

IOWA DOT BUILDING INFORMATION MODEL FOR BRIDGES AND STRUCTURES PILOT PROJECT



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BIOGRAPHY

Grant Schmitz is a Bridge Engineer in HDR's Omaha office. He has five years of experience in bridge design, modeling, and inspection work. He received his BS and MS degrees in Civil Engineering from Iowa State University. His recent work assisting in the development of Building Information Models (BIM) for bridges has led to one of the nation's first 3D BIM deliverables for a Design-Bid-Build contract.

Ahmad Abu-Hawash is the Chief Structural Engineer with the Iowa Department of Transportation and has been working with the DOT in highway construction, bridge rating, and bridge design since 1983. He is responsible for overseeing the design of major bridge projects, design policy review, coordination of bridge research, and the resolution of structural fabrication issues. Ahmad received his BS degree from the University of Iowa and his MS degree in Structural Engineering from Iowa State University. He recently took on the role as project manager for the Iowa led national pooled fund study on BIM for bridges and structures.

SUMMARY

In recent years, the application of BIM technology to bridges has offered significant advantages over traditional 2D formats. These advantages are evident in all phases of a project, from preliminary design to post-construction asset management. Much of this technology however, remains largely untested for bridge projects. The Iowa DOT Building Information Model (BIM) Pilot Project was developed to help fill this void by modeling, evaluating, and delivering a 3D BIM model for a design/bid/build bridge contract.

In an effort to push the limits of the current software, three complex steel welded plate girder bridges were selected for the pilot project. The designers utilized a combination of Bentley products to create and view the models. The two primary pieces of software used for model development were OpenBridge Modeler and ProStructures. This paper discusses the advantages and disadvantages to each as they pertain to curved steel plate girder bridges.

Along with a complete overview of the modeling process, the authors will discuss how the traditional 2D delivery method was changed to facilitate a 3D deliverable. With construction still underway, ways in which the contractor has utilized the model at the time of publishing will also be covered.

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INTRODUCTION

Building Information Modeling (BIM) for Bridges and Structures has experienced rapid development in recent years. As the number of advantages over traditional project delivery methods increase, bridge owners, designers, and contractors are beginning to take note. Many of these advantages, however, remain untested with very few projects throughout the country utilizing the technology.

In an effort to move the state and bridge industry as a whole in the direction of BIM implementation, the Iowa DOT initiated a BIM Pilot Project to investigate the advantages of developing a BIM model throughout the project life cycle. The project focused on creating a model to the highest level of development possible, assessing the software used, and evaluating model uses during construction.

The Iowa DOT selected a project based on schedule and level of complexity. In order to give designers the opportunity to realize the benefits of a BIM model during the traditional final design phase, the project would ideally be under contract for final design services. A project with a higher level of complexity would also allow designers to better evaluate the capabilities of the software. Ultimately, HDR was selected for the project and responsible for modeling three complex steel plate girder bridges in the I-80/I-380 interchange.

With the successful development of the models,

and desire for more information on BIM uses during the construction phase, one of the three bridges was chosen as the primary deliverable in place of the traditional 2D plan set. This gave the Iowa DOT and HDR even more of an opportunity to evaluate the software's use during the construction phase. It also provided each party with experience advertising and awarding this type of construction contract.

This paper outlines the process used to achieve the aforementioned goals of the Pilot Project and highlights the benefits and challenges experienced along the way.

BRIDGE OVERVIEW

The three curved steel plate girder bridges selected for the project are part of the I-80/I-380 reconstruction located northwest of Iowa City, Iowa. These ramp bridges consist of a five span diverging gore (Ramp BH), a thirteen span curved ramp carrying the northbound movement (Ramp H) and a three span curved ramp carrying the southbound movement (Ramp B). Figure 1 illustrates each of these three bridges. In total over 4,200 feet of bridge was modeled.

