software, exported into Excel, and formatted into a table to be placed on the plans. UDI stated that this would be helpful information for its use when developing the model. It was noted at this meeting that the Excel files for the tables should accompany the beam models. Vertical alignments should be set up along the centerline of the girders at the bottom of the slab using the provided .dtm file from NYSDOT. If these elevations at the centerline of bearings and tenth points matched those in the provided haunch table, the first check would be completed and the alignments could then be dropped to the top of web to create the model. If the data did not check within the required tolerances, the .dtm should be reestablished on the deck with smaller template drop locations and checked. The current standard template interval is approximately 1.0'.

The settled course of action was as follows:

1. Create a horizontal alignment along centerline of one of the beams.
2. Create a vertical alignment at top of deck slab.
3. Translate the vertical alignment to bottom of deck slab.
4. Generate report from InRoads at centerline of bearing and tenth points to check vs. the contract plan haunch table.
5. If the vertical alignment data correspond within 1/16" of the elevations in the haunch table, translate the vertical alignment to the top of the web of the beam and then create the beam model.
6. Generate report to be sent to UDI for its use in testing data transfer.
7. If all worked successfully, add additional points to the first beam and duplicate the process for the second beam.

The initial data set that was sent to UDI is shown in Figure 4. UDI requested additional information as noted below:

- Bearing points
- Points where girder horizontal geometry changes occur (PC, PCC, kinks, etc.)

- Field splices
- Girder cross-section changes (flange transitions, web thicknesses, depth changes, etc.)
- Diaphragm locations (at centerline of connection plate)
- Miscellaneous points such as locations for intermediate stiffeners, scupper connections, utility supports, under deck lighting, etc.
- Metadata information for the data points noted above, to eventually be provided with specific tags clearly denoting what the data point represents (for example, TFT_#1 could denote Top Flange Transition #1)
- Data points, as provided, at the locations noted in camber table. The camber table data, in Excel format, should probably be presented in a table that is a “copy” of the tables presented in the contract plans. Four decimal places would be preferred over three to prevent mathematical rounding discrepancies down the road.

Based on these comments, MJ transferred data as shown in Figure 5.

Designer Workflow

A workflow was developed for the procedure to create the InRoads reports that were submitted to the steel detailer UDI (see Appendix C to the report). The procedure was completed by another highway engineer to verify all pertinent information was provided and used to generate the information required for girder G5 (Figure 6). The workflow procedure is outlined below:

- An attempt was made to create a generic procedure that could be followed regardless of the complexity of the structure:
    - The procedure was established based on a structure with two spans and continuous girders.
    - Additional detail may be required in the list of required points to cover structures that are not continuous.
- The procedure took a highway engineer not familiar with bridge design ±2 hours from start to finish for a single girder:
    - This included calculations of all of the point stations (STEP 1), which accounted for about half of the time.
    - The engineer was experienced with InRoads.
    - If all of the station information is ready (STEPS 2 through 4 are completed prior to starting), the InRoads report process by itself could take 30 minutes or less per girder for someone familiar with the process and InRoads. Time savings for the detailer are yet to be quantified.
- STEP 2, which involves calculating the stations of the tenth points and other significant points along the girder, will not be required when the designer puts this information together. He or she will have already calculated all of the stations of the required points during the design process and the data will only need to be compiled.
- The elevations provided using this process are only as good as the bridge deck .dtm, or surface:
    - For example, the test structure bridge deck .dtm used did not take into account the superelevation changes near the beginning of the bridge and, therefore, some points were not within the 1/16" tolerances of the haunch table data.
- If multiple points have the same station, multiple descriptions must be noted

- The test structure was on a tangent, making creation of the data more straightforward than a structure on a curve or a combination of tangents and curves. To simplify the horizontal alignment steps for structures not only on a tangent, the HCL could be made into a complex chain or linestring then offset to the centerline of the girders and trimmed to the limits of the girder at the beginning and end abutments.
- When creating the vertical alignments, the final bridge deck surface must be copied down in the profile since the girders are directly below the bridge deck in the vertical plane. The copy parallel command must not be used. This applies to STEPS 12 and 13 when creating the vertical alignments for the bottom of deck and top of web.
- This procedure could be done for a single girder for the entire length of the structure, regardless of the number of spans and continuity of the girders.

Detailer Workflow

An outline of the steps for creating DXF files from the designer's coordinate data is provided below:

1. UDI received XYZ coordinate data from MJ in Excel format (Figure 6).

    a. Data points provided were for locations of 'Key-points' along the girder lines. 'Key-points' including beginning and end of the girders, bearings, diaphragms, shop splices for material changes, field splices, and contract camber data locations.
    b. These 'Key-points' were provided in the "final" position.
    c. Metadata labels for each 'Key-point' were provided.

2. UDI added the total deflection values as were provided in the printed contract design drawings (Figure 7 and Figure 8) at the 1/10th point locations.

    a. Deflection values for 'Key-points' not located at 1/10th point locations were extrapolated by UDI from a camber/deflection diagram created by UDI from the 1/10th point values.

3. UDI adjusted each 'Key-point' location using local dead load rotations and the extrapolated deflection values to create revised 'Key-point' locations now in the "no-load" position.

    a. All data points were adjusted based on their relative position compared with the fixed bearing point(s) at Pier 1.

4. Adjusted 'Key-points' coordinates in the "no load" position were imported into both Microstation and SDS/2 programs.
5. The full web plate geometry was developed in both programs and the geometry was comparison checked between the two software platforms.
6. For illustrative purposes (Figure 9), full 3-D modeling of all six girder pieces (two girder lines with two field splices per line) were completed with the addition of Flanges, Flange transitions, Field Splices, Stiffeners, and Connection Plates.
7. 2-D AutoCad DXF files were created by both software platforms and provided as examples of possible output files that can be used by a fabricator as preliminary import data. A screenshot of one of the DXF files is shown in Figure 10.

DETAILER ISSUES AND OBSERVATIONS

1. In the Detailing Outline, STEP 1 was to "Import designer's model."

    a. This step does not exist within current NYSDOT operations. The bridge superstructure is not required to be modeled in any format that could be transmitted downstream. Larger design/build

projects such as the Tappan Zee Bridge replacement are developed to proceed along a shared model basis since the design/build team is to function as a single entity.

b. All of the ensuing steps within the Detailing Outline follow suit with the above Note a. Within the confines of the data available, UDI “followed” the detailing outline.
c. Modeling programs that can dynamically adjust a modeled structure following the material properties of a bridge superstructure do not exist. This leads to duplication of model information when the designer would create the “Final” position model, the detailer would need to create several other models, “No-load,” “Erected,” etc. These are further complicated by the fabricator’s need to make additional changes to the modeled members to account for construction tolerances and fabrication processes.

2. Deflection data should be provided at all ‘Key-points’ to eliminate the need for extrapolation. Extrapolation is not appropriate in all cases because it can lead to errors.
3. Means and methods for calculating the adjustments to the ‘Key-points’ involve calculation of the local grades at all ‘Key-points’ in all of their dynamic positions required. The local grades vary depending on vertical curves, superelevations, and dead-load deflection states. All of these elements complicate the geometrical calculations of each ‘Key-point.’
4. The model output, whether in a DXF file, VRML, CIS/2, or any other output format from the detailing model must be further adjusted by the fabricator, erector, or contractor. No data stream remains unchanged because it flows throughout the project and, regardless of the format, must be adaptable to remain usable by all subcontractors involved in the project.

Fabricator Workflow

INITIAL REVIEW OF DATA

The fabricator received three DXF files from the detailer representing three sets of web plates that make up Girder 5. After performing some checks on the dimensions and a check of the entire girder line to do a comparison from the DXF model to what a fabricator actually scans in shop for girders, the fabricator generated a nesting diagram (Figure 11), which shows how a piece would be cut out of a rectangular piece of steel. What has been demonstrated at this point is that the graphical representation of a bridge member is a viable means of data transmission. The fabricator received this transmission in form of DXF file and, after some proprietary modifications, confirmed that he could proceed to fabrication.

Part 2: Fabrication and Verification

Based on the results from Part 1 verifying that a graphical representation of a bridge member is a viable means of data transmission, a change order was issued to proceed with fabrication and verification of the test girder. As a cost consideration, it was decided to fabricate only the 114-foot section of the G5 girder line. The Top and Bottom flanges are both 1.5" × 16" and the Web plate is 0.5625" thick and 60" deep. Bearing stiffeners (two required) are 1" x 7" and three required intermediate connection plates are all 0.5" × 7".

Certain modifications needed to be made to the files that were established in Part 1. First, the fabricator provided shop splice locations to the designer. Figure 12 includes the coordinates for field splices on the 114-foot section that were provided to the detailer. There was coordination between the detailer and fabricator on the format, information, and conventions for fabrication. All components were welded using 5/16" fillet welds, with the exception of web and flange butt splices. The stiffeners were modeled as “Mill to bear” at the bottom flange. Additionally, there was no check of the hole patterns in the connection plates since the diaphragms were not modeled.

Separate DXF files and STEP files were provided for each girder plate (top flange, bottom flange, stiffener plates) as well as a 3-D model for reference and checking (Figure 13). In the DXF files, for the ends of the web and flange plates, the plates were extended by 3" (to account for shrinkage) and a scribe line was shown for the projected cutline. On the web plates and bottom flange plates, similar scribe lines were shown to locate the position and orientation of the connection plates and stiffeners. The fabricator required about an hour to modify the models sent from the detailer, including proprietary camber adjustments due to shrinkage. The files were then imported into a CNC machine. Figure 14 is a photo taken during the fabrication process.

Study Findings

Girder fabrication was completed at the end of August 2016. Full laser scanning of the girder was conducted during available work crew periods in the first three weeks of September. Representatives from HDR and UDI witnessed girder verification on September 30, 2016. The finished girder (in lay-down position) is shown in Figure 15. Figure 16 is a photo showing the bolt holes for the field splice. The fabricated section was scanned using a Faro laser scanner and then compared with the model generated by modeling software (Figure 17). Representative scan results are provided in Appendix D of this report. The laser scan provided validation that the fabricated girder was within the usual fabrication tolerances.

The study highlighted a number of areas that will require further consideration. First, there were many elements required for fabrication that could not be shown—such as tension and stress reversal zones, weld testing limits, Mill to Bear/Tight Fit requirements, and even simple fillet welds between components—so this study only touched on the large amounts of metadata that would need to be included in making this whole process a system that would replace the current NYSDOT means and methods.

For the DXF of x1a, the wrong face of the stiffener was inadvertently exported and identified during the fabricator's review. Due to the beveled edge against the web of the girder, one face is narrower than the 7" stiffener width. The beveled edge—and how to show that on a 2-D DXF file—is one of the many issues that this methodology faces moving forwards. It is not possible to show a beveled edge other than to add the parallel "edge" shown differently. How this gets interpreted into CNC is problematic.

Second, it became evident during the course of the study that electronic data transfer will require closer coordination and continued back-and-forth communication among the designer, detailer, and fabricator. One example is the location of the optional shop splice locations, which is based solely on the purchaser's selection of economical locations.

What also became clear in witnessing verification is the great potential in the use of laser scanners in conjunction with a 3-D model to measure girders in the fabrication shop. Fabricators must demonstrate fit up of connected members in the shop. As demonstrated in Figure 18, a full-size lay down of a connected member can require considerable shop space. As demonstrated in this proof of concept study, laser scanning can measure fabricated sections that in turn can be used to detail the connection plates, thereby ensuring proper fit-up.

Statement on Implementation

The study team participants provided responses regarding the question of what would need to transpire in order for the bridge industry to achieve the ultimate objective to transfer data seamlessly from design to fabrication.

Designer's Response

Ideally, it would be beneficial to keep all information in only one or two interfaces, at least between the designer and fabricator. We envision a modification to existing software programs or development of new ones to limit the number of interfaces. For example, if a program similar to MIDAS or CSiBridge were created and then used—which would have the capabilities to develop a structural model, design the structure, and create all the necessary tables that could be exported to Microstation V8i for use in the contract plans, as well as be available for the detailer's use—the information would be from a singular interface and would reduce possible data transferring issues. This modeling program would be a hybrid between a design software and BrIM software, and would be required to detail/design everything from the main girder system to the bolts of the splices/cross frames in order to allow for complete fabrication of the structure. The software would also have to be able to develop COGO points for each major elements (10th points, splice locations, diaphragm/connection plate locations, etc.) that would be placed in a table to be easily converted into the necessary file type for the fabricator.

The previously mentioned software interfaces already have a function to look at staged construction, so that could be used in developing points for the no-load condition, as well as during staged deck pouring. This model could also be forwarded onto the detailer, who could then import it into which ever file type needed by the fabricator for fabrication, as well as used for making shop drawings.

The limitation of this software is that it would likely be proprietary and quite expensive considering the cost of the software packages of MIDAS and CSiBridge, which can do quite a bit and get to a point of modeling/design. This software would have to go even further.

This process would also eliminate one step that detailers typically perform under the current approach. The detailer typically provides an independent check of the design by using the information provided in the contract plans to construct the model and provide additional details that are then sent to the fabricator. During the process of developing the model, the detailer may notice some inconsistencies that can be worked out with the designer prior to sending the information for fabrication. Using this "euphoric" approach, the sole responsibility of the design and QC/QA process will lie mainly with the designer, with the detailer acting mainly as a middle man, just converting the model to the necessary file type for the fabricator. The fabricator would mainly use the model provided by the designer, and then the designer would check the shop drawings. The independent review of the design would be eliminated from the process unless the detailer would be used solely as a check of the data and model prior to transferring to the fabricator to provide an independent check.

Detailer's Response

Bridge model data—accessible to all involved with the project—hosted by NYSDOT would be an entry point. This would then be expanded to several models: "No-load," "Fabricated," "Erected," etc. to then extract each party's data needs. Designers develop their "model" based on the final finished condition, but this condition needs significant modification to become an as-built reality. In a true "paperless" environment, software would exist that could move and adjust all members within a model based on the various positions: final, erected, no-load. Dead-load rotations would be accounted for. Crossframes would adjust for differential deflections. Girders would roll in and out of plumb as deflections and member strengths allow. Our view is that software with that capability will not be available in the near future.

Fabricator's Response

Although challenges to effectively implementing this new data-based technology are numerous, the opportunities are seemingly endless for the structural steel fabrication industry when considering the

continued development of CNC and robotic equipment and processes. A few examples of how these data-driven processes can be used in structural steel fabrication include:

- Automated cutting/burning of webs, flanges, parts, rolled shapes
- Automated drilling, punching, milling
- Automated placement of parts into an assembly
- Automated or robotic building and welding
- Automated or robotic blast cleaning and painting
- Virtual/digital measurement of as-fabricated pieces and comparison to theoretical for quality checks
- Virtual assembly of as-fabricated pieces for verification of fit
- Digital fabrication records (e.g., QC documents) for storage with project files/data model

Recommendations and Conclusion

The results of this study provide impetus for further research of this kind. Since only the first part of a girder line was fabricated as part of this scope of work, the next step would be to undertake the fabrication and virtual assembly of an entire girder line. A subsequent step would be to digitally fabricate and assemble a two-girder bridge of 75 to 100 feet that would include the modeling and assembly of cross frames. As the first documented fabrication of a steel bridge girder based solely on the transfer of electronic data and without the use of paper drawings, the results of this study represent an encouraging and important milestone in the pursuit of the digital steel bridge fabrication.

Glossary of Terms

BrIM (Bridge Information Modeling)
A three-dimensional model of a bridge that is linked to a wide variety of data.

COGO (Coordinate Geometry)
A suite of programs used in civil engineering to solve coordinate geometry problems.

CNC (Computer Numerical Control)
CNC is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool.

Digital Fabrication
Broadly speaking, the use of a digital model to automate fabrication processes. Examples include:

- Automated cutting/burning of webs, flanges, parts, rolled shapes
- Automated drilling, punching, milling
- Automated placement of parts into an assembly
- Automated or robotic building and welding
- Automated or robotic blast cleaning and painting
- Virtual/digital measurement of as-fabricated pieces and comparison to theoretical for quality checks
- Virtual assembly of as-fabricated pieces for verification of fit
- Digital fabrication records (e.g., QC documents) for storage with project files/data model

Virtual Assembly
Digitized information of an as-fabricated piece is back-fed into software to check against the theoretically fabricated piece.

Virtual Design and Construction
The management of integrated multidisciplinary performance models of design-construction projects, including the product (i.e., facilities), work processes, and organization of the design-construction-operation team to support explicit and public business objectives.

Appendix A

Figures

Figure 1 Current Workflow

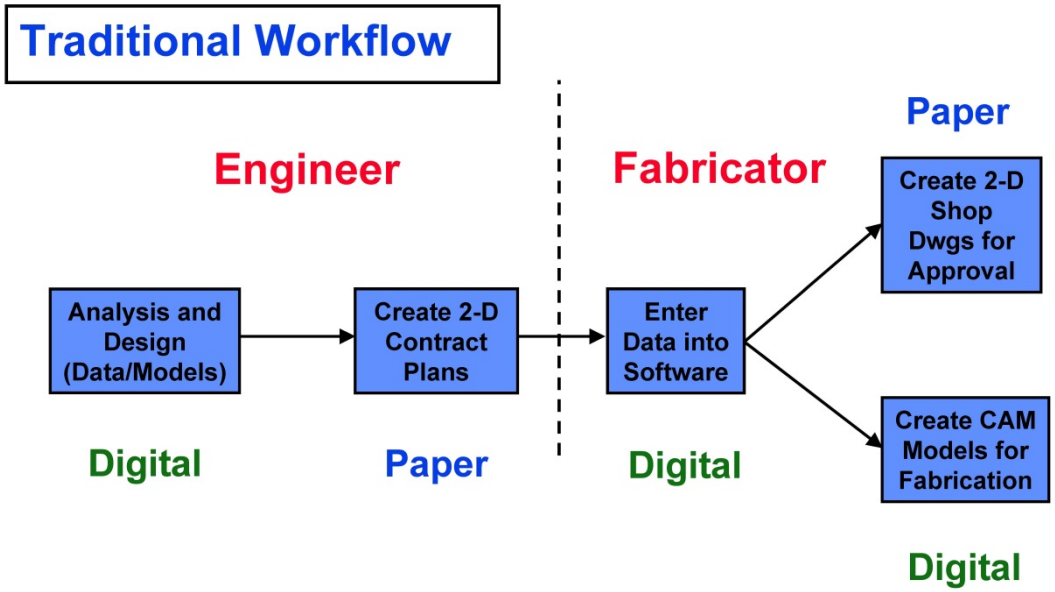


Figure 2 Preferred Workflow

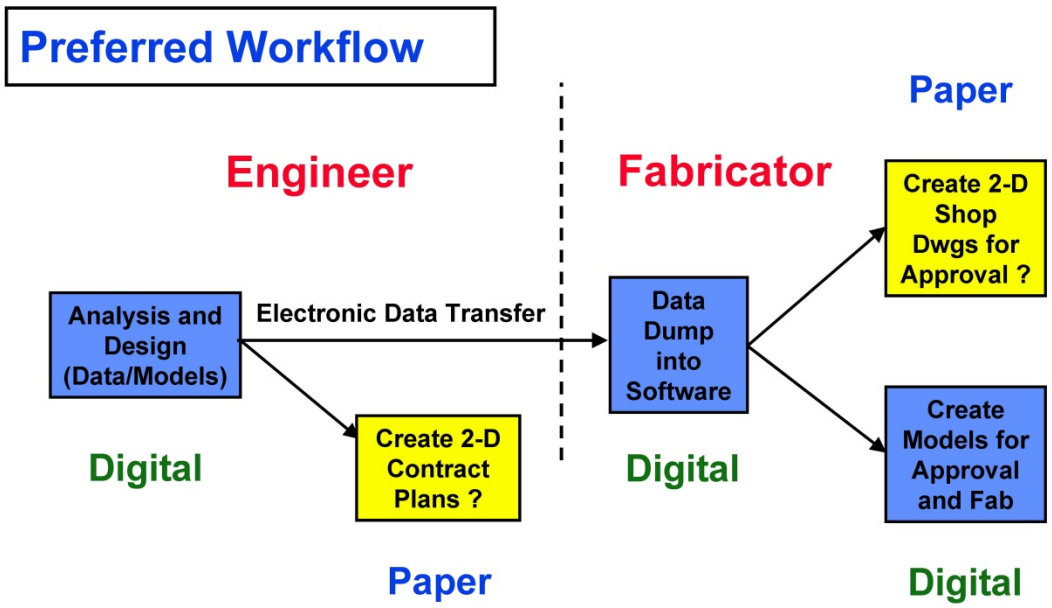


Figure 3 Test Girder Elevation

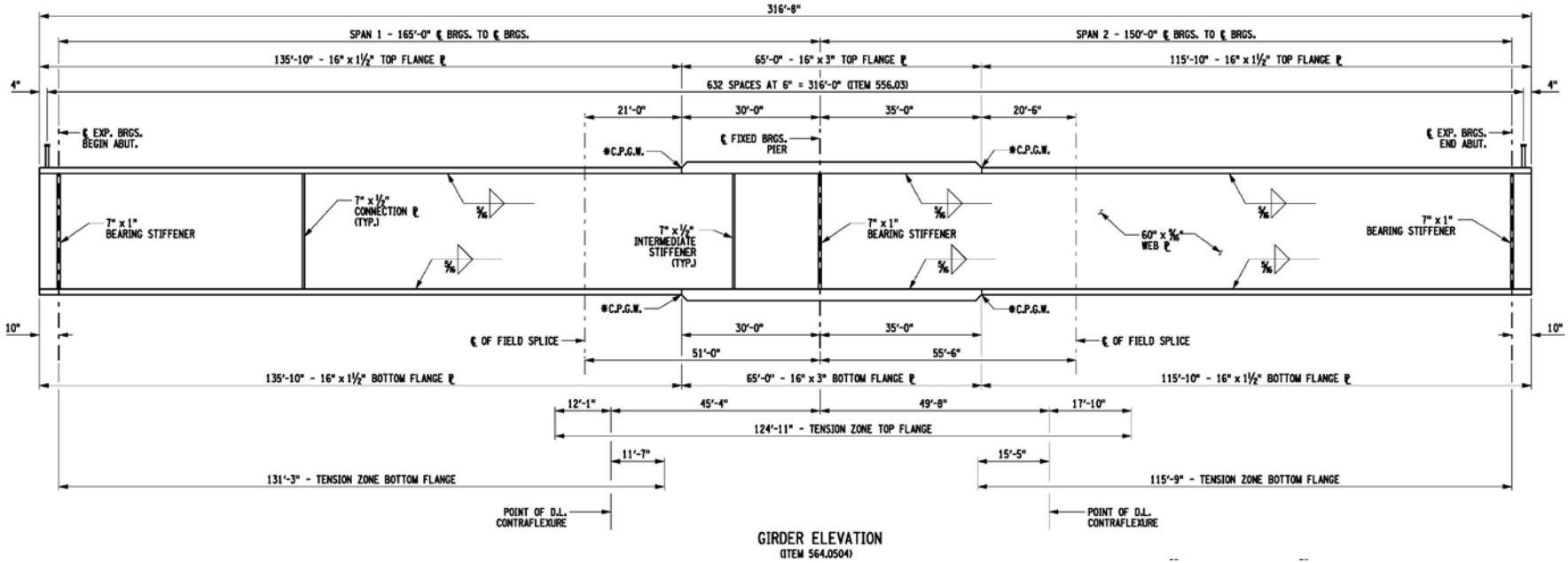


Figure 4 Initial Data Set Sent to UDI

Vertical Events Report

Report Created: 8/5/2015
Time: 2:51pm

Project: S3DFVA_GIRDER_TOP OF WEB
Description: GIRDER ALIGNMENTS
File Name: F:\MJ744\mj744.03\InRoads\S3DFVA_GIRDER_TOP OF WEB.alg
Last Revised: cschneider 8/5/2015 2:50:20 PM

Input Grid Factor: 1

Note: All units in this report are in feet unless specified otherwise.

Horizontal Alignment Name: GIRDER 6 ENTIRE LENGTH
Horizontal Alignment Style: AC_P
Vertical Alignment Name: GIRDER 6_T/WEB
Vertical Alignment Style: AC_P

Type	Station	Northing	Easting	Elevation	Grade	
S+E	PB 210+88.29	1134353.522	1179175.982	453.564	-0.55%	G6_CL BEG BRG
S+E	PB 211+04.79	1134369.96	1179177.406	453.473	-0.55%	G6_L1 0.1
S+E	PB 211+21.29	1134386.398	1179178.831	453.382	-0.55%	G6_L1 0.2
S+E	PB 211+37.79	1134402.837	1179180.255	453.281	-0.67%	G6_L1 0.3
S+E	PB 211+54.29	1134419.275	1179181.68	453.161	-0.80%	G6_L1 0.4
S+E	PB 211+70.79	1134435.713	1179183.105	453.019	-0.91%	G6_L1 0.5
S+E	PB 211+87.29	1134452.152	1179184.529	452.858	-1.04%	G6_L1 0.6
S+E	PB 212+03.79	1134468.59	1179185.954	452.677	-1.16%	G6_L1 0.7
S+E	PB 212+20.29	1134485.029	1179187.378	452.475	-1.29%	G6_L1 0.8
S+E	PB 212+36.79	1134501.467	1179188.803	452.253	-1.40%	G6_L1 0.9
S+E	PB 212+53.29	1134517.905	1179190.227	452.011	-1.53%	G6_CL PIER BRG
S+E	PB 212+68.29	1134532.849	1179191.522	451.773	-1.64%	G6_L2 0.1
S+E	PB 212+83.29	1134547.793	1179192.817	451.519	-1.75%	G6_L2 0.2
S+E	PB 212+98.29	1134562.737	1179194.112	451.248	-1.86%	G6_L2 0.3
S+E	PB 213+13.29	1134577.681	1179195.407	450.96	-1.98%	G6_L2 0.4
S+E	PB 213+28.29	1134592.625	1179196.702	450.657	-2.03%	G6_L2 0.5
S+E	PB 213+43.29	1134607.569	1179197.998	450.352	-2.03%	G6_L2 0.6
S+E	PB 213+58.29	1134622.513	1179199.293	450.047	-2.03%	G6_L2 0.7
S+E	PB 213+73.29	1134637.457	1179200.588	449.742	-2.03%	G6_L2 0.8
S+E	PB 213+88.29	1134652.401	1179201.883	449.437	-2.03%	G6_L2 0.9
S+E	PB 214+03.29	1134667.345	1179203.178	449.132	-2.03%	G6_CL END BRG

Figure 5 Girder 6 Data Points with Additional Data Points

Vertical Events Report

Report Created: 8/18/2015
Time: 2:26pm

Project: S3DFVA_GIRDER_TOP OF
Description: GIRDER ALIGNMENTS
File Name:
Last Revised: cschneider 8/18/2015 2:22:53 PM

Input Grid Factor: 1

Note: All units in this report are in feet unless specified otherwise.

Horizontal Alignment Name: GIRDER 6 ENTIRE LENGTH
Horizontal Alignment Style: AC_P
Vertical Alignment Name: GIRDER 6_T/WEB
Vertical Alignment Style: AC_P

Type	Station	Northing	Easting	Elevation	Grade	DESCRIPTION
S+E	PB 210+87.46	1134352.6917	1179175.9098	453.5680	-0.55%	START STATION
S+E	PB 210+88.29	1134353.5220	1179175.9818	453.5640	-0.55%	CL BEGIN BEARING
S+E	PB 211+04.79	1134369.9604	1179177.4063	453.4730	-0.55%	0.1 L1
S+E	PB 211+11.86	1134377.0054	1179178.0169	453.4340	-0.55%	CL DIAPHRAGM SPAN 1 LOC 2 (D1 RT, D2 LT)
S+E	PB 211+21.29	1134386.3987	1179178.8309	453.3820	-0.55%	0.2 L1
S+E	PB 211+35.44	1134400.4887	1179180.0519	453.2970	-0.65%	CL DIAPHRAGM SPAN 1 LOC 3 (D1 RT, D2 LT)
S+E	PB 211+37.79	1134402.8371	1179180.2554	453.2810	-0.67%	0.3 L1
S+E	PB 211+54.29	1134419.2755	1179181.6800	453.1610	-0.80%	0.4 L1
S+E	PB 211+59.01	1134423.9722	1179182.0870	453.1220	-0.83%	CL DIAPHRAGM SPAN 1 LOC 4 (D1 RT, D2 LT)
S+E	PB 211+62.01	1134426.9610	1179182.3460	453.0970	-0.86%	CL DIAPHRAGM D3 SPAN 1 LOC 1 (LIGHTING)
S+E	PB 211+70.79	1134435.7139	1179183.1045	453.0190	-0.91%	0.5 L1
S+E	PB 211+82.58	1134447.4556	1179184.1221	452.9060	-1.00%	CL DIAPHRAGM SPAN 1 LOC 5 (D1 RT, D2 LT)
S+E	PB 211+87.29	1134452.1523	1179184.5291	452.8580	-1.04%	0.6 L1
S+E	PB 212+02.29	1134467.0963	1179185.8241	452.6940	-1.15%	CL FIELD SPLICE SPAN 1
S+E	PB 212+03.79	1134468.5907	1179185.9536	452.6770	-1.16%	0.7 L1
S+E	PB 212+06.15	1134470.9390	1179186.1571	452.6490	-1.18%	CL DIAPHRAGM SPAN 1 LOC 6 (D1 RT, D2 LT)
S+E	PB 212+09.15	1134473.9278	1179186.4161	452.6130	-1.20%	CL DIAPHRAGM D3 SPAN 1 LOC 2 (LIGHTING)
S+E	PB 212+20.29	1134485.0291	1179187.3782	452.4750	-1.29%	0.8 L1
S+E	PB 212+23.29	1134488.0179	1179187.6372	452.4360	-1.31%	BEGIN FLANGE TRANSITION (TOP & BOT)
S+E	PB 212+29.72	1134494.4224	1179188.1922	452.3500	-1.35%	CL DIAPHRAGM SPAN 1 LOC 7 (D1 RT, D2 LT)
S+E	PB 212+36.79	1134501.4675	1179188.8027	452.2530	-1.40%	0.9 L1
S+E	PB 212+37.59	1134502.2561	1179188.8711	452.2420	-1.41%	INTERMEDIATE STIFFENER PLATES SPAN 1 RT
S+E	PB 212+45.44	1134510.0810	1179189.5492	452.1280	-1.47%	INTERMEDIATE STIFFENER PLATES SPAN 1 LT
S+E	PB 212+53.29	1134517.9059	1179190.2273	452.0110	-1.53%	CL PIER BEARING
S+E	PB 212+61.63	1134526.2081	1179190.9467	451.8810	-1.59%	INTERMEDIATE STIFFENER PLATES SPAN 2 LT
S+E	PB 212+68.29	1134532.8499	1179191.5223	451.7730	-1.64%	0.1 L2
S+E	PB 212+69.96	1134534.5102	1179191.6662	451.7460	-1.65%	INTERMEDIATE STIFFENER PLATES SPAN 2 RT
S+E	PB 212+78.29	1134542.8125	1179192.3857	451.6050	-1.72%	CL DIAPHRAGM SPAN 2 LOC 2 (D1 RT, D2 LT)
S+E	PB 212+81.29	1134545.8013	1179192.6447	451.5540	-1.74%	CL DIAPHRAGM D3 SPAN 2 LOC 1 (LIGHTING)
S+E	PB 212+83.29	1134547.7938	1179192.8173	451.5190	-1.75%	0.2 L2
S+E	PB 212+88.29	1134552.7752	1179193.2490	451.4300	-1.79%	END FLANGE TRANSITION (TOP & BOT)
S+E	PB 212+98.29	1134562.7378	1179194.1124	451.2480	-1.86%	0.3 L2
S+E	PB 213+03.29	1134567.7192	1179194.5441	451.1540	-1.90%	CL DIAPHRAGM SPAN 2 LOC 3 (D1 RT, D2 LT)
S+E	PB 213+08.79	1134573.1986	1179195.0189	451.0480	-1.94%	CL FIELD SPLICE SPAN 2
S+E	PB 213+13.29	1134577.6818	1179195.4074	450.9600	-1.98%	0.4 L2
S+E	PB 213+14.67	1134579.0517	1179195.5261	450.9330	-1.98%	SCUPPER CONNECTION PLATE SPAN 2 RT
S+E	PB 213+28.29	1134592.6258	1179196.7025	450.6570	-2.03%	0.5 L2
S+E	PB 213+28.29	1134592.6258	1179196.7025	450.6570	-2.03%	CL DIAPHRAGM SPAN 2 LOC 4 (D1 RT, D2 LT)
S+E	PB 213+43.29	1134607.5698	1179197.9975	450.3520	-2.03%	0.6 L2
S+E	PB 213+53.29	1134617.5325	1179198.8609	450.1490	-2.03%	CL DIAPHRAGM SPAN 2 LOC 5 (D1 RT, D2 LT)
S+E	PB 213+56.29	1134620.5213	1179199.1199	450.0880	-2.03%	CL DIAPHRAGM D3 SPAN 2 LOC 2 (LIGHTING)
S+E	PB 213+58.29	1134622.5138	1179199.2926	450.0470	-2.03%	0.7 L2
S+E	PB 213+73.29	1134637.4578	1179200.5876	449.7420	-2.03%	0.8 L2
S+E	PB 213+78.29	1134642.4391	1179201.0193	449.6400	-2.03%	CL DIAPHRAGM SPAN 2 LOC 6 (D1 RT, D2 LT)
S+E	PB 213+88.29	1134652.4018	1179201.8826	449.4370	-2.03%	0.9 L2
S+E	PB 214+03.29	1134667.3458	1179203.1777	449.1320	-2.03%	CL END BEARING
S+E	PB 214+04.13	1134668.1752	1179203.2496	449.1150	-2.03%	END STATION

Figure 6 Girder 5 Data Prepared from User Manual

Vertical Events Report

Report Created: 8/25/2015
Time: 5:12pm

Project: S3DFVA Girder 5
Description: Girder 5
File Name: F:\MJ744\mj744.03\InRoads\Girde
Last Revised: cschneider 8/25/2015 5:12:06 PM

Input Grid Factor: 1

Note: All units in this report are in feet unless specified otherwise.

Horizontal Alignment Name: 2134.41 Girder 5
Horizontal Alignment Style: Default
Vertical Alignment Name: 2134.41 Girder 5_T/Webb
Vertical Alignment Style: Default

Type	Station	Northing	Easting	Elevation	Grade	Description
S+E	PB 210+89.0471	1134355.0496	1179167.0804	453.6874	-0.55%	START STATION
S+E	PB 210+89.8804	1134355.8798	1179167.1524	453.6829	-0.55%	CL BEGIN BEARING
S+E	PB 211+06.3804	1134372.3182	1179168.5769	453.5921	-0.55%	0.1 L1
S+E	PB 211+13.4518	1134379.3632	1179169.1875	453.5532	-0.55%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 211+16.4518	1134382.3520	1179169.4465	453.5367	-0.55%	CL DIAPHRAGM D3 SPAN 1 LOC 1 (LIGHTING)
S+E	PB 211+22.8804	1134388.7566	1179170.0015	453.5013	-0.56%	0.2 L1
S+E	PB 211+37.0233	1134402.8467	1179171.2225	453.4145	-0.67%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 211+39.3804	1134405.1950	1179171.4260	453.3986	-0.68%	0.3 L1
S+E	PB 211+55.8804	1134421.6334	1179172.8506	453.2757	-0.80%	0.4 L1
S+E	PB 211+60.5947	1134426.3301	1179173.2576	453.2369	-0.84%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 211+72.3804	1134438.0718	1179174.2751	453.1327	-0.93%	0.5 L1
S+E	PB 211+84.1661	1134449.8135	1179175.2927	453.0181	-1.02%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 211+88.8804	1134454.5102	1179175.6997	452.9694	-1.05%	0.6 L1
S+E	PB 212+03.8804	1134469.4541	1179176.9947	452.8034	-1.16%	CL FIELD SPLICE SPAN 1
S+E	PB 212+05.3804	1134470.9485	1179177.1242	452.7859	-1.17%	0.7 L1
S+E	PB 212+07.7375	1134473.2968	1179177.3277	452.7580	-1.19%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 212+21.8804	1134487.3869	1179178.5488	452.5822	-1.29%	0.8 L1
S+E	PB 212+24.8804	1134490.3757	1179178.8078	452.5430	-1.32%	BEGIN FLANGE TRANSITION (TOP & BOT)
S+E	PB 212+31.3090	1134496.7803	1179179.3628	452.4567	-1.37%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 212+38.3804	1134503.8253	1179179.9733	452.3583	-1.42%	0.9 L1
S+E	PB 212+39.1721	1134504.6141	1179180.0417	452.3471	-1.43%	INTERMEDIATE STIFFENER PLATES SPAN 1 LT
S+E	PB 212+47.0262	1134512.4388	1179180.7198	452.2329	-1.49%	INTERMEDIATE STIFFENER PLATES SPAN 1 RT
S+E	PB 212+54.8804	1134520.2637	1179181.3979	452.1142	-1.54%	CL PIER BEARING
S+E	PB 212+63.2137	1134528.5659	1179182.1173	451.9833	-1.60%	INTERMEDIATE STIFFENER PLATES SPAN 2 LT
S+E	PB 212+69.8804	1134535.2077	1179182.6929	451.8748	-1.65%	0.1 L2
S+E	PB 212+71.5471	1134536.8682	1179182.8368	451.8472	-1.66%	INTERMEDIATE STIFFENER PLATES SPAN 2 RT
S+E	PB 212+79.8804	1134545.1704	1179183.5563	451.7059	-1.72%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 212+84.8804	1134550.1517	1179183.9879	451.6187	-1.76%	0.2 L2
S+E	PB 212+89.8804	1134555.1330	1179184.4196	451.5296	-1.80%	END FLANGE TRANSITION (TOP & BOT)
S+E	PB 212+99.8804	1134565.0957	1179185.2830	451.3459	-1.87%	0.3 L2
S+E	PB 213+04.8804	1134570.0770	1179185.7147	451.2512	-1.91%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 213+10.3804	1134575.5565	1179186.1895	451.1450	-1.95%	CL FIELD SPLICE SPAN 2
S+E	PB 213+14.8804	1134580.0397	1179186.5780	451.0564	-1.98%	0.4 L2
S+E	PB 213+29.8804	1134594.9837	1179187.8731	450.7529	-2.03%	).5 L2; CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT
S+E	PB 213+44.8804	1134609.9277	1179189.1681	450.4478	-2.03%	0.6 L2
S+E	PB 213+54.8804	1134619.8903	1179190.0315	450.2444	-2.03%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 213+59.8804	1134624.8716	1179190.4632	450.1427	-2.03%	0.7 L2
S+E	PB 213+74.8804	1134639.8156	1179191.7582	449.8377	-2.03%	0.8 L2
S+E	PB 213+79.8804	1134644.7970	1179192.1899	449.7360	-2.03%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)
S+E	PB 213+89.8804	1134654.7596	1179193.0532	449.5326	-2.03%	0.9 L2
S+E	PB 214+04.8804	1134669.7036	1179194.3483	449.2275	-2.03%	CL END BEARING
S+E	PB 214+05.7137	1134670.5338	1179194.4202	449.2106	-2.03%	END STATION

Figure 7 Deflection Values from Contract Design Drawings

CAMBER TABLE		C.L. BRGS. BEGIN ABUT.	0.10 L1	0.20 L1	0.30 L1	0.40 L1	0.50 L1	0.60 L1	0.70 L1	0.80 L1	0.90 L1	C.L. BRGS. PIER	0.10 L2	0.20 L2	0.30 L2	0.40 L2	0.50 L2	0.60 L2	0.70 L2	0.80 L2	0.90 L2	C.L. BRGS. END ABUT.
GIRDER 1	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.10	0.19	0.24	0.27	0.26	0.21	0.15	0.09	0.03	0.00	0.00	0.02	0.05	0.09	0.12	0.13	0.12	0.10	0.05	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.04	0.07	0.10	0.11	0.10	0.09	0.06	0.04	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.16	0.29	0.42	0.53	0.62	0.68	0.73	0.76	0.77	0.75	0.72	0.67	0.61	0.53	0.44	0.35	0.26	0.17	0.08	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.34	0.62	0.85	1.00	1.07	1.06	1.00	0.91	0.82	0.75	0.72	0.71	0.71	0.69	0.65	0.58	0.48	0.34	0.18	0.00
GIRDER 2	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.11	0.20	0.27	0.29	0.28	0.23	0.17	0.09	0.03	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.06	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.10	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.17	0.30	0.44	0.54	0.63	0.69	0.74	0.77	0.77	0.76	0.73	0.69	0.62	0.53	0.45	0.36	0.27	0.18	0.09	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.35	0.65	0.89	1.04	1.10	1.09	1.02	0.93	0.83	0.76	0.73	0.73	0.72	0.70	0.67	0.61	0.50	0.36	0.19	0.00
GIRDER 3	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.11	0.20	0.27	0.29	0.28	0.23	0.17	0.09	0.03	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.06	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.10	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.15	0.30	0.43	0.54	0.62	0.70	0.74	0.77	0.77	0.77	0.73	0.69	0.63	0.55	0.45	0.37	0.27	0.18	0.09	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.34	0.64	0.88	1.03	1.10	1.09	1.02	0.93	0.83	0.77	0.73	0.73	0.73	0.72	0.67	0.61	0.50	0.36	0.19	0.00
GIRDER 4	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.11	0.20	0.27	0.29	0.28	0.23	0.17	0.09	0.03	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.06	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.10	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.16	0.31	0.44	0.54	0.64	0.70	0.75	0.77	0.79	0.77	0.74	0.69	0.64	0.56	0.46	0.37	0.28	0.19	0.10	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.35	0.65	0.89	1.04	1.11	1.09	1.03	0.93	0.85	0.77	0.74	0.74	0.74	0.73	0.68	0.62	0.51	0.37	0.20	0.00
GIRDER 5	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.10	0.18	0.23	0.26	0.25	0.21	0.15	0.08	0.03	0.00	0.00	0.02	0.05	0.08	0.11	0.12	0.12	0.09	0.05	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.04	0.07	0.10	0.11	0.10	0.09	0.06	0.04	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.16	0.30	0.44	0.55	0.63	0.70	0.75	0.78	0.79	0.78	0.75	0.70	0.64	0.56	0.48	0.38	0.29	0.19	0.10	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.34	0.63	0.86	1.01	1.07	1.07	1.02	0.93	0.84	0.78	0.75	0.74	0.74	0.72	0.68	0.60	0.50	0.36	0.19	0.00
GIRDER 6	I STEEL D.L. (ft)	0.00	0.04	0.07	0.10	0.10	0.10	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.09	0.17	0.22	0.24	0.23	0.19	0.14	0.08	0.03	0.00	0.00	0.02	0.05	0.08	0.11	0.12	0.11	0.09	0.05	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.03	0.06	0.08	0.08	0.08	0.07	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.03	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.14	0.28	0.41	0.53	0.62	0.69	0.74	0.76	0.77	0.77	0.74	0.70	0.64	0.56	0.47	0.37	0.28	0.19	0.09	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.30	0.58	0.81	0.96	1.03	1.03	0.99	0.90	0.82	0.77	0.74	0.73	0.72	0.70	0.66	0.58	0.48	0.35	0.18	0.00
GIRDER 7	I STEEL D.L. (ft)	0.00	0.04	0.07	0.10	0.11	0.10	0.09	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.11	0.20	0.27	0.29	0.28	0.23	0.17	0.09	0.03	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.06	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.03	0.06	0.07	0.08	0.08	0.07	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.03	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.14	0.28	0.41	0.52	0.61	0.68	0.73	0.76	0.77	0.76	0.74	0.70	0.64	0.56	0.47	0.38	0.28	0.19	0.09	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.32	0.62	0.85	1.00	1.07	1.07	1.01	0.92	0.83	0.76	0.75	0.74	0.74	0.73	0.69	0.62	0.51	0.37	0.19	0.00
GIRDER 8	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.11	0.20	0.27	0.29	0.28	0.23	0.17	0.09	0.03	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.06	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.03	0.06	0.07	0.08	0.08	0.07	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.03	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.14	0.28	0.41	0.52	0.62	0.69	0.74	0.77	0.78	0.77	0.74	0.70	0.65	0.57	0.48	0.39	0.28	0.19	0.10	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.32	0.61	0.84	0.99	1.07	1.06	1.01	0.92	0.84	0.77	0.74	0.74	0.75	0.73	0.69	0.62	0.50	0.37	0.20	0.00
GIRDER 9	I STEEL D.L. (ft)	0.00	0.04	0.07	0.09	0.10	0.09	0.08	0.06	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.05	0.05	0.05	0.04	0.02	0.00
	II CONCRETE D.L. (ft)	0.00	0.11	0.20	0.27	0.29	0.28	0.23	0.17	0.09	0.03	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.06	0.00
	III SUPERIMPOSED D.L. (ft)	0.00	0.03	0.06	0.07	0.08	0.08	0.07	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.03	0.02	0.00
	IV VERTICAL CURVE (ft)	0.00	0.12	0.26	0.39	0.51	0.60	0.68	0.73	0.76	0.77	0.76	0.74	0.70	0.65	0.57	0.49	0.39	0.29	0.19	0.10	0.00
	TOTAL = I + II + III + IV (ft)	0.00	0.30	0.59	0.82	0.98	1.05	1.05	1.00	0.91	0.83	0.76	0.74	0.74	0.75	0.73	0.70	0.62	0.51	0.37	0.20	0.00

PROJECT MANAGER T. LUSSIER
CHECK D. BYRNE
DRAFTING E. LANTZY
CHECK D. BYRNE
DESIGN E. LANTZY
JOB MANAGER E. LANTZY
DESIGN SUPERVISOR M. ROYCE

FILE NAME = 213441_opb_T1_dtl_3of5.dgn
DATE/TIME = 06-DEC-2013 10:23
USER = eklantzy

AFFIX SEAL:
ON:

STATE OF NEW YORK
ERIC J. LANTZY
082974
LICENSED PROFESSIONAL ENGINEER
D262512

ALTERED BY:
ON:

AS-BUILT REVISIONS
DESCRIPTION OF ALTERATIONS:

NY RT. 5/8/12 OVER ORISKANY BLVD.
CITY OF UTICA
COUNTY: ONEIDA

PIN 2134.41

BRIDGES 1079550

CULVERTS

ALL DIMENSIONS IN ft UNLESS OTHERWISE NOTED

GIRDER DETAILS
(3 OF 5)
NY RT. 5/8/12
OVER
ORISKANY BLVD.