These bridges contained a variety of challenging features, some of which include discontinuous girders, complex superelevation transitions, inspection walkways, and highly aesthetic substructure elements. Additionally, the three bridges were part of a major interchange

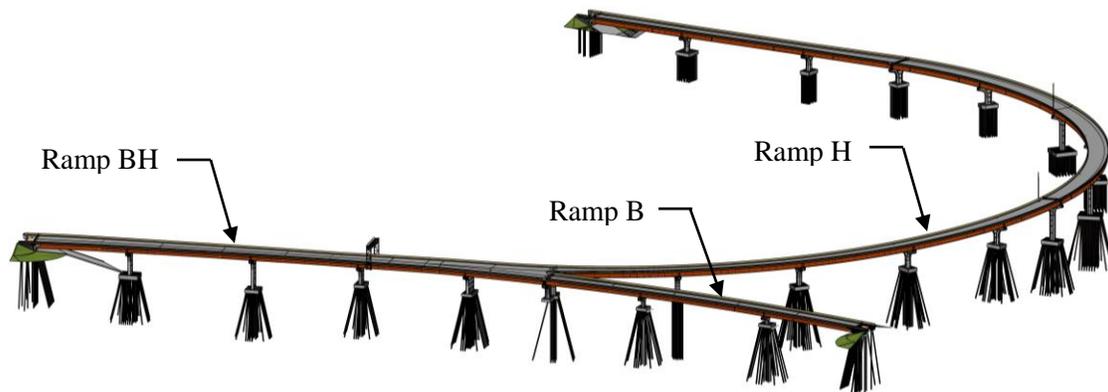


Figure 1: I-80/I-380 BIM Model Isometric

reconstruction that included many other bridges, new alignments, roadway widening, and extensive grading. Each of these complexities allowed the Iowa DOT and HDR to better evaluate the capabilities of the software and understand the advantages of the BIM model during the design phase.

MODEL DEVELOPMENT

In order to achieve the goals of the Pilot project, software capable of producing high Level of Development (LOD) models was identified. LOD is a numerical value assigned to objects or groups of objects within a model that help users gauge the level of detail and information contained within the model. LOD typically ranges from 100, which is generally used for conceptual development, to 500, which is representative of an as-built condition and may be used for asset management.

For this project, Bentley software was used exclusively because of the owner's familiarity with other Bentley products such as MicroStation. Early testing by the Iowa DOT also showed good results when using Bentley's software for lower LOD models. As a result, two pieces of software were selected. OpenBridge Modeler V8i was used to create the primary bridge elements to a low LOD. ProStructures V8i was then used to supplement the model with additional details. MicroStation CONNECT and i-Model Transformer were also used to modify information within the model.

During the modeling process, attention was given to modeling efficiency, errors within the program, and advantages over traditional design methods. Nearly all issues encountered were vetted through Bentley support for verification.

OPENBRIDGE MODELER

Modeling began with OpenBridge Modeler (OBM) V8i by importing the bridge alignments into a new DGN file. Using Geopak alignments provided by others, this information was easily imported into the model. Start and end points of the bridge, pier locations, and skews were also defined at this point. Next, a top down approach was taken to developing individual elements. Elements were created using a series of templates and tables. The templates were used to define the

deck and barrier geometry and provided the user with a lot of flexibility in handling things such as superelevation transitions and custom barrier shapes. Some limitations were encountered when modeling the deck in the gore area of the Ramp BH Bridge, as well as the end dams used to support the modular joints. These deficiencies were ultimately addressed in ProStructures.

All other primary bridge elements were created with the use of tables. This included the haunch, girders, cross-frames, stiffeners, pier footings and piles. Due to the complex geometry of the pier cap and columns as well as the stub abutments, OBM was not able to model them correctly. These would later be modeled in ProStructures. Figure 2 illustrates all elements generated exclusively with OBM.