CONTRACT NUMBER
D262512
DRAWING NO. ST4-40
SHEET NO. 698

IT IS A VIOLATION OF LAW FOR ANY PERSON, UNLESS THEY ARE ACTING UNDER THE DIRECTION OF A LICENSED PROFESSIONAL ENGINEER, ARCHITECT, LANDSCAPE ARCHITECT, OR LAND SURVEYOR, TO ALTER AN ITEM IN ANY WAY. IF AN ITEM BEARING THE STAMP OF A LICENSED PROFESSIONAL IS ALTERED, THE ALTERING ENGINEER, ARCHITECT, LANDSCAPE ARCHITECT, OR LAND SURVEYOR SHALL STAMP THE DOCUMENT AND INCLUDE THE NOTATION "ALTERED BY" FOLLOWED BY THEIR SIGNATURE, THE DATE OF SUCH ALTERATION, AND A SPECIFIC DESCRIPTION OF THE ALTERATION.

NEW YORK STATE DEPARTMENT OF TRANSPORTATION REGION 02
DOCUMENT NAME: 213441_opb_T1_dtl_3of5.dgn

Figure 8 Coordinate and Camber Data for Girder 5

Vertical Events Report

Report Created: 8/25/2015
Time: 5:12pm

Project: S3DFVA Girder 5
Description: Girder 5
File Name: 5.alg
Last Revised: cschneider 8/25/2015 5:12:06 PM

Input Grid Factor: 1

Note: All units in this report are in feet unless specified otherwise.

Horizontal Alignment Name: 2134.41 Girder 5
Horizontal Alignment Style: Default
Vertical Alignment Name: 2134.41 Girder 5_T/Webb
Vertical Alignment Style: Default

Type	Station	Northing	Easting	Elevation	Grade	Description	Total DL Deflect
S+E	PB 210+89.0471	1134355.0496	1179167.0804	453.6874	-0.55%	START STATION	
S+E	PB 210+89.8804	1134355.8798	1179167.1524	453.6829	-0.55%	CL BEGIN BEARING	0.0000
S+E	PB 211+06.3804	1134372.3182	1179168.5769	453.5921	-0.55%	0.1 L1	0.1800
S+E	PB 211+13.4518	1134379.3632	1179169.1875	453.5532	-0.55%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 211+16.4518	1134382.3520	1179169.4465	453.5367	-0.55%	CL DIAPHRAGM D3 SPAN 1 LOC 1 (LIGHTING)	
S+E	PB 211+22.8804	1134388.7566	1179170.0015	453.5013	-0.56%	0.2 L1	0.3200
S+E	PB 211+37.0233	1134402.8467	1179171.2225	453.4145	-0.67%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 211+39.3804	1134405.1950	1179171.4260	453.3986	-0.68%	0.3 L1	0.4200
S+E	PB 211+55.8804	1134421.6334	1179172.8506	453.2757	-0.80%	0.4 L1	0.4700
S+E	PB 211+60.5947	1134426.3301	1179173.2576	453.2369	-0.84%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 211+72.3804	1134438.0718	1179174.2751	453.1327	-0.93%	0.5 L1	0.4400
S+E	PB 211+84.1661	1134449.8135	1179175.2927	453.0181	-1.02%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 211+88.8804	1134454.5102	1179175.6997	452.9694	-1.05%	0.6 L1	0.3800
S+E	PB 212+03.8804	1134469.4541	1179176.9947	452.8034	-1.16%	CL FIELD SPLICE SPAN 1	
S+E	PB 212+05.3804	1134470.9485	1179177.1242	452.7859	-1.17%	0.7 L1	0.2600
S+E	PB 212+07.7375	1134473.2968	1179177.3277	452.7580	-1.19%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 212+21.8804	1134487.3869	1179178.5488	452.5822	-1.29%	0.8 L1	0.1500
S+E	PB 212+24.8804	1134490.3757	1179178.8078	452.5430	-1.32%	BEGIN FLANGE TRANSITION (TOP & BOT)	
S+E	PB 212+31.3090	1134496.7803	1179179.3628	452.4567	-1.37%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 212+38.3804	1134503.8253	1179179.9733	452.3583	-1.42%	0.9 L1	0.0500
S+E	PB 212+39.1721	1134504.6141	1179180.0417	452.3471	-1.43%	INTERMEDIATE STIFFENER PLATES SPAN 1 LT	
S+E	PB 212+47.0262	1134512.4388	1179180.7198	452.2329	-1.49%	INTERMEDIATE STIFFENER PLATES SPAN 1 RT	
S+E	PB 212+54.8804	1134520.2637	1179181.3979	452.1142	-1.54%	CL PIER BEARING	0.0000
S+E	PB 212+63.2137	1134528.5659	1179182.1173	451.9833	-1.60%	INTERMEDIATE STIFFENER PLATES SPAN 2 LT	
S+E	PB 212+69.8804	1134535.2077	1179182.6929	451.8748	-1.65%	0.1 L2	0.0000
S+E	PB 212+71.5471	1134536.8682	1179182.8368	451.8472	-1.66%	INTERMEDIATE STIFFENER PLATES SPAN 2 RT	
S+E	PB 212+79.8804	1134545.1704	1179183.5563	451.7059	-1.72%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 212+84.8804	1134550.1517	1179183.9879	451.6187	-1.76%	0.2 L2	0.0400
S+E	PB 212+89.8804	1134555.1330	1179184.4196	451.5296	-1.80%	END FLANGE TRANSITION (TOP & BOT)	
S+E	PB 212+99.8804	1134565.0957	1179185.2830	451.3459	-1.87%	0.3 L2	0.0900
S+E	PB 213+04.8804	1134570.0770	1179185.7147	451.2512	-1.91%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 213+10.3804	1134575.5565	1179186.1895	451.1450	-1.95%	CL FIELD SPLICE SPAN 2	
S+E	PB 213+14.8804	1134580.0397	1179186.5780	451.0564	-1.98%	0.4 L2	0.1500
S+E	PB 213+29.8804	1134594.9837	1179187.8731	450.7529	-2.03%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 213+29.8804	1134594.9837	1179187.8731	450.7529	-2.03%	0.5 L2	0.2000
S+E	PB 213+44.8804	1134609.9277	1179189.1681	450.4478	-2.03%	0.6 L2	0.2200
S+E	PB 213+54.8804	1134619.8903	1179190.0315	450.2444	-2.03%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 213+59.8804	1134624.8716	1179190.4632	450.1427	-2.03%	0.7 L2	0.2200
S+E	PB 213+74.8804	1134639.8156	1179191.7582	449.8377	-2.03%	0.8 L2	0.1700
S+E	PB 213+79.8804	1134644.7970	1179192.1899	449.7360	-2.03%	CL DIAPHRAGM SPAN 1 LOC 2 (D2 RT, D1 LT)	
S+E	PB 213+89.8804	1134654.7596	1179193.0532	449.5326	-2.03%	0.9 L2	0.0900
S+E	PB 214+04.8804	1134669.7036	1179194.3483	449.2275	-2.03%	CL END BEARING	0.0000
S+E	PB 214+05.7137	1134670.5338	1179194.4202	449.2106	-2.03%	END STATION	

Figure 9 3D Modeling of Girder Pieces

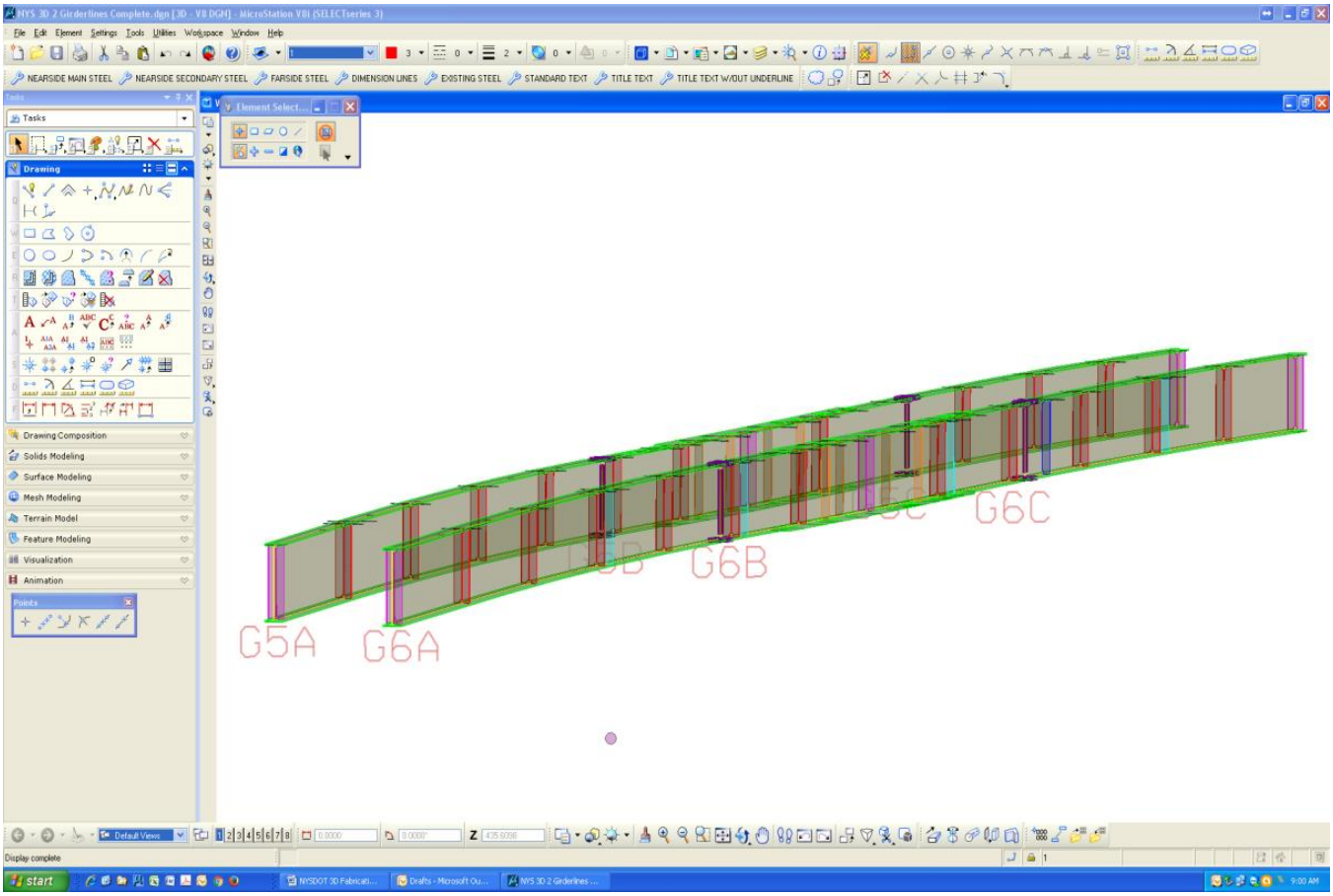


Figure 10 DXF File Screenshot

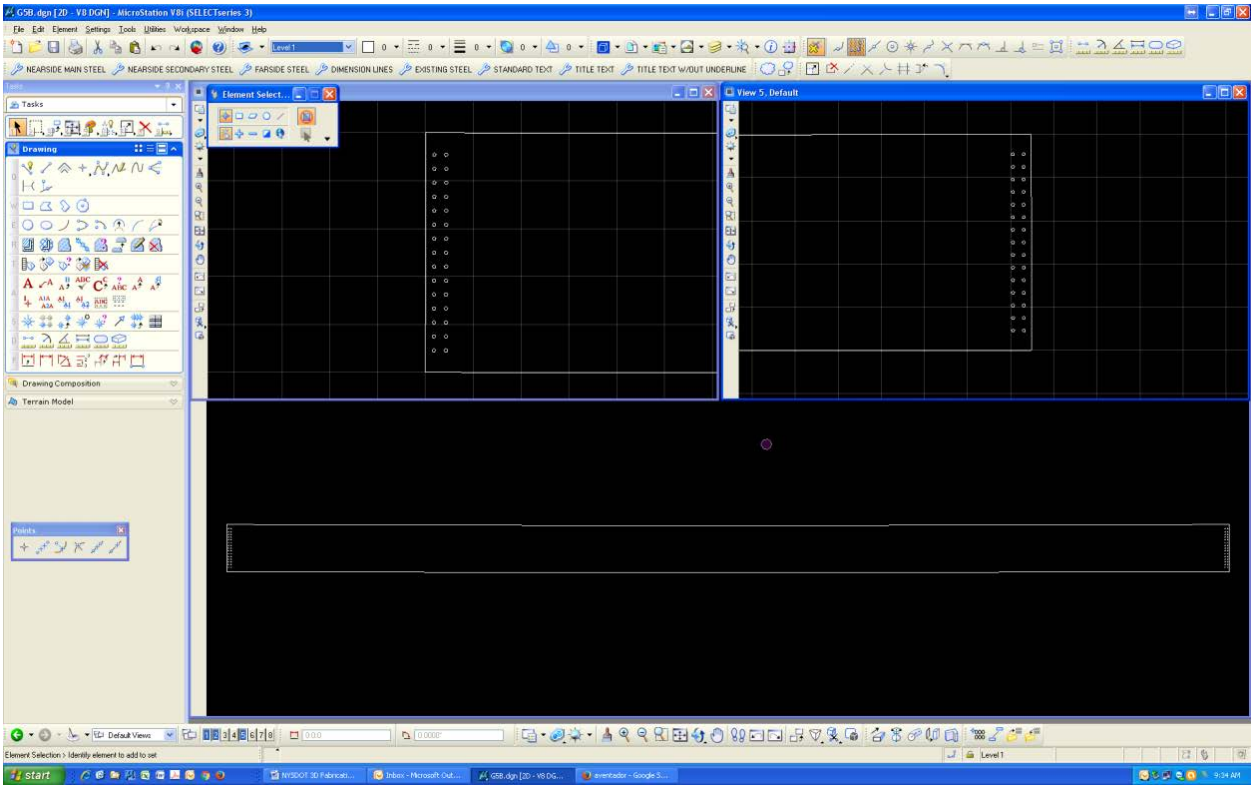
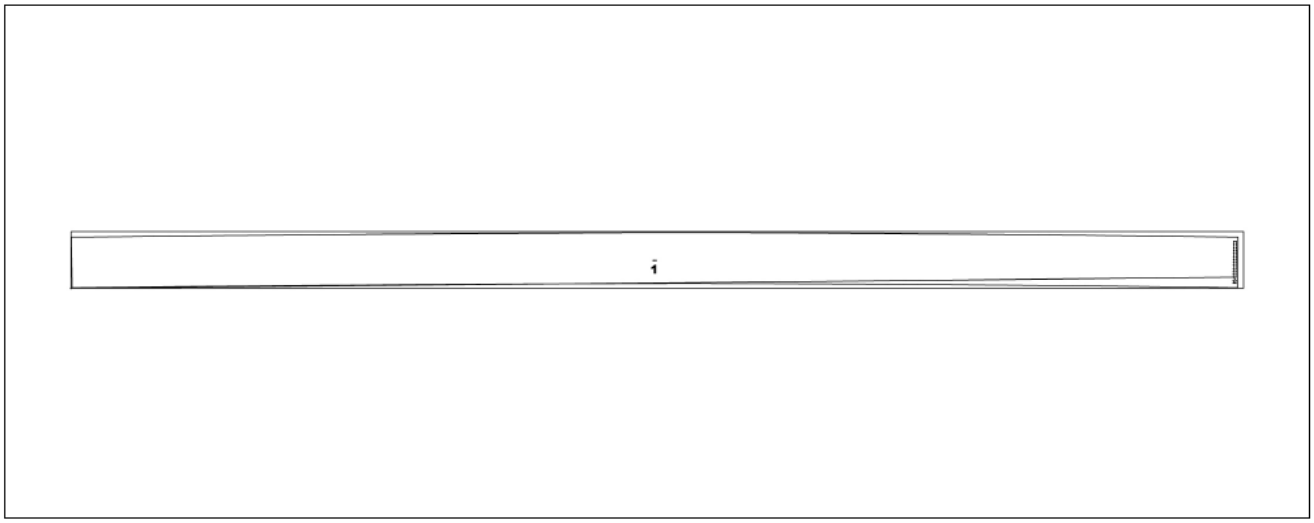


Figure 11 Nesting Diagram

Run this Program: **G5A-NEW** **Machine:** GS_KINETIC **Date:** 3/22/2016 **Time:** 9:16 am

Task Name: T47205 **Cut # OF TIMES** 1 **Qty Required** 1 **Qty Nested** 1 **Layout** 1 **of** 1



400A_O2_AIR **SPEC:** USA Last Use: Heat Lot: Prog by ____ Checked by ____

Thickness: 1 **Material:** A709-50W PO# TaskSheet165739 Size: 67 X 1385 X Used: 1378.818 Y Used: 65.853

Tool Number 1 **Description:** KSEM.9375 0 **Diameter:** 0.9375 **Number of uses:** 30

Part ID	Part Name	SHOP	Job	Qty. Req	Qty. Nested	Part X / Part Y	Remark	Work Order
1	G5A-NEW		TEST	1	1	1378.43 / 65.097	Holes	

Figure 12 Coordinates for 114' Section, including Shop Splice Locations

Vertical Events Report

Report Created: 7/12/2016
Time: 0:53am

Project: 2134.41 Girder 5
Description: Girder 5
File Name: F:\MJ744\mj744.03\InRoads\Girder 5.alg
Last Revised: cschneider 7/12/2016 12:50:51 AM
Input Grid Factor: 1
Note: All units in this report are in feet unless specified otherwise.

Horizontal Alignment Name: 2134.41 Girder 5
Horizontal Alignment Style: Default
Vertical Alignment Name: 2134.41 Girder 5_T/Webb
Vertical Alignment Style: Default

Type	Station	Northing	Easting	Elevation	Grade	DESCRIPTION
S+E	PB 210+89.0471	1134355.05	1179167.08	453.6874	-0.55%	Start of Beam
S+E	PB 210+89.8804	1134355.88	1179167.152	453.6829	-0.55%	CL Begin Bearing
S+E	PB 211+05.1304	1134371.073	1179168.469	453.599	-0.55%	Top and Bottom Flange Butt Splice 1
S+E	PB 211+06.3804	1134372.318	1179168.577	453.5921	-0.55%	Tenth Point Span 1
S+E	PB 211+13.4518	1134379.363	1179169.188	453.5532	-0.55%	Span 1 Diaphragm
S+E	PB 211+16.4518	1134382.352	1179169.447	453.5367	-0.55%	Span 1 Diaphragm D3
S+E	PB 211+22.8804	1134388.757	1179170.002	453.5013	-0.56%	Tenth Point Span 1
S+E	PB 211+28.8804	1134394.734	1179170.52	453.4663	-0.60%	Web Butt Splice 1
S+E	PB 211+37.0233	1134402.847	1179171.223	453.4145	-0.67%	Span 1 Diaphragm
S+E	PB 211+39.3804	1134405.195	1179171.426	453.3986	-0.68%	Tenth Point Span 1
S+E	PB 211+44.9637	1134410.757	1179171.908	453.3593	-0.72%	Top and Bottom Flange Butt Splice 2
S+E	PB 211+48.7137	1134414.493	1179172.232	453.3316	-0.75%	Web Butt Splice 2
S+E	PB 211+55.8804	1134421.633	1179172.851	453.2757	-0.80%	Tenth Point Span 1
S+E	PB 211+60.5947	1134426.33	1179173.258	453.2369	-0.84%	Span 1 Diaphragm
S+E	PB 211+68.5471	1134434.253	1179173.944	453.1677	-0.90%	Web Butt Splice 3
S+E	PB 211+72.3804	1134438.072	1179174.275	453.1327	-0.93%	Tenth Point Span 1
S+E	PB 211+84.1661	1134449.814	1179175.293	453.0181	-1.02%	Span 1 Diaphragm
S+E	PB 211+84.7971	1134450.442	1179175.347	453.0117	-1.02%	Top and Bottom Flange Butt Splice 3
S+E	PB 211+88.8804	1134454.51	1179175.7	452.9694	-1.05%	Tenth Point Span 1
S+E	PB 212+03.8804	1134469.454	1179176.995	452.8034	-1.16%	CL of Field Splice

Figure 13 Screen Shot of 3-D Model Sent to Fabricator

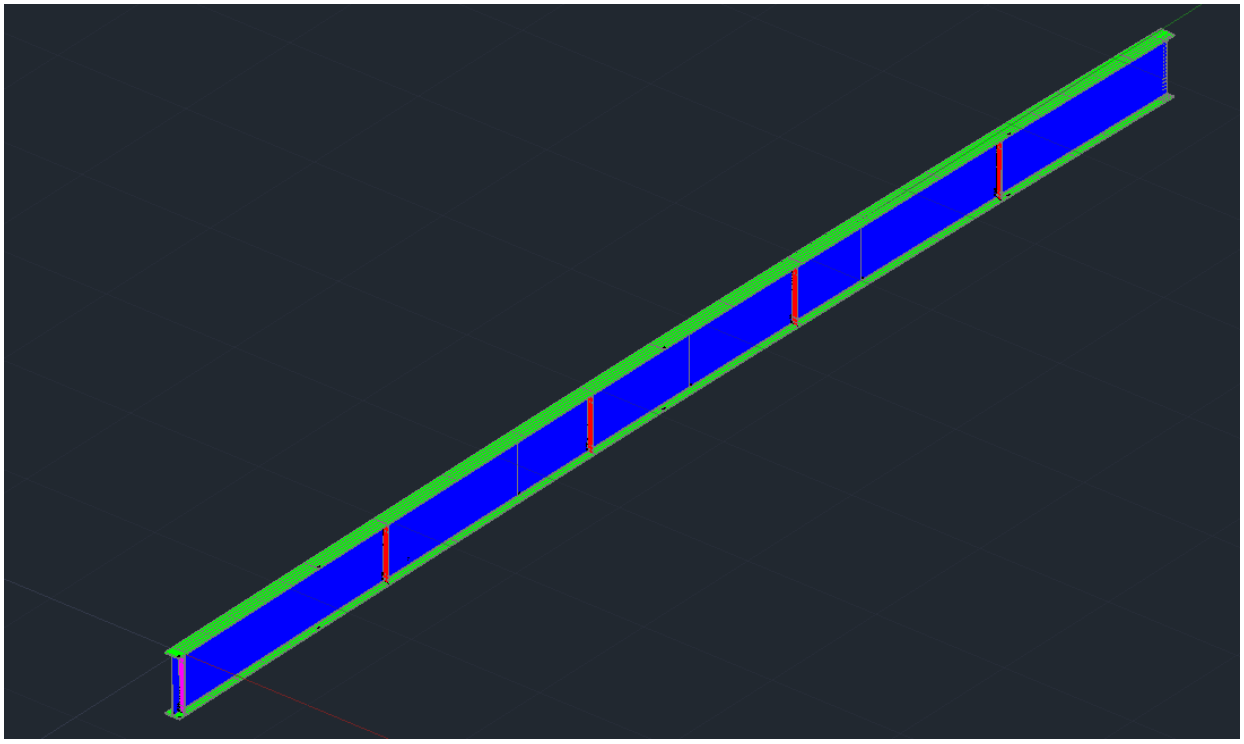


Figure 14 Fabrication of Test Girder Plate

Figure 15 Finished Girder in Lay-Down Position

Figure 16 Girder End Showing Bolt Holes for Field Splice

Figure 17 Girder Verification Using Laser Scanner

Figure 18 Girder Fit-Up in Shop

Appendix B

Detailed Outline of Methodology

I. Outline of Methodology

a. Description of Sample Project

i. NY Route 5/8/12 over Oriskany Blvd

ii. Two-span continuous girder bridge

iii. Modeling of two girder lines and cross frames

b. Outline of Work Flow

i. Hard copy of drawings

ii. Electronic files from NYSDOT

1. 3-D Deck surface and alignment file

iii. Designer developed 3-D graphic models for girders G5 and G6 using Bentley InRoads program

iv. Designer created horizontal alignment along centerline of G6

v. Designer created vertical alignment at bottom of deck slab for G6

vi. Designer generated report from InRoads at centerline of bearing and tenth points to check versus the contract plan haunch table

vii. Designer confirmed for G6 that the vertical alignment data corresponded to within 1/16" of the elevations in the haunch table

viii. Designer created another vertical alignment at the top of the web of the beam

ix. Designer created G6 beam model

x. Designer formulated model as an InRoads file and generated report initially as a text file

xi. Designer placed text file in Excel format based on detailer's request

xii. Designer submitted report for G6 (Figure 4) in Excel format with information on northing, easting, and elevations at centerline of bearings and tenth points along girder to steel detailer as a test of data transfer

xiii. Detailer confirmed that points were successfully imported and is usable data for them to develop information for the fabricator

xiv. Detailer requested additional data points

xv. Generated report for G6 (Figure 5) with additional data points in Excel and sent to detailer

xvi. MJ developed a workflow for the procedure used to create the InRoads report

xvii. Report for Girder G5 was developed (Figure 6) based on the workflow and submitted to detailer

xviii. Detailer performed calculations to translate final position data from MJ to no-load position data

xix. Detailer modeled no-load position

xx. Detailer provided web and flange DXF files to fabricator for "fabrication"

xxi. Fabricator generated a nesting diagram and confirmed that he could proceed to fabrication with information provided

xxii. Fabricator provided shop splice locations

xxiii. Team agreed to use 5/16" fillet welds at all weld locations other than for butt splices

xxiv. Designer submitted coordinates for girder section including shop splice locations

xxv. Detailer provided individual DXF files and STEP files for each plate as well as 3-D model to fabricator

xxvi. Fabricator imported files into CNC machine

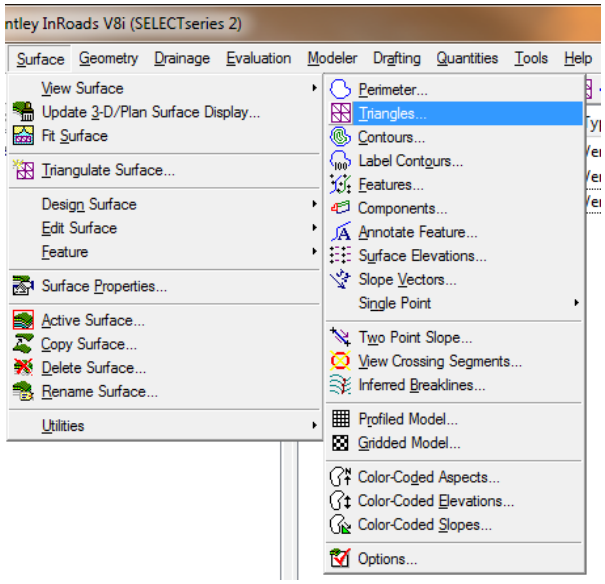
xxvii. Girder is fabricated and dimensions validated using laser scanner

Appendix C

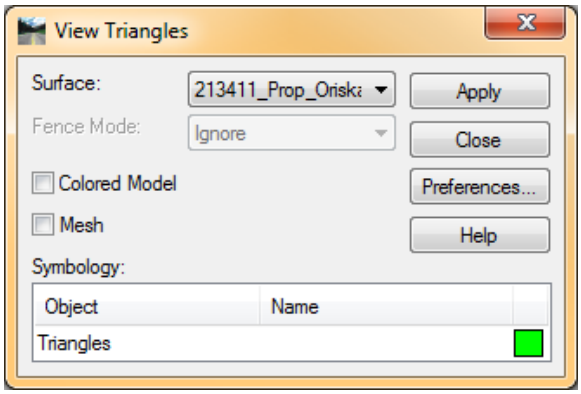
Designer Workflow

Steps for Creating InRoads© Data Report for 3D Girder Points

1. Verify Digital Terrain Model (DTM) triangulation intervals for the bridge deck surface. Template drops shall be at 1'-0" intervals.
    a. Open a 2D Microstation© file and load InRoads©
    b. Load the Bridge Deck DTM file and project ALG file
    c. In the InRoads© window, choose **"Surface" > "View Surface" > "Triangles"**



    d. The *View Triangles* dialog opens
        i. Click **"Apply"**



        ii. Measure between triangle vertices along a line parallel to the project alignment to ensure that the template intervals are 1'-0" drops

2. Calculate stations based off the roadway HCL for the following locations to four decimal places:
    a. Start of Beam
    b. Centerline of Begin Bearing
    c. Centerline of Pier(s) Bearing, if necessary
    d. Centerline of End Bearing
    e. End of Beam
    f. Horizontal Geometry Changes in Beam (Check Project Alignment)
        i. PC
        ii. PCC

iii. Kinks, etc.

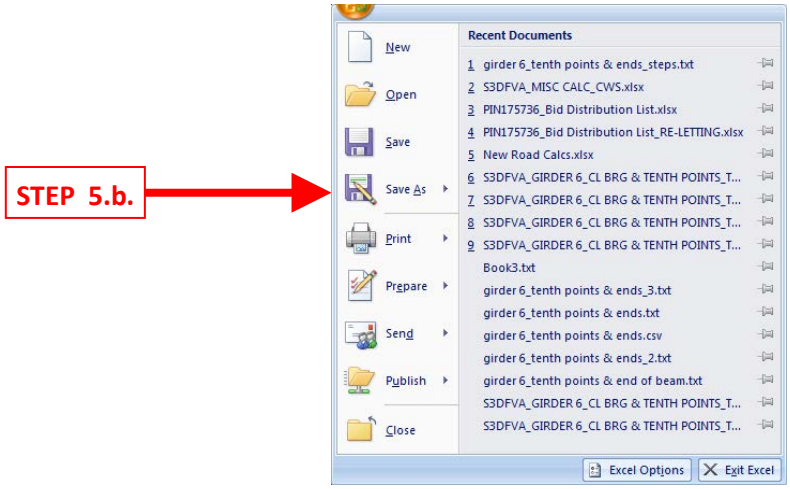
g. Field Splices
h. Girder Cross-Section Changes
i. Diaphragm Locations (at centerline of connection plate)
j. Miscellaneous Points
    i. Intermediate Stiffeners
    ii. Scupper Connections
    iii. Utility Supports
    iv. Under Deck Lighting, etc.

3. Calculate stations for tenth points of all spans to four decimal places
    a. These tenth points may coincide with other point mentioned in STEP 2 above. When this occurs, these points shall be represented by one station having multiple descriptions.
4. Save stations is ascending order in Excel© with Point Names. See sample table below.

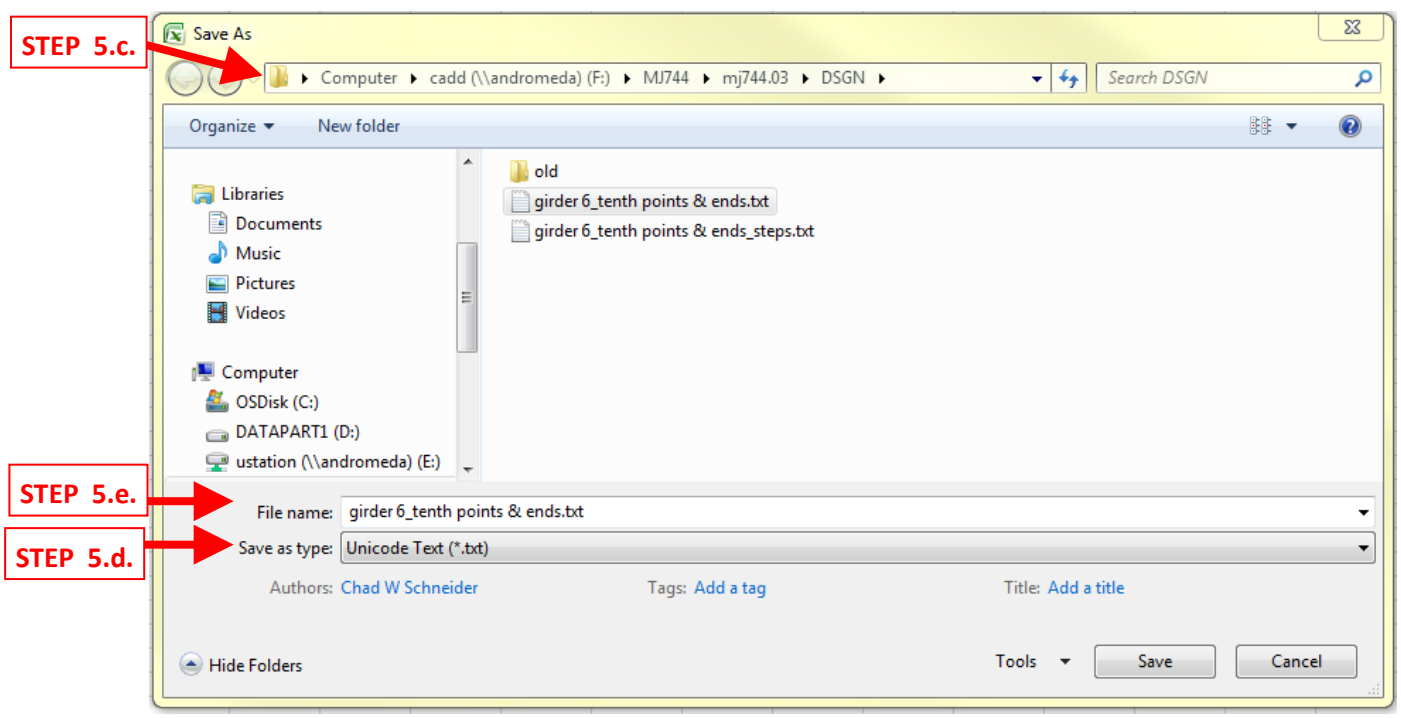
DESCRIPTION	STATION	STATION
START STATION	PB	210+87.4601
CL BEGIN BEARING	PB	210+88.2935
0.1 L1	PB	211+04.7935
CL DIAPHRAGM SPAN 1 LOC 2 (D1 RT, D2 LT)	PB	211+11.8649
0.2 L1	PB	211+21.2935
CL DIAPHRAGM SPAN 1 LOC 3 (D1 RT, D2 LT)	PB	211+35.4363
0.3 L1	PB	211+37.7935
0.4 L1	PB	211+54.2935
CL DIAPHRAGM SPAN 1 LOC 4 (D1 RT, D2 LT)	PB	211+59.0078
CL DIAPHRAGM D3 SPAN 1 LOC 1 (LIGHTING)	PB	211+62.0078
0.5 L1	PB	211+70.7935
CL DIAPHRAGM SPAN 1 LOC 5 (D1 RT, D2 LT)	PB	211+82.5792
0.6 L1	PB	211+87.2935
CL FIELD SPLICE SPAN 1	PB	212+02.2935
0.7 L1	PB	212+03.7935
CL DIAPHRAGM SPAN 1 LOC 6 (D1 RT, D2 LT)	PB	212+06.1506
CL DIAPHRAGM D3 SPAN 1 LOC 2 (LIGHTING)	PB	212+09.1506
0.8 L1	PB	212+20.2935
BEGIN FLANGE TRANSITION (TOP & BOT)	PB	212+23.2935
CL DIAPHRAGM SPAN 1 LOC 7 (D1 RT, D2 LT)	PB	212+29.7220
0.9 L1	PB	212+36.7935
INTERMEDIATE STIFFENER PLATES SPAN 1 RT	PB	212+37.5851
INTERMEDIATE STIFFENER PLATES SPAN 1 LT	PB	212+45.4393
CL PIER BEARING	PB	212+53.2935
INTERMEDIATE STIFFENER PLATES SPAN 2 LT	PB	212+61.6268
0.1 L2	PB	212+68.2935
INTERMEDIATE STIFFENER PLATES SPAN 2 RT	PB	212+69.9601
CL DIAPHRAGM SPAN 2 LOC 2 (D1 RT, D2 LT)	PB	212+78.2935
CL DIAPHRAGM D3 SPAN 2 LOC 1 (LIGHTING)	PB	212+81.2935
0.2 L2	PB	212+83.2935
END FLANGE TRANSITION (TOP & BOT)	PB	212+88.2935
0.3 L2	PB	212+98.2935
CL DIAPHRAGM SPAN 2 LOC 3 (D1 RT, D2 LT)	PB	213+03.2935
CL FIELD SPLICE SPAN 2	PB	213+08.7935
0.4 L2	PB	213+13.2935
SCUPPER CONNECTION PLATE SPAN 2 RT	PB	213+14.6685
0.5 L2; CL DIAPHRAGM SPAN 2 LOC 4 (D1 RT, D2 LT)	PB	213+28.2935
0.6 L2	PB	213+43.2935
CL DIAPHRAGM SPAN 2 LOC 5 (D1 RT, D2 LT)	PB	213+53.2935
CL DIAPHRAGM D3 SPAN 2 LOC 2 (LIGHTING)	PB	213+56.2935
0.7 L2	PB	213+58.2935
0.8 L2	PB	213+73.2935
CL DIAPHRAGM SPAN 2 LOC 6 (D1 RT, D2 LT)	PB	213+78.2935
0.9 L2	PB	213+88.2935
CL END BEARING	PB	214+03.2935
END STATION	PB	214+04.1268

STEP 3.a.

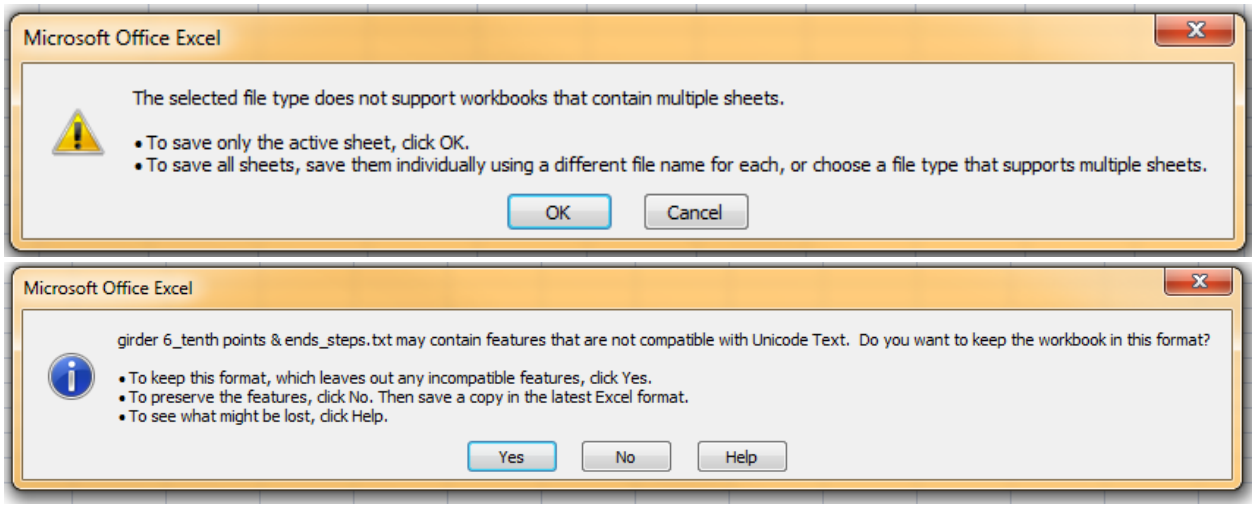
5. Create a text file with the stations from STEP 4
   a. Copy columns 2 & 3 and paste into new Excel© file in the upper left cell. This data must be pasted as VALUES using the Paste Special command in Excel©
   b. Click on the symbol in Excel© and choose **"Save As"**



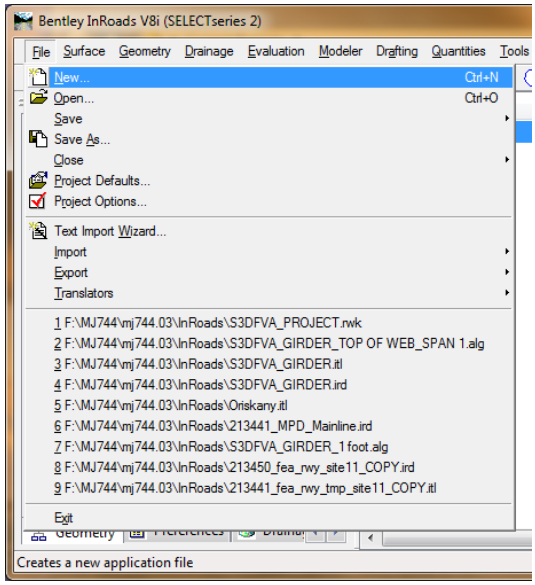
   c. In the *Save As* dialog box, navigate to the project directory where you want to save your file
   d. Under "Save as type:" dropdown menu, choose **"Unicode Text (.txt)"**
   e. Type in the file name "Girder X", where X represents the Girder number



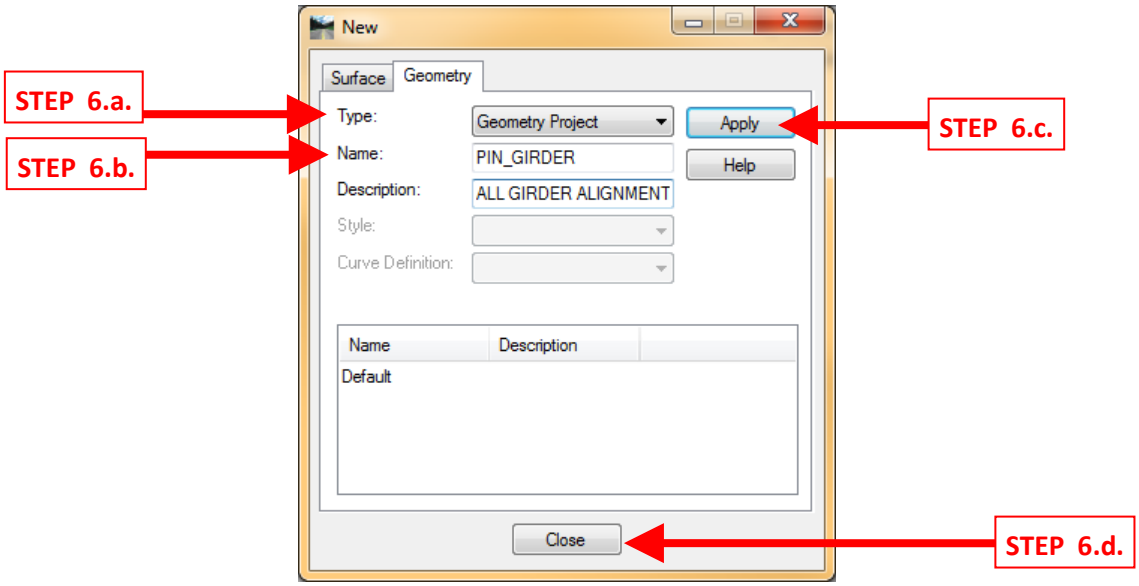
f. The following messages will appear after you click save. Click “OK” on the first and “Yes” on the second.