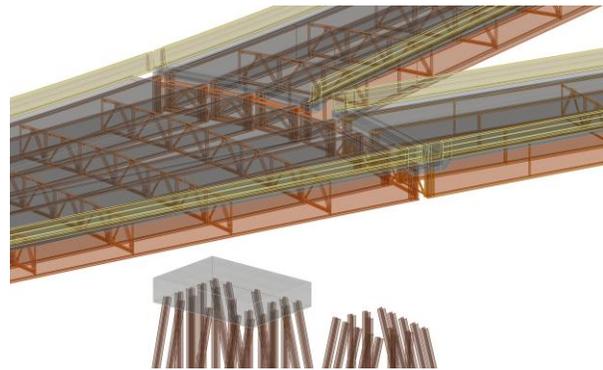


Figure 2: OBM Generated Elements

One of the biggest advantages to OBM is the ability to quickly update the model for design changes. The elements maintain a connection with the original parameters defined in the templates and tables making this possible. As parameters such as alignments or element sizes change, the model is automatically regenerated. This makes OBM very useful during the early stages of design.

The level of detail added to elements within OBM is limited to the previously mentioned templates and tables. This was a significant drawback when targeting a high LOD model. Haunches could only be set at a constant width, and girders and cross-frames could not be coped or cut. These were only a few of the issues encountered. There were also a number of elements OBM did not support, such as cross-frame bolts, field splices, and shear connectors. Modeling time would have been

significantly reduced had these features been available.

Two different methods were used to handle these deficiencies. When within reason, OBM elements were replaced and others added within ProStructures. When the impact of the deficiency was deemed low, or the modeling time required to address the issues to substantial, links to correct 2D details were added to the model.

With the development of 3D modeling across various disciplines on the rise, BIM models lend themselves well to interdisciplinary coordination. For this project, existing, interim, and final site grading was imported along with existing and proposed roadway alignments. This allowed engineers to check for conflicts at all phases of the interchange reconstruction. Borings and a bedrock surface were also provided by the geotechnical engineer for incorporation into the model.

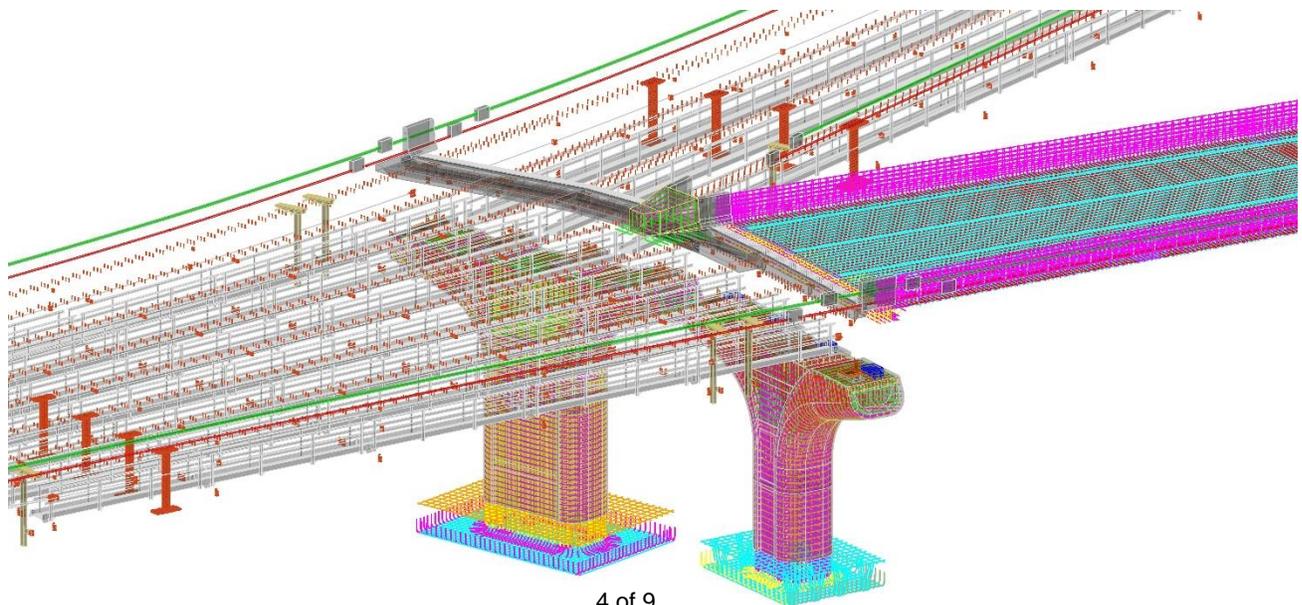
PROSTRUCTURES

After development of the OBM model, ProStructures was used to add additional detail. A new DGN file was created specifically for ProStructures elements to allow users to work in both the OBM and ProStructures files simultaneously. This also reduced individual file sizes, making navigating the model smoother.