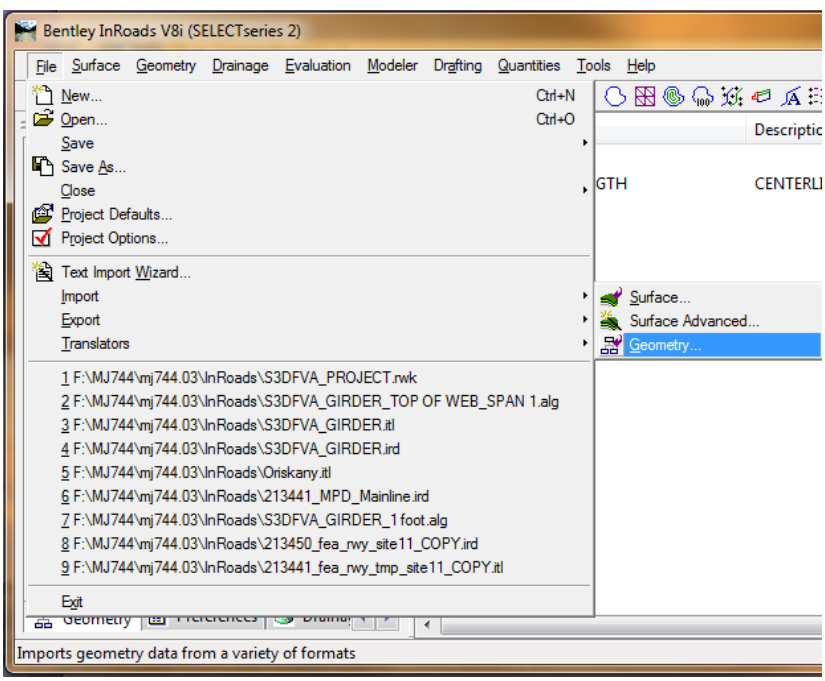
6. Create a geometry project: In the InRoads© window, choose **“File” > “New”**



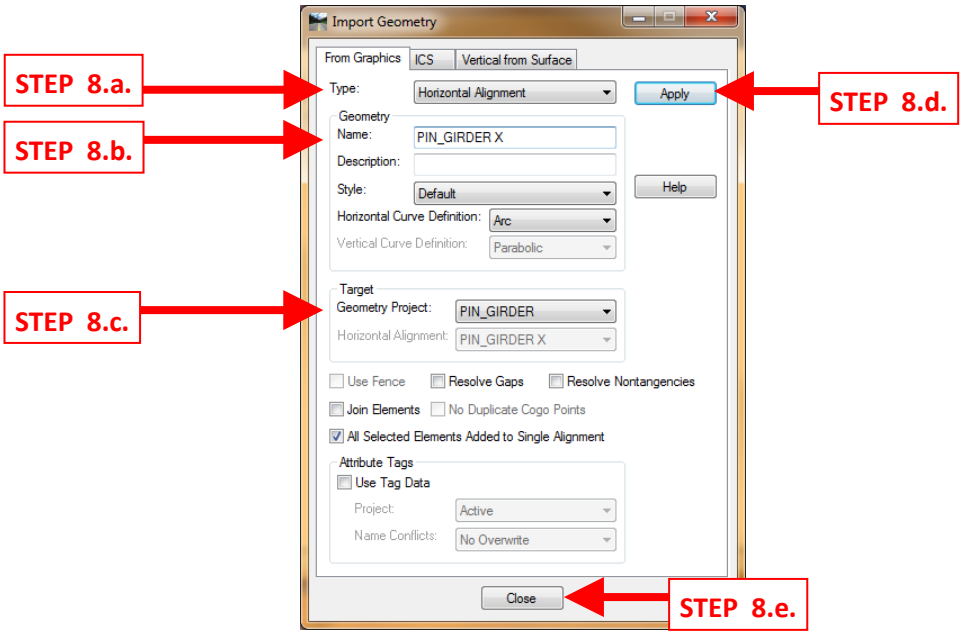
a. Under Type, select **"Geometry Project"**
b. Enter in the name of the geometry project as shown below using the Project Identification Number (PIN)
c. Click **"Apply"**
d. Click **"Close"**



7. Reference in the framing plan and create a line or linestring over the girder for the entire length of the bridge from start of girder to end of girder. A line can be utilized for bridges with alignments on a tangent section and linestrings will be utilized for bridges with alignments that have a combination of tangents and curves.
8. In the InRoads© window, click on **"File" > "Import" > "Geometry"**

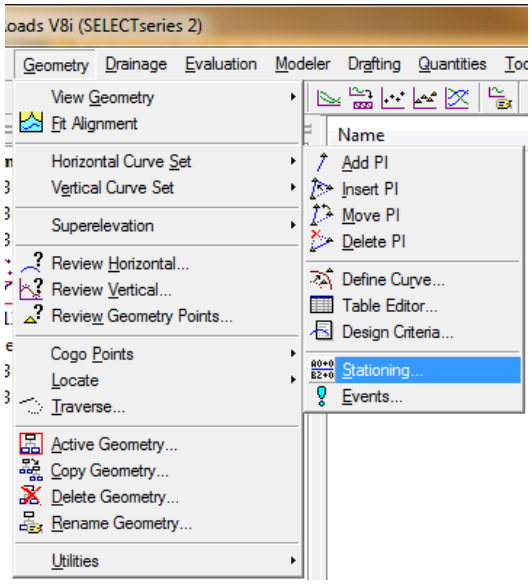


The following dialog box will appear:

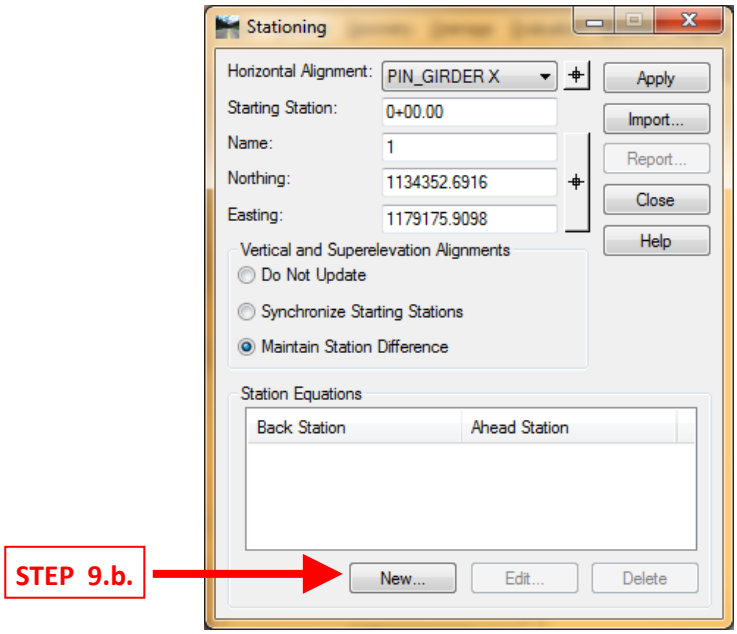


a. Under Type, make sure **"Horizontal Alignment"** is chosen
b. Under Geometry, type in the name of the alignment consisting of the project pin number followed by an underscore and then "Girder X" where X represents the girder number for the alignment being imported (see picture above)
c. Under Target, Select the geometry project created in STEP 6
d. Click **"Apply"** then select the line or linestring drawn in STEP 7
e. Click **"Close"**

9. Set the stations to coincide with the roadway centerline stationing
   a. In the InRoads© program window, choose **"Geometry" > "Horizontal Curve Set" > "Stationing"**



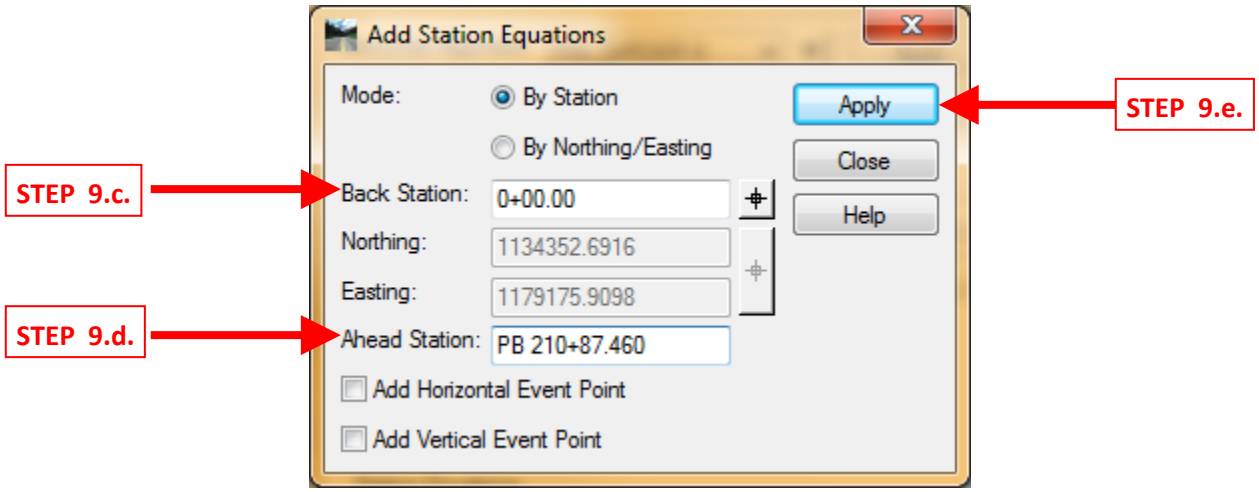
b. At the bottom of the *Stationing* dialog box, click new



c. In the *Add Station Equations* dialog box, set the Back Station to 0+00.00

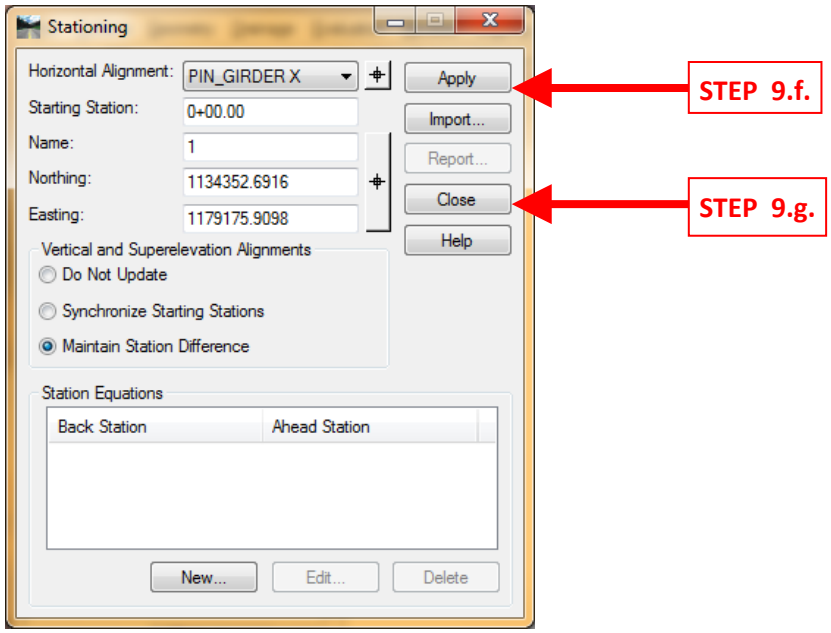
d. Set the Ahead Station to station calculated for the start of beam from <u>STEP 2</u>

e. Click **"Apply"** on *Add Station Equations* dialog



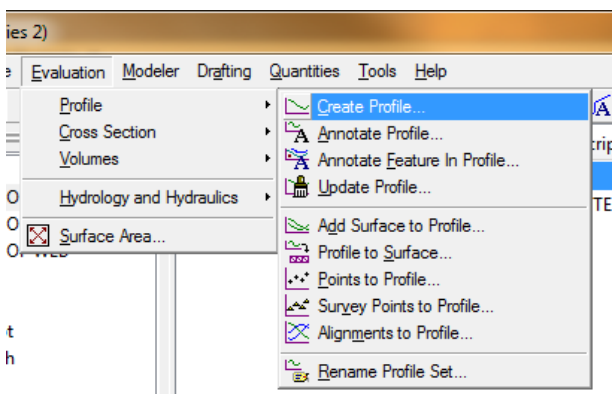
f. Click **"Apply"** on *Stationing* dialog

g. Click **"Close"** on *Stationing* dialog

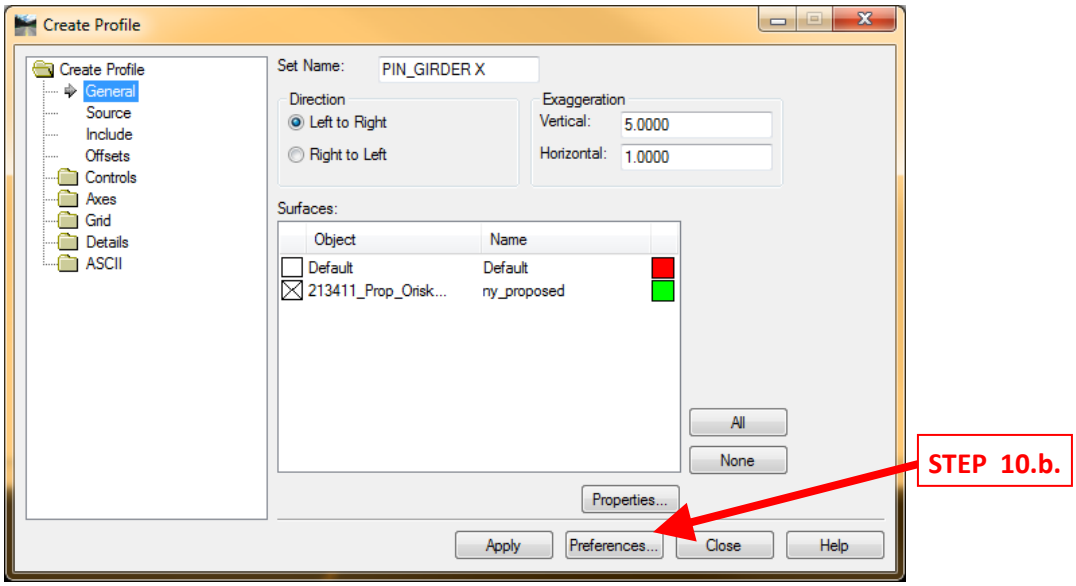


10. Cut a profile along the alignment created in <u>STEPS 7-9</u>

a. In the InRoads© program window, choose **"Evaluation" > "Profile" > "Create Profile"**



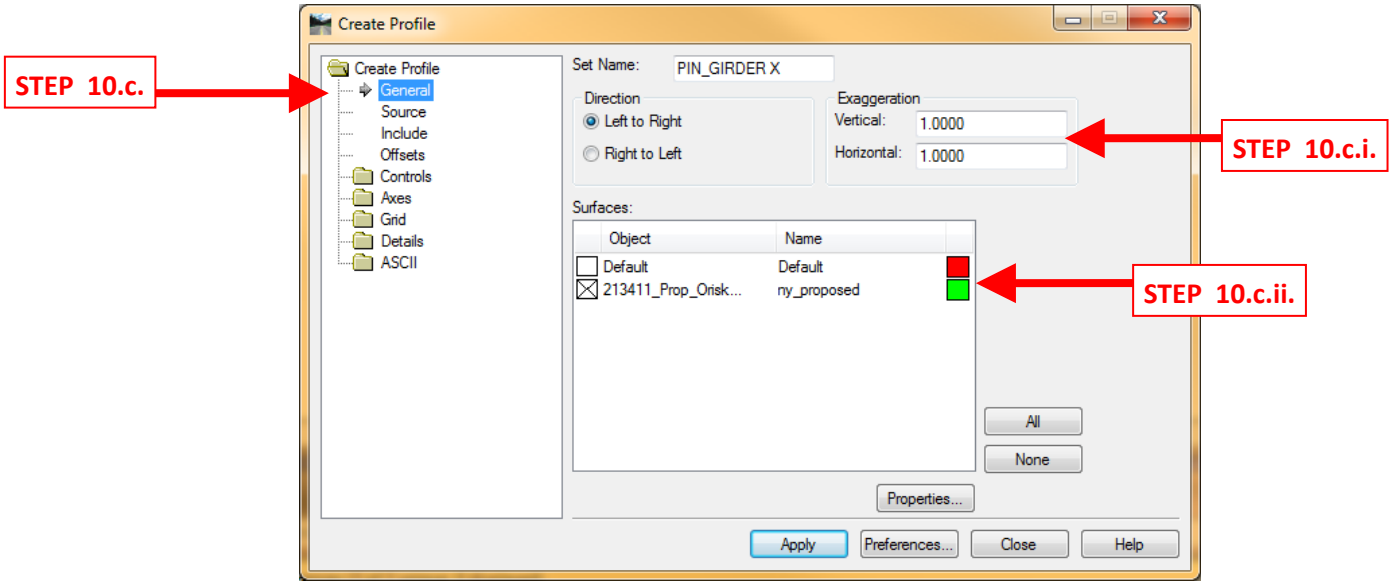
b. Load the preferences you want the profile to display



c. Under "General" in the left pane:

i. Set the Exaggeration to 1 for Vertical and Horizontal

ii. Select the bridge deck surface to be displayed



d. Under **"Controls"** in the left pane:

   i. Click **"Use"** under the Elevation section and set the elevations according to the project elevations. These elevations shall be set to ensure the proposed surface is visible for the entire length of the girder alignment created in STEP 8.