Due to the high level of detail and total length of the bridges a majority of the modeling time was spent within this program. Elements included items such as reinforcing steel, electrical conduit, junction boxes, expansion joints, field splices, shear connectors, bearings and subdrains. These elements along with all others modeled within

ProStructures are shown in Figure 3. Unlike OBM, elements within ProStructures are not tied to templates or tables. This gives the user more flexibility when creating customized elements, but greatly hampers the ability to quickly update the model.

Of all of the elements created within the model, reinforcing steel was the most labor intensive. This was primarily due to the complex geometry of the concrete elements. This included the deck, barriers, piers and abutments. Typical pier reinforcing is shown in Figure 4. The tools used to model the reinforcing is dependent on the type of concrete element the reinforcing is being placed within. For simple geometric shapes such as circular columns or rectangular pier caps, parametric modeling tools are available. These tools allow designers to define rebar size, spacing, and clear cover within a dialog. The program then fits the reinforcing within the selected concrete element accordingly. As the shape or location of the concrete element changes, so does the reinforcing. These tools were utilized for reinforcing the concrete footing within the model. For more complex concrete elements, such as pier caps, columns, decks and barriers on this project, non-parametric tools were required. The process involved the creation of Guidelines that were used to define the shape of each bar. These Guidelines had no parametric connection to the concrete element, which became problematic when design changes occurred.



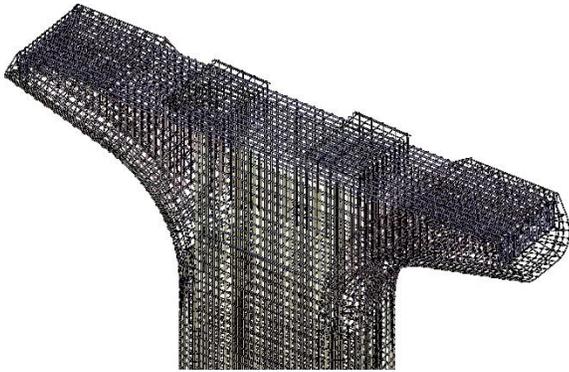


Figure 4: Typical Pier Reinforcing

Once the bars were created, bar marks were assigned and a reinforcing bar schedule produced. The bar schedule was found to be very customizable and designers were able to incorporate all information typically found on a traditional plan set. Bar bends and corresponding dimensions were displayed within the report. A portion of the abutment bar schedule is shown in Figure 5. For more complex bars, some issues associated with bar lengths and details were encountered. These items were addressed manually after the bar schedule was produced by the designer.

Many of the other elements modeled within ProStructures followed the bridge alignment in some capacity. For longitudinal elements, the alignment defined shape and location. For all other elements, the alignment defined the location and

orientation. This introduced a new set of challenges as ProStructures did not have the capability of importing, producing or interpreting this data.

In order to place elements in the correct location, the OBM file was referenced into ProStructures. This did not allow access to the data associated with the alignments, but did allow designers to copy the shape of the alignment and position elements relative to OBM objects. For longitudinal elements such as barrier conduits and inspection access cables, shapes were defined by extracting edges of OBM objects. None of the tools used to define steel elements were capable of following these bi-planar curves, so each object was chorded to a level compatible with the tools. For smaller items such as shear connectors, field splices, and cross frame bolts, the elements were individually copied and rotated into place.