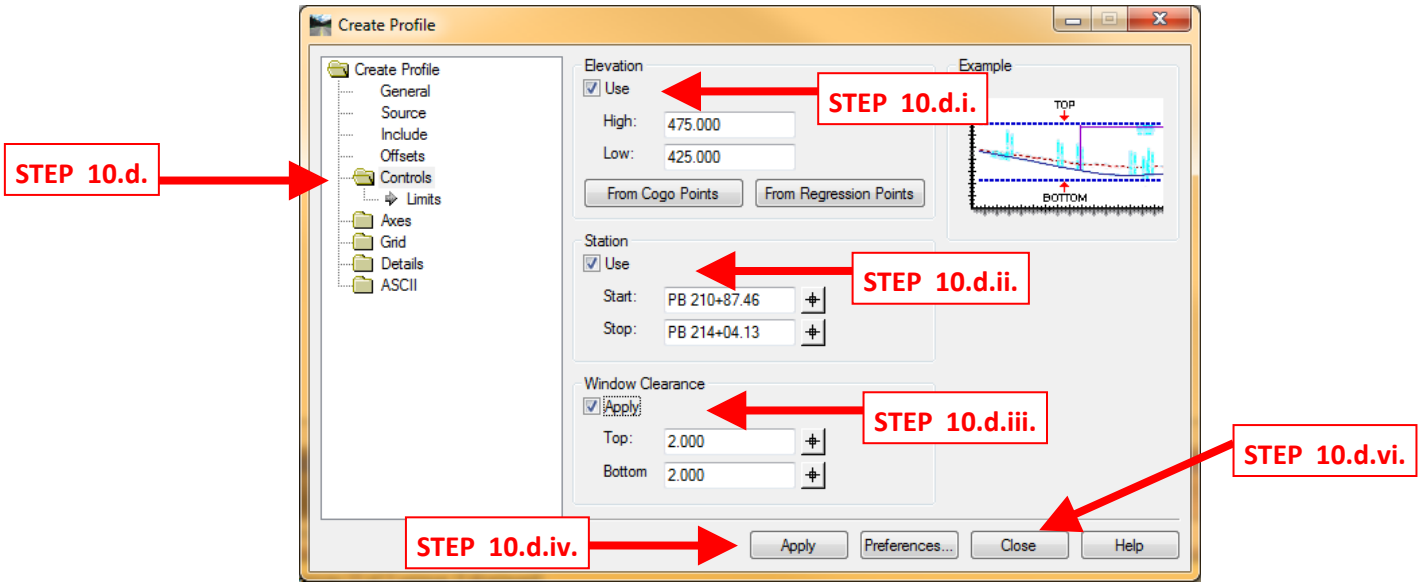
   ii. Click **"Use"** under the Station section and verify the stations are for the entire length of beam

   iii. Click **"Apply"** under the Window Clearance section and set the Top and Bottom values to 2

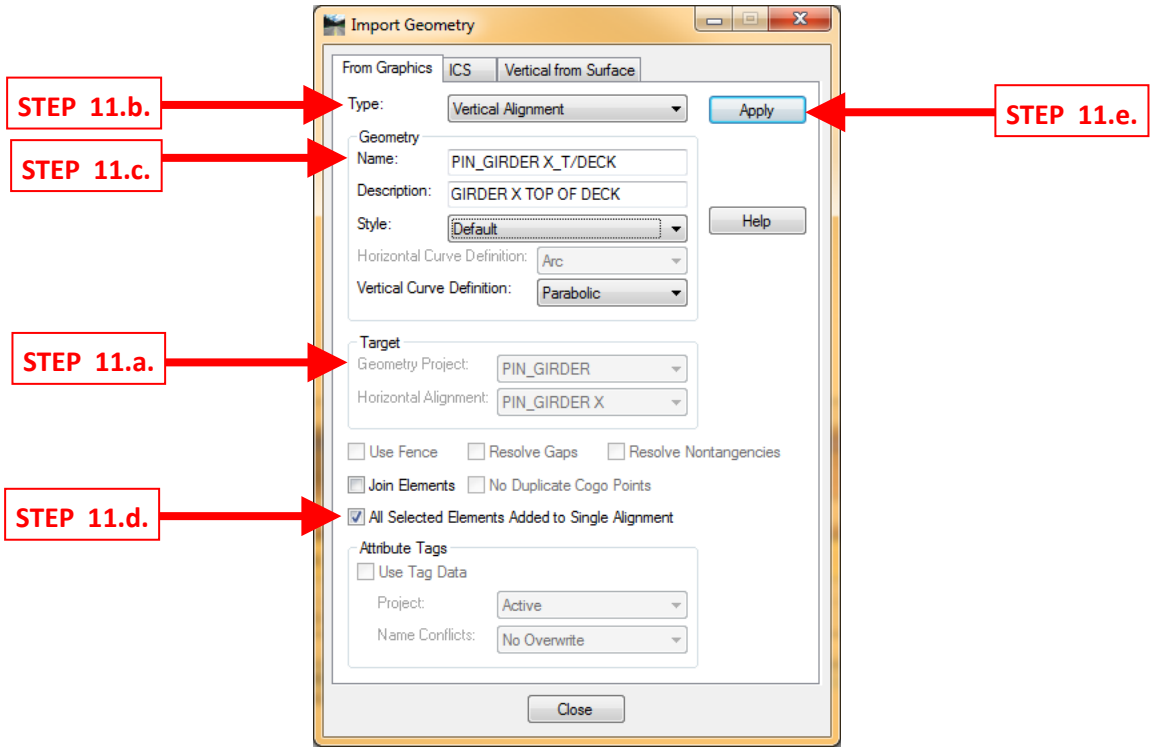
   iv. Click **"Apply"** at the bottom of the *Create Profile* dialog

   v. Click inside Microstation© design space where you want the profile to appear

   vi. Click **"Close"** at the bottom of the *Create Profile* dialog

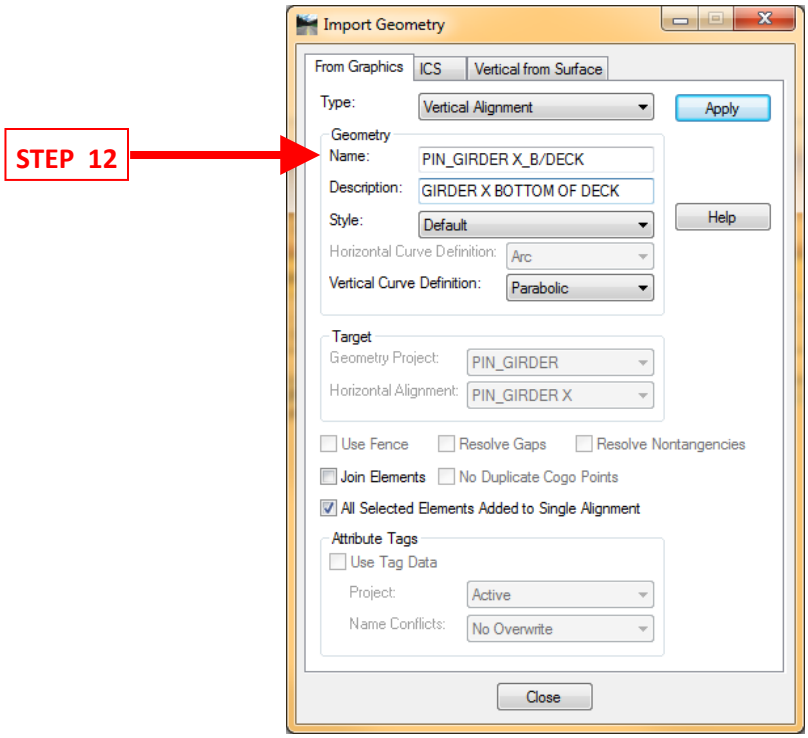


11. Create a Vertical Alignment for the **TOP OF DECK** along Girder X: In the InRoads© window, click on **"File" > "Import" > "Geometry"** (see STEP 8 for picture)
    a. Make sure the alignment created in STEP 8 is active. This shows up under the Target section
    b. Under Type, make sure **"Vertical Alignment"** is chosen
    c. Under Geometry, type in the name of the alignment as shown in screen shot below
    d. Make sure "All Selected Elements Added to Single Alignment" is checked
    e. Click **"Apply"**, the dialog will disappear

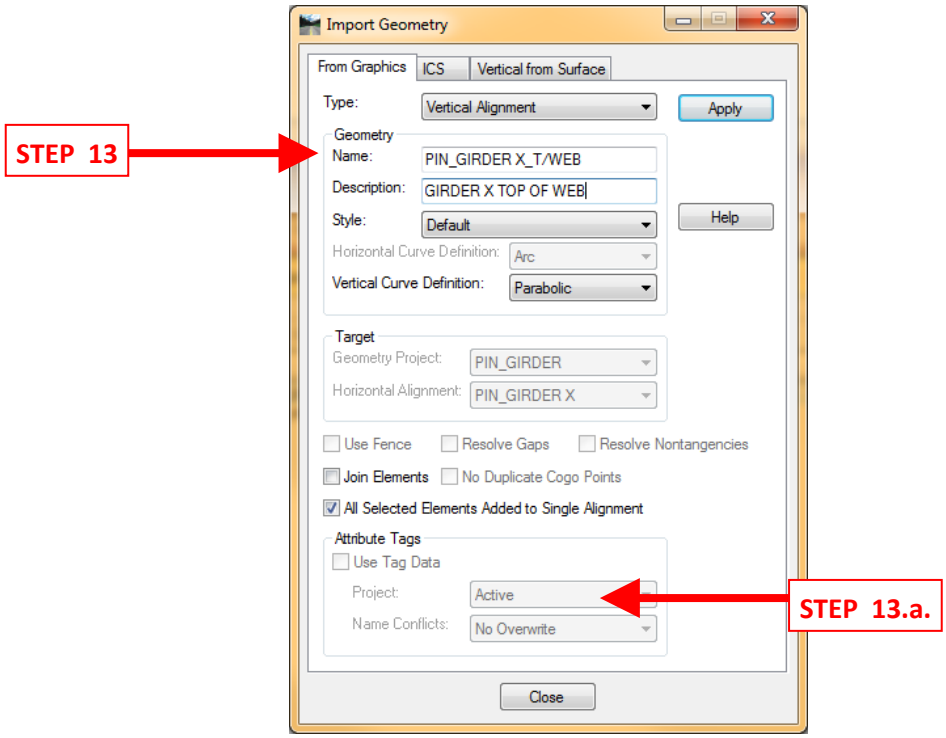


    f. select the line in profile created in STEP 10
    g. **Left Click** to Accept line
    h. **Right Click** to reset and the *Import Geometry* dialog will pop up

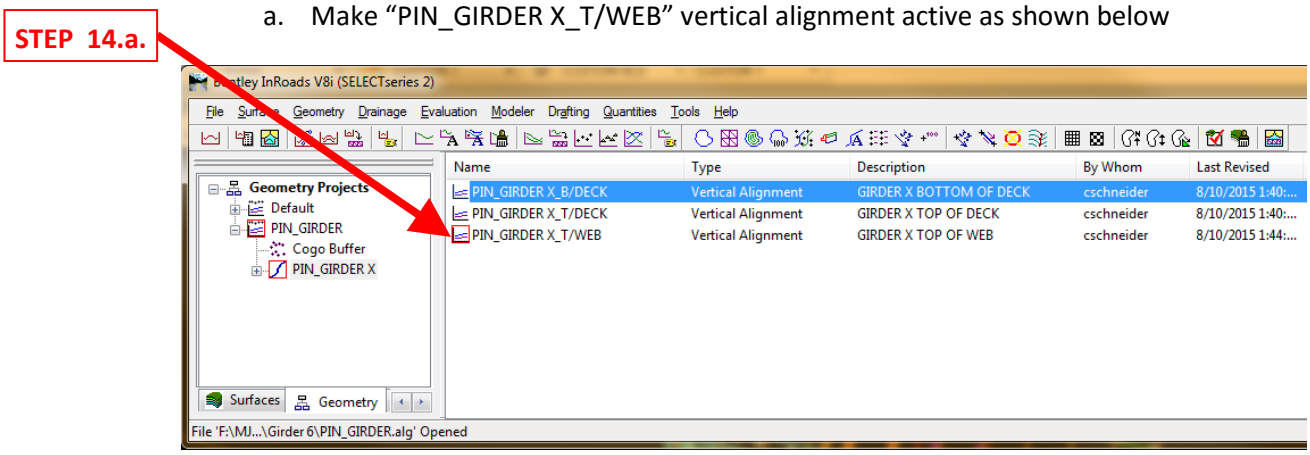
12. Create a Vertical Alignment for the **BOTTOM OF DECK** along Girder X: In the profile created in STEP 10, copy the deck surface down a distance equal to the depth of the structural slab. **DO NOT** use the copy parallel command as the girders are directly below the top surface in the vertical plane and will match the profile of the top of deck. Repeat STEPS 11.a. thru 11.d. utilizing the name shown below



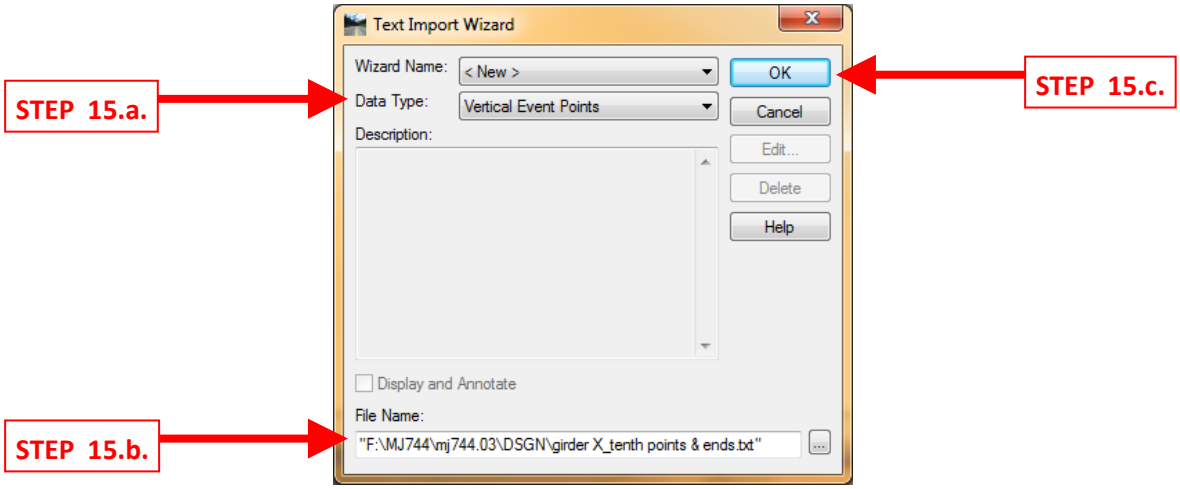
13. Create a Vertical Alignment for the **TOP OF WEB** along Girder X: In the profile created in STEP 10, copy the bottom of deck surface down a distance equal to the haunch plus the top flange and repeat STEPS 11.a. thru 11.d. utilizing the name shown below
    a. Click **"Close"**



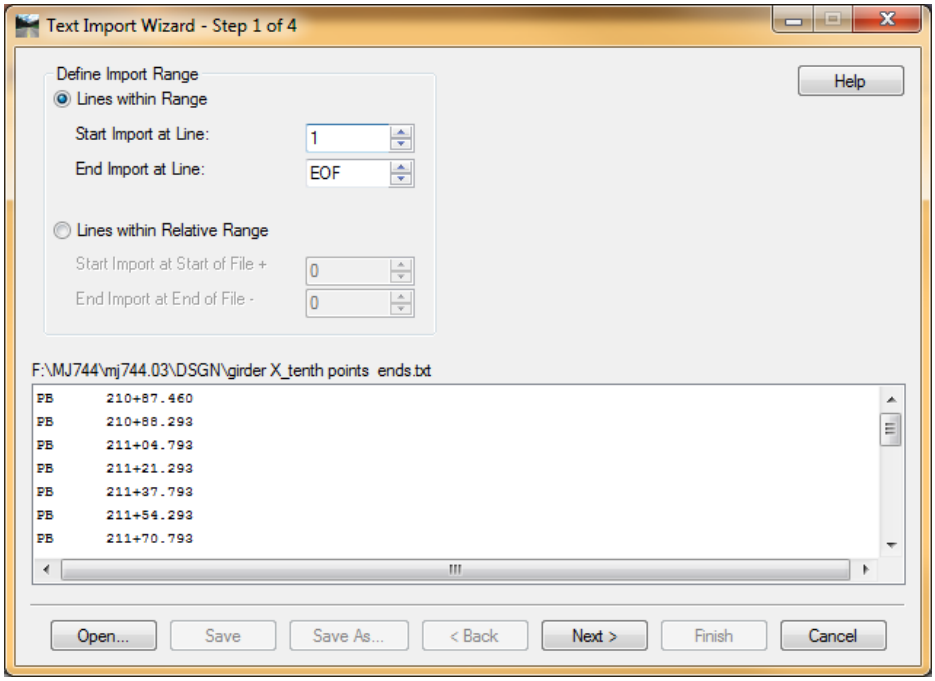
14. When you are done importing the Vertical Alignments, your InRoads© geometry tab should look like this for GIRDER X
    a. Make "PIN_GIRDER X_T/WEB" vertical alignment active as shown below



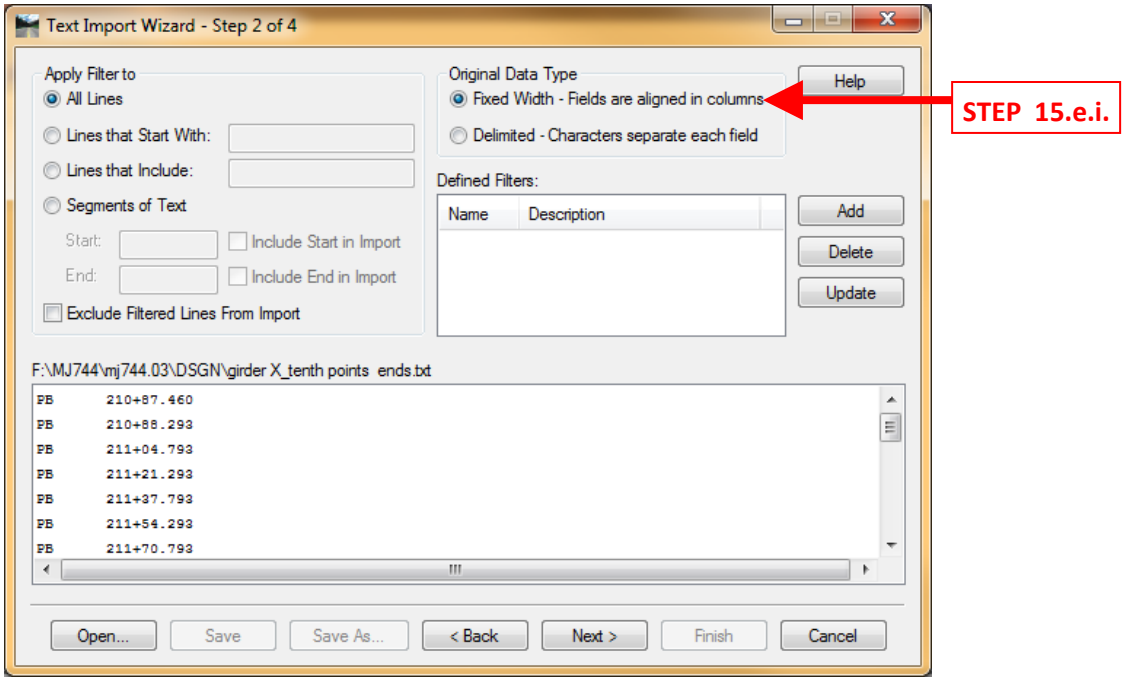
15. In the InRoads© window, click on **"File" > "Text Import Wizard"**
    a. Under Data Type, choose **"Vertical Event Points"**
    b. Under filename, navigate to the text file created in <u>STEP 5</u>
    c. Click **"OK"**



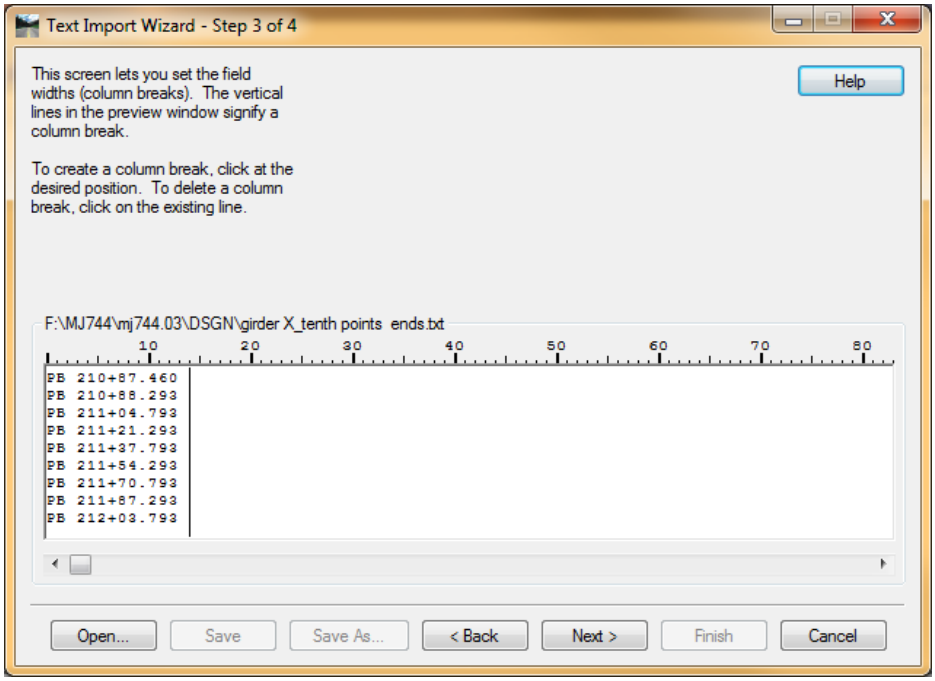
d. The *Text Import Wizard – Step 1 of 4* dialog will open
   i. The picture below shows the default set up
   ii. Verify your window looks like this and all stations show up
   iii. Click **"Next"**



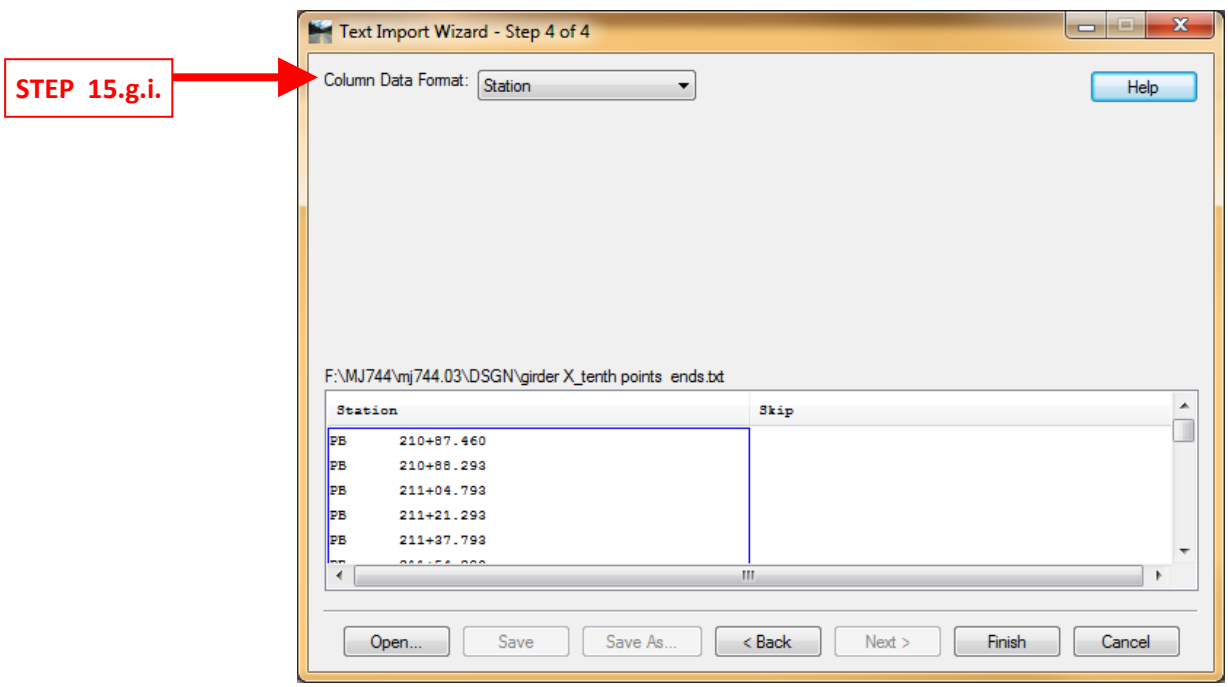
e. You will proceed to the *Text Import Wizard – Step 2 of 4* dialog
   i. Under the Original Data Type, select **"Fixed Width"**
   ii. Verify your window looks like this and all stations show up
   iii. Click **"Next"**



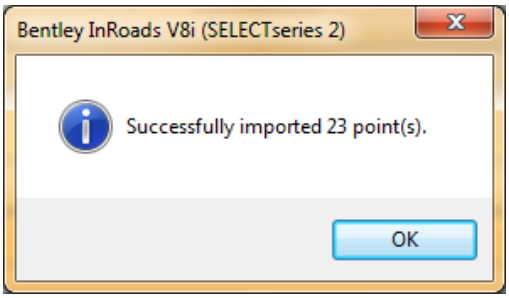
f. You will proceed to the *Text Import Wizard – Step 3 of 4* dialog
   i. Click to the right of the station decimals to create a line as shown below
   ii. Verify your window looks like this and all stations show up
   iii. Click **"Next"**



g. You will proceed to the *Text Import Wizard – Step 4 of 4* dialog
   i. Under Column Data Format, select **"Station"**
   ii. Verify your window looks like this and all stations show up
   iii. Click **"Finish"**

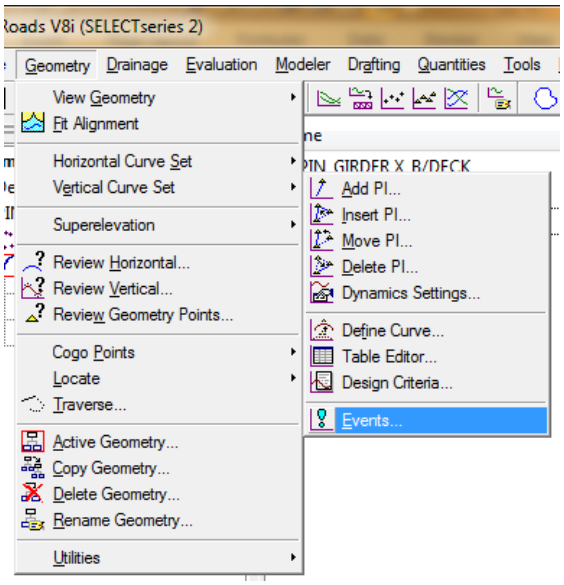


h. The window below will appear, Click **"OK"**

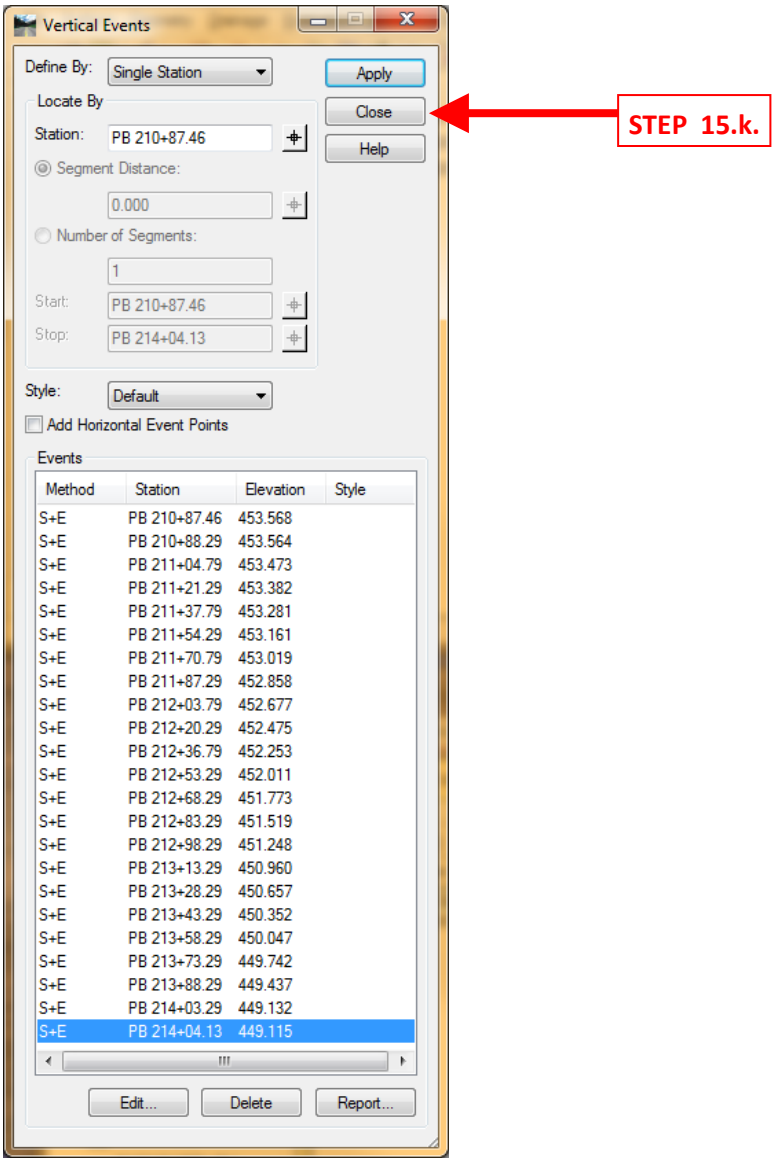


i. Both windows will disappear

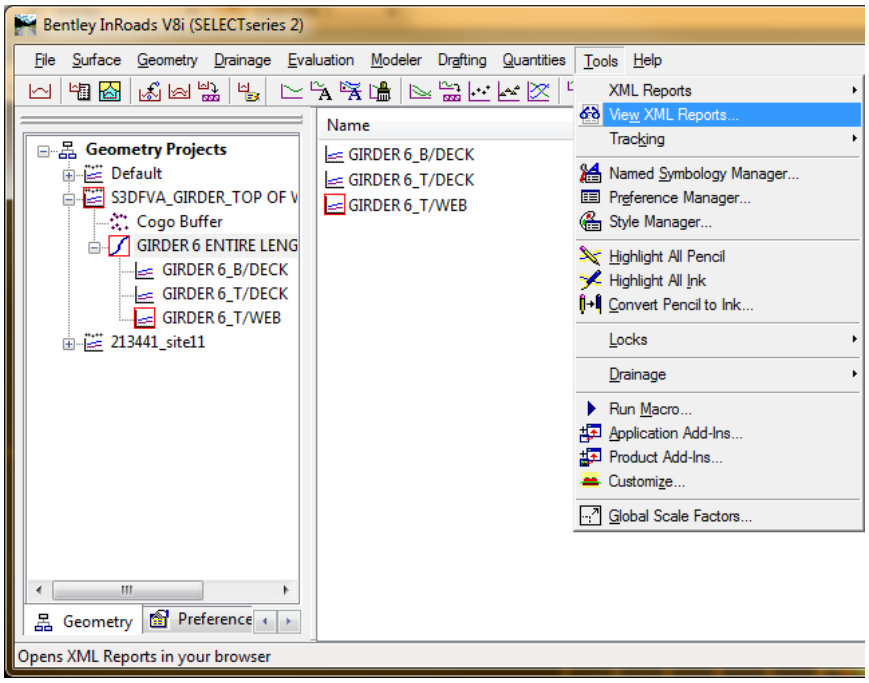
j. In the InRoads© program window, choose **"Geometry" > "Vertical Curve Set" > "Events"**



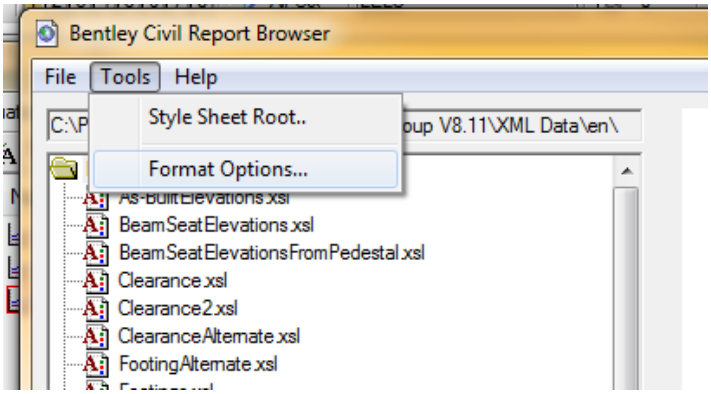
k. Verify all stations are present along with corresponding elevations and click **"Close"**



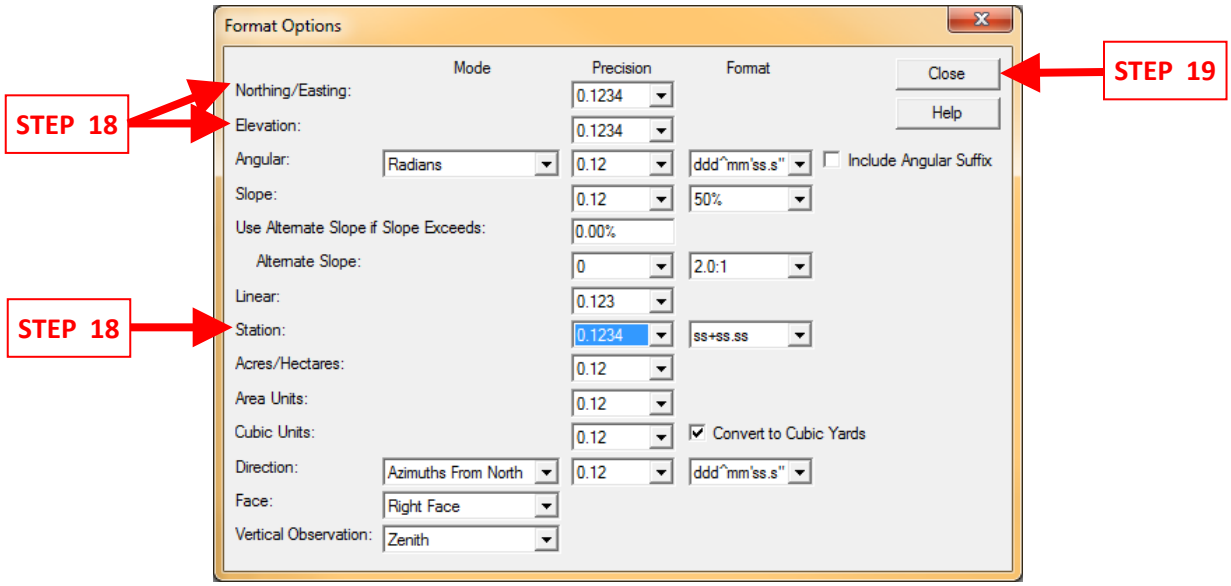
16. Open the Bentley Civil Report Browser



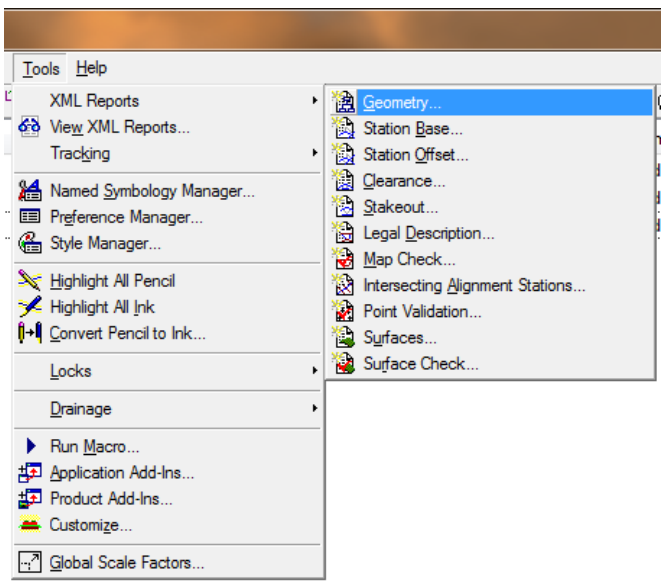
17. Got to **"Tools" > "Format Option"**



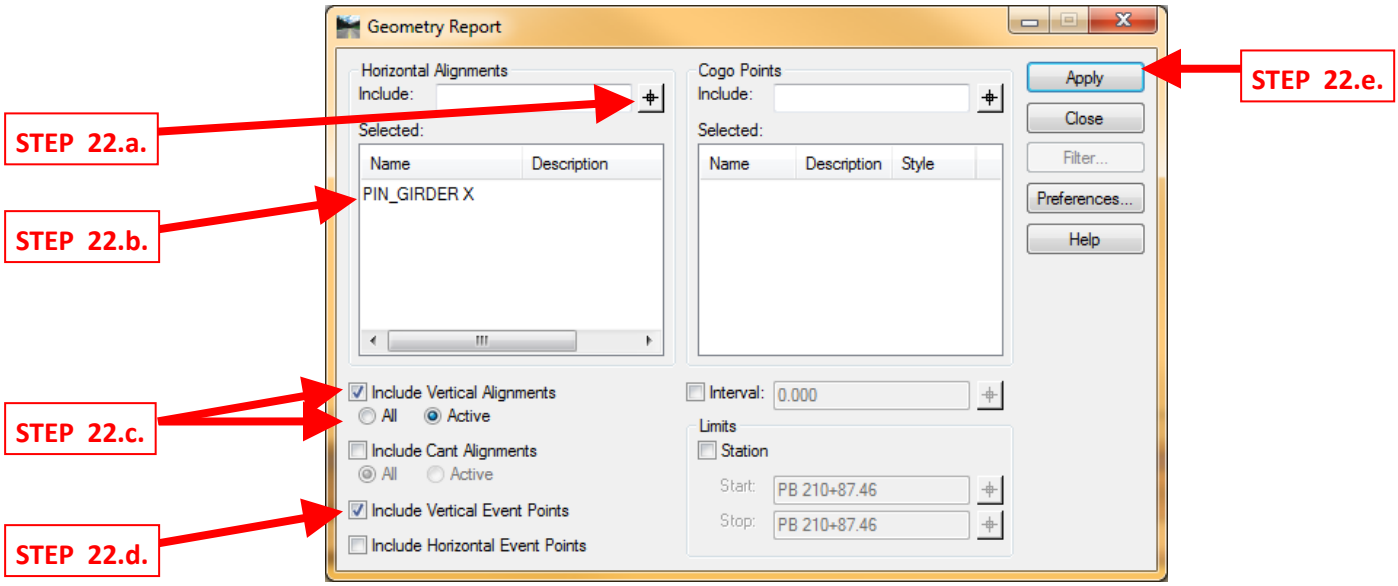
18. Set the Northing/Easting, Station and Elevation precision to FOUR decimal places
19. Choose **"Close"**



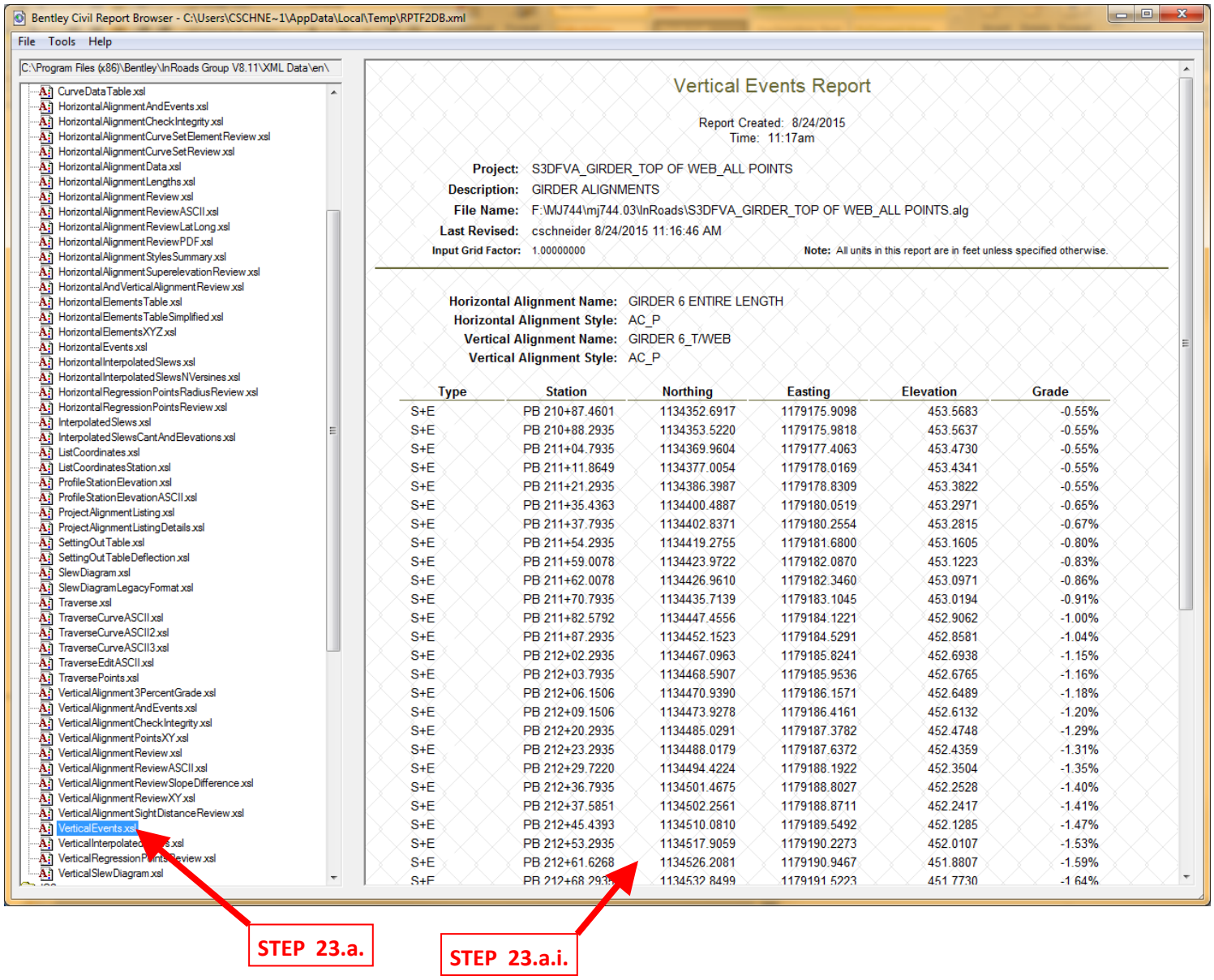
20. Close the Bentley Civil Report Browser
21. In the InRoads© program window, choose **"Tools" > "XML Reports" > "Geometry"**



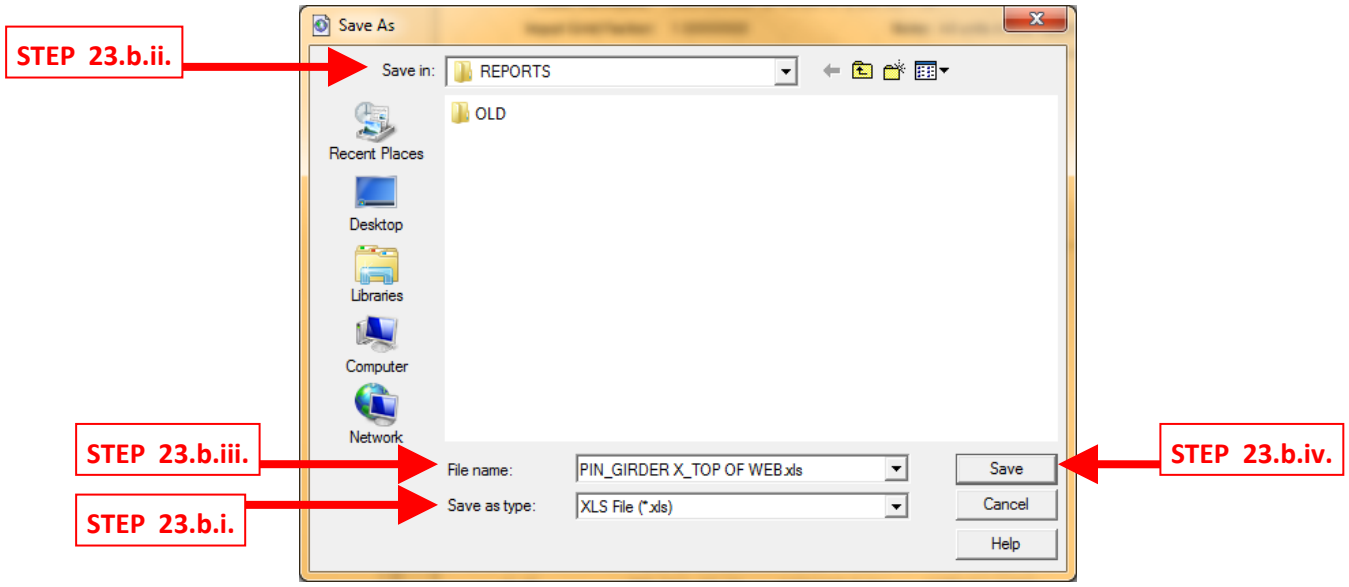
22. The *Geometry Report* dialog opens
    a. Select the locator button under Horizontal Alignments next to “Include:”
    b. Select the alignment in the Microstation© drawing window and the alignment will appear under “Selected:”
    c. Check **“Include Vertical Alignment”**, Select **“Active”** under “Include Vertical Alignment”
        i. Verify the TOP OF WEB vertical alignment is active under GIRDER X
    d. Check **“Include Vertical Event Points”**
    e. Click **“Apply”**