Although there were obvious drawbacks related to modeling time within ProStructures, designers were able to create nearly all features within each of the three bridges. This high level of development allowed for the creation of detailed quantity reports and higher-level class detection. Class detection was used to identify overlapping elements. This was particularly useful when laying out the inspection walkways on the Ramp BH Bridge, which contained a number of flaring girders with variable cross-frame layouts. The use of the model as a visualization aid for the owner,

Bar Mark	Location	Quantity	Material	Bar Size	Pin Dia. (in)	Length (ft:in)	Bent Bar Detail (ft-in)	Weight (lbs)
8A186	Abut Footing Longitudinal	17	60E	#8	0.0	29:1		1,320
5A187	Abut_Footing_Hoops	4	60E	#5	2.5	19:2		80
5A188	Abut_Footing_Hoops	24	60E	#5	2.5	18:2		455
6A189	Abut Backwall B.F. Vertical	51	60E	#6	0.0	12:3		938
5A190	Abut Backwall F.F. Vertical	25	60E	#5	0.0	11:11		311
5A191	Abut_Paving Notch	25	60E	#5	2.5	4:6		117

Figure 5: Reinforcing Bar Schedule

contractor, and other engineers was also very beneficial during the design phase. Tools such as Clip Volume allowed users to isolate a particular area of the bridge to provide a better vantage point of a particular area. Figure 6 shows a clip volume of structural steel around a sign support structure.

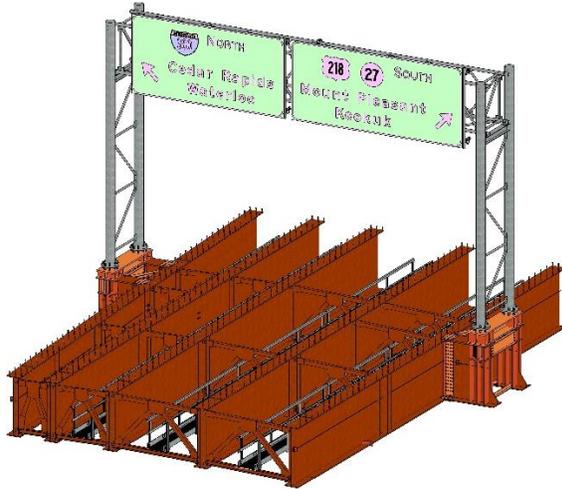


Figure 6: Clip Volume of Superstructure Steel

MODEL INFORMATION AND LINKS

After each element had been created, designers focused on the information contained within the model. This information included items such as material properties, dimensions, bar marks, construction notes and all other items that would be found in a traditional 2D plan set. Some of this data was automatically generated within the program and displayed in the element information dialog. Much of it, however, was found to be irrelevant and potentially misleading to other users. To illustrate this, Figure 7 shows various properties automatically assigned to an H-pile.

Some of the native properties within the table are left blank or repetitive. This needed to be more concise to allow other users to quickly and accurately extract the data. Additionally, some information was not included. To address both of these issues, two additional programs were used.

Bentley's i-Model Transformer was used to edit and remove some of the native element information. The program works by importing an

existing i-model, modifying the schema defining the element information, and publishing a new i-model. An i-model is simply a read-only version of the original DGN file used to create the model. They can be published from both OBM and ProStructures.

To add additional properties to the element information dialog, MicroStation CONNECT was used. This product includes a tool called "Item Types", which gave designers the ability to define custom properties within the Element Information dialog. The type of properties varied by element, but included items such as bid items names and numbers.

After modifying the properties with i-Model Transformer and MicroStation CONNECT, the information appears much more concise. Figure 8 shows the modified properties of the same H-Pile shown in in Figure 7.

ProStructuresObject	
Surface Area Formatted	657.51 sf2
Weight Formatted	3.436 tons
Weight Gross [lbs]	6882.998
Surface Area [sf2]	94681.972
Volume [sf3]	24233.911
Weight Net Formatted	3.436 tons
Weight Gross Formatted	3.441 tons
Weight Net [lbs]	6872.715
Shape Name	HP14x73
Weight_Ref_Formatted	41.61 tons
Weight_Ref	83220.16
Shape Size	HP14X73
Volume Gross [sf3]	24270.169
Volume Net [sf3]	24233.911
Shape Class	AISC_IMPERIAL.AISC_I_HP
Height Formatted	1.136 sf
Pos. No.	
Shipping No.	
Weight [lbs]	6872.715
Note 2	
Element Id	105959
Item No.	
Length [sf]	1140.002
Width [sf]	14.625
Material	ASTM A36 Gr.36
Width Formatted	1.219 sf
Length Formatted	95.000 sf
Description	01_None
Height [sf]	13.625
Name	HP14x73
Process Status	None

Figure 7: Native Element Information

Elem_Info_Pile	
Width	1.219 sf
Length	95.000 sf
Material	ASTM A 572 Gr. 50
Weight_lbs	6872.715
Net_Volume_in3	24233.911
Shape_Size	HP14X73
Height	1.136 sf
Surface_Area_in2	94681.972
Pile_Points	No
Bid_Item_Name	Piles, Steel, HP 14 x 73
Steel_Shape	HP 14x73
Description	Pier No. 6A Pile
Bid_Item_Code	2501-0201473
Batter_Angle	1 H/4 V
Uplift_Anchors	No
Pile_Length	95'
Concrete_Embed_Length	1'-0

Figure 8: Altered Element Information

Not all information could be included in the element information dialog. This included items such as long plan notes, tables, details for vendor supplied items and details for elements that could not be accurately modeled. To address this issue, links were created within the model. These links were assigned to various elements requiring additional information. Users are able to select the links within the model and open the corresponding file. Links to PDF documents, Excel files and websites were all provided. One downside to this process was the creation of numerous files. Each would need to be provided with the primary DGN file for the user to access all of the data.

By utilizing i-Model Transformer, MicroStation CONNECT and links, all necessary information was successfully incorporated into the model. This gave the Iowa DOT the opportunity to utilize one of the BIM models as the primary construction document in place of the traditional 2D plan set.

PROJECT DELIVERY AND ADVERTISEMENT

The initial intent for each of the three BIM models was to provide them for information only during the construction phase. The primary construction document would remain a 2D plan set developed under a separate final design contract. The hope was that contractors would frequently access the model and provide feedback on how it was used and where improvements could be made. After

discussions with the Iowa DOT and local contractors, it was determined that the use of the model would be very limited due to the lack of experience and cost of the software. It was recommended that the BIM models be used in place of a 2D plan set.

With the successful development of the three bridge models, it was decided that the BIM model for Ramp B would be utilized as the primary construction document. This would require contractors to work in the model to gather information pertinent to construction. Not only would this allow the Iowa DOT to gather feedback, but also give contractors more of an opportunity to realize the advantages of a BIM model.

Replacing the Ramp B 2D plan set with the BIM model required additional consideration by the designer prior to delivery. Quality control procedures specific to the BIM models were not initially developed given their intended use. These procedures were however, used during the development of the 2D plans. This simplified the process of checking the model. The checker was able to utilize the finalized 2D plan set to verify all information accessible in the model. This included items such as element geometry, coordinates, elevations, element information and linked documents.

In order to convey all pertinent information specific to the BIM model to the contractor, a special provision was developed. This included a complete list of all files, instructions to access, and recommended software. An information hierarchy was also outlined should a discrepancy exist between files. During the development of the model, it was clear that not all elements could be modeled to precisely match the design intent. These items were reflected in the special provision by utilizing an LOD table. Various groups of elements were assigned an LOD classification number ranging from 100 to 400. Elements with known deficiencies in the model were assigned a lower LOD value. A full list of these issues was also provided.

In order to sign and seal the digital documents, an appendix was added to the special provision. This included a complete list of files as well as the

engineer's signature and seal. All other files were provided for information only.

An i-model was used as the final electronic deliverable for the Ramp B Bridge. This file type gave designers more control over element information and eliminated the possibility of unintentional modifications by other users. Though advantageous during the advertisement period, it would ultimately hamper the contractor's ability to fully utilize the model during construction. For this reason, the DGN files used to develop the model were to be provided to the selected bidder. The contractor could then choose to purchase ProStructures to access additional tools not available in Bentley View.