23. The *Bentley Civil Report Browser* dialog will open
    a. In the left pane select the **"VerticalEvents.xsl"** report (See picture below)
        i. All stations imported from the text file should appear with Northing, Easting, Elevation and Grade values

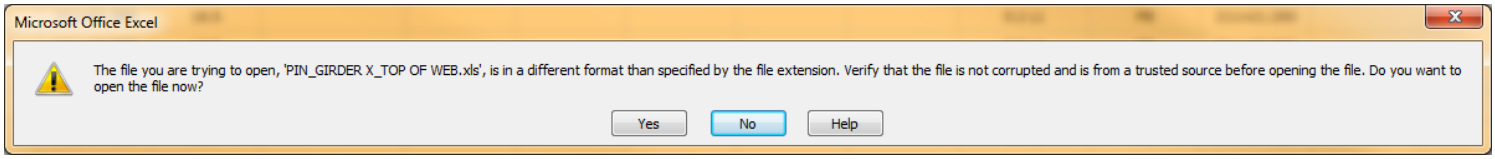


b. In the *Bentley Civil Report Browser* dialog, choose **File > Save As**
   i. Under "Save as type:", choose **"XLS File (*.xls)"**
   ii. Navigate to the folder where you want to save the report
   iii. Enter filename as shown
   iv. Click **"Save"**



c. Close the *Bentley Civil Report Browser* dialog

24. Close the *Geometry Report* dialog
25. Open the **"PIN_GIRDER X_TOP OF WEB.xls"** file created in STEP 23.b
    a. The following message window will appear, Click **"Yes"**



26. Copy in the point names from STEP 4, Column 1 and paste to the right of the Grade column (See below)

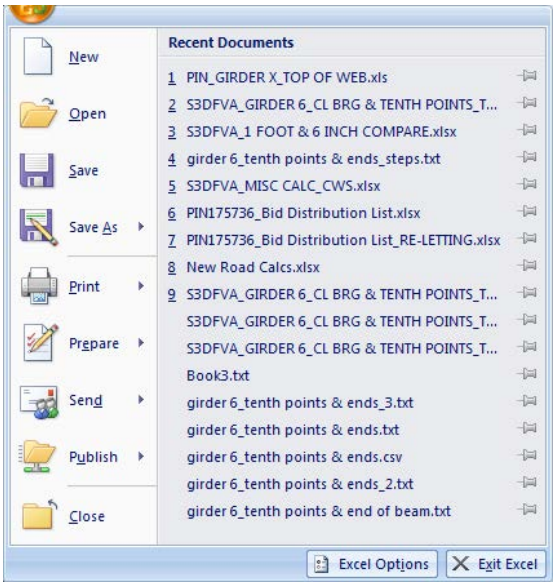
STEP 26

Type	Station	Northing	Easting	Elevation	Grade	DESCRIPTION
S+E	PB 210+87.46	1134352.6917	1179175.9098	453.5680	-0.55%	START STATION
S+E	PB 210+88.29	1134353.5220	1179175.9818	453.5640	-0.55%	CL BEGIN BEARING
S+E	PB 211+04.79	1134369.9604	1179177.4063	453.4730	-0.55%	0.1 L1
S+E	PB 211+11.86	1134377.0054	1179178.0169	453.4340	-0.55%	CL DIAPHRAGM SPAN 1 LOC 2 (D1 RT, D2 LT)
S+E	PB 211+21.29	1134386.3987	1179178.8309	453.3820	-0.55%	0.2 L1
S+E	PB 211+35.44	1134400.4887	1179180.0519	453.2970	-0.65%	CL DIAPHRAGM SPAN 1 LOC 3 (D1 RT, D2 LT)
S+E	PB 211+37.79	1134402.8371	1179180.2554	453.2810	-0.67%	0.3 L1
S+E	PB 211+54.29	1134419.2755	1179181.6800	453.1610	-0.80%	0.4 L1
S+E	PB 211+59.01	1134423.9722	1179182.0870	453.1220	-0.83%	CL DIAPHRAGM SPAN 1 LOC 4 (D1 RT, D2 LT)
S+E	PB 211+62.01	1134426.9610	1179182.3460	453.0970	-0.86%	CL DIAPHRAGM D3 SPAN 1 LOC 1 (LIGHTING)
S+E	PB 211+70.79	1134435.7139	1179183.1045	453.0190	-0.91%	0.5 L1
S+E	PB 211+82.58	1134447.4556	1179184.1221	452.9060	-1.00%	CL DIAPHRAGM SPAN 1 LOC 5 (D1 RT, D2 LT)
S+E	PB 211+87.29	1134452.1523	1179184.5291	452.8580	-1.04%	0.6 L1
S+E	PB 212+02.29	1134467.0963	1179185.8241	452.6940	-1.15%	CL FIELD SPLICE SPAN 1
S+E	PB 212+03.79	1134468.5907	1179185.9536	452.6770	-1.16%	0.7 L1
S+E	PB 212+06.15	1134470.9390	1179186.1571	452.6490	-1.18%	CL DIAPHRAGM SPAN 1 LOC 6 (D1 RT, D2 LT)
S+E	PB 212+09.15	1134473.9278	1179186.4161	452.6130	-1.20%	CL DIAPHRAGM D3 SPAN 1 LOC 2 (LIGHTING)
S+E	PB 212+20.29	1134485.0291	1179187.3782	452.4750	-1.29%	0.8 L1
S+E	PB 212+23.29	1134488.0179	1179187.6372	452.4360	-1.31%	BEGIN FLANGE TRANSITION (TOP & BOT)
S+E	PB 212+29.72	1134494.4224	1179188.1922	452.3500	-1.35%	CL DIAPHRAGM SPAN 1 LOC 7 (D1 RT, D2 LT)
S+E	PB 212+36.79	1134501.4675	1179188.8027	452.2530	-1.40%	0.9 L1
S+E	PB 212+37.59	1134502.2561	1179188.8711	452.2420	-1.41%	INTERMEDIATE STIFFENER PLATES SPAN 1 RT
S+E	PB 212+45.44	1134510.0810	1179189.5492	452.1280	-1.47%	INTERMEDIATE STIFFENER PLATES SPAN 1 LT
S+E	PB 212+53.29	1134517.9059	1179190.2273	452.0110	-1.53%	CL PIER BEARING
S+E	PB 212+61.63	1134526.2081	1179190.9467	451.8810	-1.59%	INTERMEDIATE STIFFENER PLATES SPAN 2 LT
S+E	PB 212+68.29	1134532.8499	1179191.5223	451.7730	-1.64%	0.1 L2
S+E	PB 212+69.96	1134534.5102	1179191.6662	451.7460	-1.65%	INTERMEDIATE STIFFENER PLATES SPAN 2 RT
S+E	PB 212+78.29	1134542.8125	1179192.3857	451.6050	-1.72%	CL DIAPHRAGM SPAN 2 LOC 2 (D1 RT, D2 LT)
S+E	PB 212+81.29	1134545.8013	1179192.6447	451.5540	-1.74%	CL DIAPHRAGM D3 SPAN 2 LOC 1 (LIGHTING)
S+E	PB 212+83.29	1134547.7938	1179192.8173	451.5190	-1.75%	0.2 L2
S+E	PB 212+88.29	1134552.7752	1179193.2490	451.4300	-1.79%	END FLANGE TRANSITION (TOP & BOT)
S+E	PB 212+98.29	1134562.7378	1179194.1124	451.2480	-1.86%	0.3 L2
S+E	PB 213+03.29	1134567.7192	1179194.5441	451.1540	-1.90%	CL DIAPHRAGM SPAN 2 LOC 3 (D1 RT, D2 LT)
S+E	PB 213+08.79	1134573.1986	1179195.0189	451.0480	-1.94%	CL FIELD SPLICE SPAN 2
S+E	PB 213+13.29	1134577.6818	1179195.4074	450.9600	-1.98%	0.4 L2
S+E	PB 213+14.67	1134579.0517	1179195.5261	450.9330	-1.98%	SCUPPER CONNECTION PLATE SPAN 2 RT
S+E	PB 213+28.29	1134592.6258	1179196.7025	450.6570	-2.03%	0.5 L2; CL DIAPHRAGM SPAN 2 LOC 4 (D1 RT, D2 LT)
S+E	PB 213+43.29	1134607.5698	1179197.9975	450.3520	-2.03%	0.6 L2
S+E	PB 213+53.29	1134617.5325	1179198.8609	450.1490	-2.03%	CL DIAPHRAGM SPAN 2 LOC 5 (D1 RT, D2 LT)
S+E	PB 213+56.29	1134620.5213	1179199.1199	450.0880	-2.03%	CL DIAPHRAGM D3 SPAN 2 LOC 2 (LIGHTING)
S+E	PB 213+58.29	1134622.5138	1179199.2926	450.0470	-2.03%	0.7 L2
S+E	PB 213+73.29	1134637.4578	1179200.5876	449.7420	-2.03%	0.8 L2
S+E	PB 213+78.29	1134642.4391	1179201.0193	449.6400	-2.03%	CL DIAPHRAGM SPAN 2 LOC 6 (D1 RT, D2 LT)
S+E	PB 213+88.29	1134652.4018	1179201.8826	449.4370	-2.03%	0.9 L2
S+E	PB 214+03.29	1134667.3458	1179203.1777	449.1320	-2.03%	CL END BEARING
S+E	PB 214+04.13	1134668.1752	1179203.2496	449.1150	-2.03%	END STATION

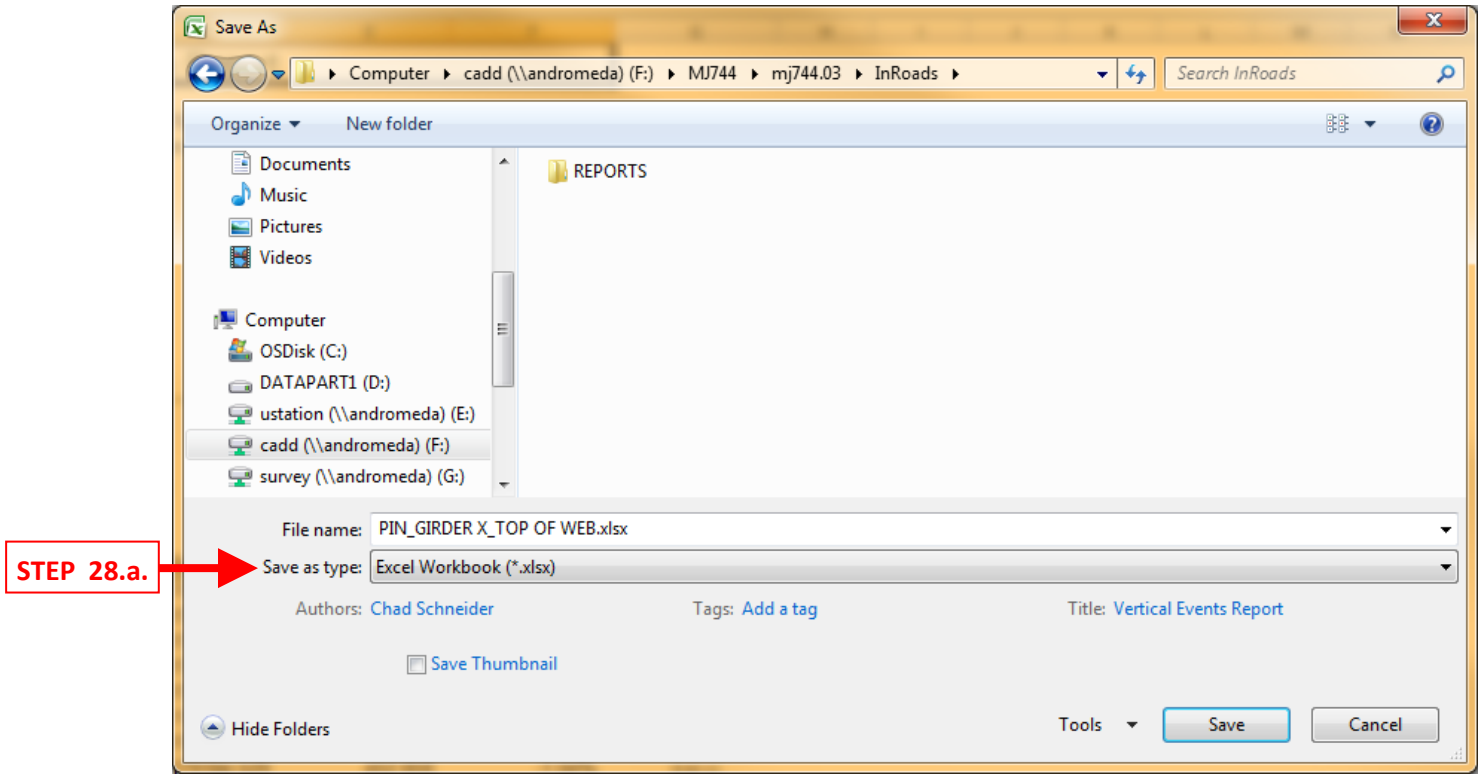
STEP 27

27. If there are two points that have the same station, note this in the description column with both point descriptions

28. In Excel©, Select **"Save As"**



a. Save file as **"Excel Workbook (*.xlsx)"**

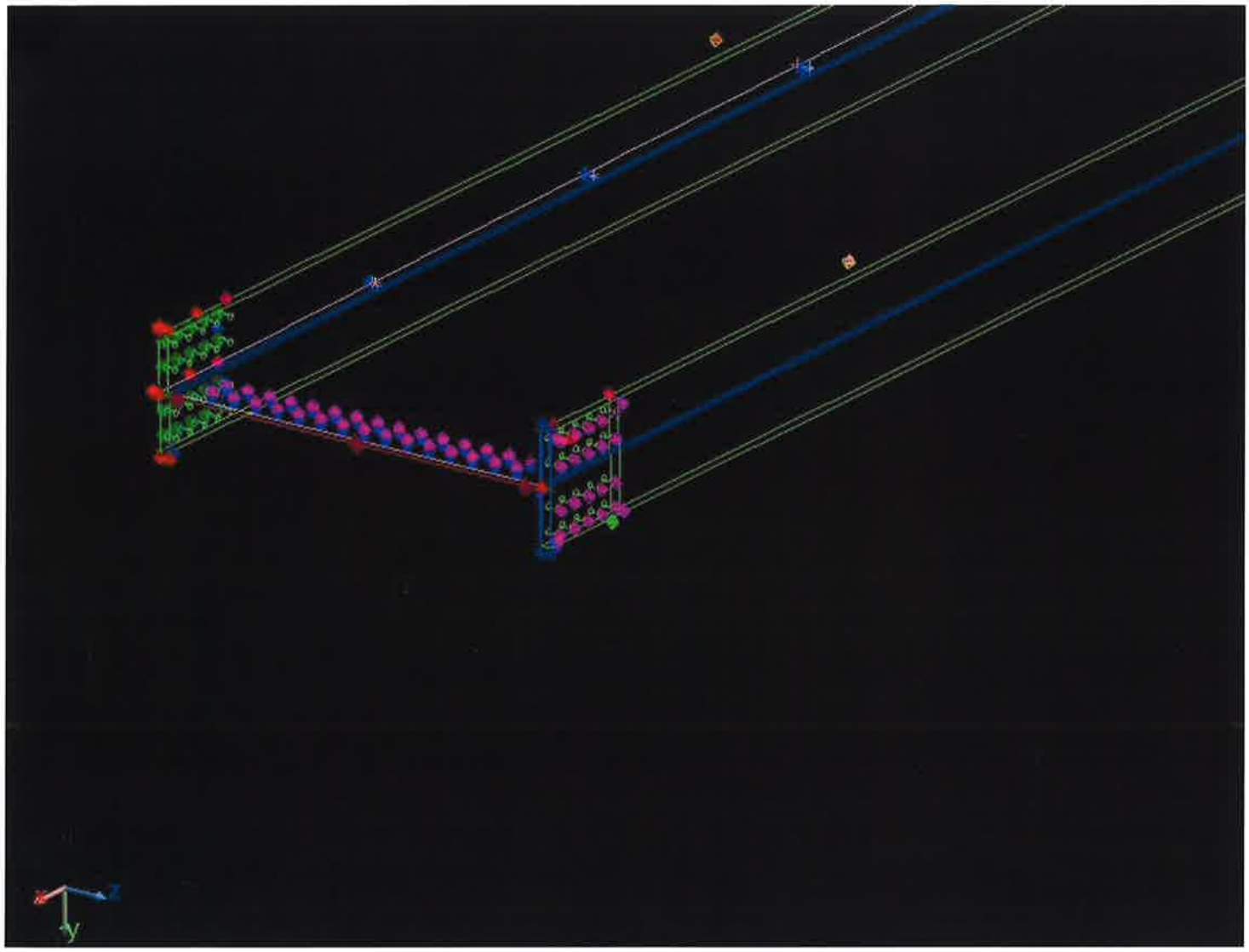


29. **<u>YOU ARE DONE!!</u>** This file will be submitted as part of the deliverable

Appendix D

Representative Scan Results

TF-HOLE CENTERS to TF-HOLES ACTUAL



Summary: Group to Group Relationship TF-HOLE CENTERS to TF-HOLES ACTUAL				
Statistic	dX (in)	dY (in)	dZ (in)	Mag (in)
Min	-0.0322	-0.1089	-0.6945	0.3778
Max	-0.0021	-0.0647	-0.3658	0.6993
Average	-0.0184	-0.0879	-0.5399	0.5480
StdDev from Avg	0.0099	0.0108	0.1242	0.1220
StdDev from Zero	0.0213	0.0908	0.5677	0.5753
RMS	0.0208	0.0885	0.5534	0.5608
Tol Range				
In Tol				
Out Tol				
Count	20			

TF-HOLE CENTERS to TF-HOLES ACTUAL

Group to Group Relationship TF-HOLE CENTERS to TF-HOLES ACTUAL (Reported in FRAMES::BF-HOLE-FRAME)										
Name	TF-HOLE CENTERS			TF-HOLES ACTUAL			Delta			
	X1 (in)	Y1 (in)	Z1 (in)	X2 (in)	Y2 (in)	Z2 (in)	dX (in)	dY (in)	dZ (in)	Mag (in)
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1001	0.0001	13.0000	-63.0000	-0.0264	12.9038	-63.6810	-0.0264	-0.0962	-0.6810	0.6883
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1002	3.0001	13.0000	-63.0000	2.9759	12.9179	-63.6835	-0.0242	-0.0821	-0.6835	0.6888
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1003	6.0001	13.0000	-63.0000	5.9706	12.9110	-63.6900	-0.0294	-0.0890	-0.6900	0.6963
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1004	9.0001	13.0000	-63.0000	8.9696	12.9244	-63.6945	-0.0305	-0.0756	-0.6945	0.6993
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1005	12.0001	13.0000	-63.0000	11.9734	12.9133	-63.6908	-0.0267	-0.0867	-0.6908	0.6967
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1006	0.0001	9.5000	-63.0000	-0.0242	9.4051	-63.6112	-0.0242	-0.0949	-0.6112	0.6190
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1007	3.0001	9.5000	-63.0000	2.9760	9.4243	-63.6169	-0.0241	-0.0757	-0.6169	0.6220
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1008	6.0001	9.5000	-63.0000	5.9764	9.4156	-63.6172	-0.0237	-0.0844	-0.6172	0.6234
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1009	9.0001	9.5000	-63.0000	8.9711	9.4353	-63.6214	-0.0290	-0.0647	-0.6214	0.6254
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1010	12.0001	9.5000	-63.0000	11.9812	9.4175	-63.6283	-0.0188	-0.0825	-0.6283	0.6340
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1011	0.0001	3.5000	-63.0000	-0.0078	3.3911	-63.4592	-0.0079	-0.1089	-0.4592	0.4720
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1012	3.0001	3.5000	-63.0000	2.9910	3.4004	-63.4632	-0.0090	-0.0996	-0.4632	0.4739
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1013	6.0001	3.5000	-63.0000	5.9815	3.4007	-63.4727	-0.0185	-0.0993	-0.4727	0.4834
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1014	9.0001	3.5000	-63.0000	8.9888	3.4168	-63.4867	-0.0112	-0.0832	-0.4867	0.4939
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1015	12.0001	3.5000	-63.0000	11.9679	3.4065	-63.4858	-0.0322	-0.0935	-0.4858	0.4957
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1016	0.0001	0.0000	-63.0000	-0.0035	-0.0941	-63.3658	-0.0035	-0.0941	-0.3658	0.3778
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1017	3.0001	0.0000	-63.0000	2.9979	-0.0945	-63.3717	-0.0021	-0.0945	-0.3717	0.3836
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1018	6.0001	0.0000	-63.0000	5.9950	-0.0884	-63.3799	-0.0051	-0.0884	-0.3799	0.3901
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1019	9.0001	0.0000	-63.0000	8.9898	-0.0942	-63.3889	-0.0102	-0.0942	-0.3889	0.4003
CAD MODEL MEASUREMENTS::TF-HOLE CENTERS::1020	12.0001	0.0000	-63.0000	11.9894	-0.0703	-63.3900	-0.0107	-0.0703	-0.3900	0.3965