It was well understood that many of the contractors expected to submit bids on the project had little or no experience with Bentley products. Requiring an expensive license for software such as MicroStation or ProStructures to access the information could have potentially limited the field of bidders and left many with an unused product license. For this reason, Bentley View was the preferred choice during the advertisement period. Bentley View is available for download for free on Bentley's website and grants users access to all information necessary to bid the project.

In an effort to minimize the learning curve associated with Bentley View, training was made available in two different formats. First, an in-person training session was offered to both Iowa DOT personnel and any potential bidders. The session covered everything from basic navigation to specific examples of data extraction within the Ramp B model. Additionally, an hour-long training video was posted online for future reference. The video covered many of the same topics addressed in the in-person training session but allowed users to follow along at their own pace. The training was considered successful based on the relatively low number of questions received during advertisement. Those that were received pertained mostly to accessing information within the model. The answers to each question were made available to all bidders.

The contract for the three bridges was awarded on July 31, 2018 for \$38.2 Million. This was just under the engineers estimate, implying that the use

of a BIM model had little effect on the overall construction cost.

CONTRACTOR USE

Understanding the use of the BIM model by contractors, subs, and fabricators is critical to the successful implementation of BIM into a project life cycle. At the time of writing this paper, there was still much to be learned from the Iowa DOT Pilot Project given it was still in the early phases of construction. Some feedback however, was available.

Due to the cost of the software and lack of experience with 3D modeling, subcontractors and fabricators did not purchase the software necessary to fully utilize the BIM model. This required the prime contractor to extract all necessary information for each party. In the case of custom concrete form liners, 2D sheets were developed and annotated by the contractor from cut sections within the model. These were then sent to the fabricator. To do this, the contractor utilized ProStructures, which was purchased after being awarded the construction contract. Although this process is not ideal, it does allow the contractor to better understand the tools at their disposal. Also, as BIM deliverables become more prevalent in the bridge industry, it is believed that more fabricators will purchase and devote resources to learning the software.

One of the most significant advantages to BIM is the use of digital information to define a bridge. This allows fabricators to import data directly from the model rather than interpreting information from a 2D plan set. For this project, rebar fabricators were able to utilize the model to import rebar shapes directly into aSa Rebar Software. This was a significant time savings when compared to manually inputting the information.

CONCLUSIONS

The BIM for Bridges and Structures Pilot Project has provided both the Iowa DOT and HDR valuable insight into the current state of Bentley's BIM software. Throughout this project, both OpenBridge Modeler and ProStructures were evaluated for use on projects in the near future.

OBM was found to be very useful as a preliminary design tool. The ability to quickly incorporate changes through the use of parametric modeling tools makes it a good fit for this type of application. For more complex and higher LOD modeling, the program was found to be lacking in basic tools that would significantly reduce modeling time in other programs. The parametric tools also limited the ability to incorporate custom details. Being able to supplement the model with ProStructures objects and links however, makes high LOD modeling possible.

The level of detail achievable within ProStructures makes it ideal for complex and high LOD modeling. Numerous tools exist within the program that allow designers to produce most components of a traditional bridge. Achieving a high LOD model is not without its disadvantages. Numerous bugs were found within ProStructures that made detailing difficult and required custom workarounds. The lack of alignment data also make placing objects very time consuming. For this reason, ProStructures is not recommended during preliminary design and should only be used when a high LOD model is required.

Although there were a number of challenges encountered during the development of the three complex curved steel plate girder bridges on this project, each bridge was successfully modeled. This allowed the Iowa DOT to utilize the Ramp B Bridge for one of the nation's first BIM bridge deliverables for a design/bid/build contract. As construction of the project gets underway, feedback from contractors and fabricators will allow designers to improve upon future models.

When it comes to BIM technology, users should not hesitate to explore and evaluate the software for themselves. BIM is rapidly developing with new software version being released often. Finding the right balance between project complexity and LOD, and understanding the advantages to each is critical to the successful implementation of BIM for Bridges and Structures.