Capitol Improvements

BY MARK TAMARO, P.E., JEFFREY D'ANDREA, P.E. AND LUCAS NISLEY

WASHINGTON, D.C., IN 2005, ONCE AGAIN BECAME HOME TO A MAJOR LEAGUE BASEBALL TEAM. The Washington Nationals, formerly the Montreal Expos, made existing RFK Stadium their home turf for the time being, but with the stipulation that the city government would build them a new, modern ballpark. Thus began a race to select a site and design and construct a 41,000-seat stadium in time for Opening Day this spring; the result is the fastest major league ballpark construction project ever completed.

Design Development

During the conceptual design phase of Nationals Park, the design-build team determined that a predominantly steel superstructure was best suited for the project. The fact that steel could be erected quickly and could accommodate the large clear-spans and significant cantilevers for the seating bowls made it an easy choice for the designers. The question was: How quickly could the steel be procured and fabricated for erection? Early critical path scheduling determined that the foundations and below-grade service levels could begin construction immediately using cast-in-place concrete. But by the time workers got to the main concourse level, fabricated steel would be ready and would quickly surpass concrete when it came to speed of construction.

To manage and expedite the design process, the entire ballpark was separated into multiple areas by expansion joints, creating independent structural systems for each section. The lateral force resisting system of each of these areas was comprised of two different structural systems. Large structural bents, located 50 ft on center in a radial pattern around the ballpark, provide lateral resistance in the direction perpendicular to the field. These bents consist of cantilevered trusses that support the precast seating stadia, and a combination of moment frames and braced frames in the bays supporting the concourse levels and suites. The bents are then tied together along the circumference with four "belt

An innovative construction methodology speeds the way for the Washington Nationals' new ballpark.

trusses" and a series of five moment frames, which resist lateral loads in the transverse direction.

The structural designers created separate finite-element analysis models for each independent area of the structure. Each model was then analyzed for sensitivity to crowd-induced vibration as well as for gravity and lateral loading. To meet vibration-control criteria, many of the large cantilever truss members needed to be up-sized. Engineers used virtual work methods to determine which members had the greatest potential to reduce vibration, minimizing the need for additional materials while optimizing the structure's response.

Design-Build Phase

As soon as the general contractor was selected by the owner, the two firms began searching for a steel fabricator to perform a design-assist role with the engineers and architects. To ensure a competitive selection, candidates were required to submit a schedule of unit prices for a dozen different steel categories.

Working with the prospective fabricators, the structural team developed estimated tonnages for each category. Incorporating this information into the schematic documents allowed the contractor to make a more accurate calculation of costs and to select the fabricator that would provide the best value to the project.

With the steel fabricator on board and the guaranteed maximum price approved by the D.C. Sports and Entertainment Commission, the contractor set an "ultra-fast-track" final schedule. The tight timeframe necessitated a unique design approach; the structural team produced ten consecutive design packages, one for each of the independent areas of the ballpark, that were used to place five separate mill orders. Based on early and extensive input from the steel erector, these design packages were laid out in the order in which erection would proceed. The entire ballpark was designed, detailed, fabricated, and erected in this order.

Milestone dates for completion of the superstructure were established by the contractor, with the ultimate goal of removing all cranes from the infield by July 2007. This information allowed the architects and engineers to focus design efforts in parallel with the critical path for fabrication and erection. The project team launched a nine-month-long series of weekly progress meetings that involved regular participation by the architect, structural engineer, general contractor, fabricator, detailer, steel erector, and structural precast supplier. These meetings focused on making sure the design was on schedule and within budget, and all parties were engaged to make sure that their respective work was being planned in the most efficient manner possible.

The structural design and coordination process was streamlined by the use of building information modeling (BIM). Because each design package had to advance from schematic design to construction documents in only two months, the structural team built initial models of the steel frame and precast seating stadia units using Tekla Structures software. The models, which included basic geometry and member sizes and configurations, were created in parallel with the structural analysis prior to the production of paper drawings. Advance bills of material for each mill order were determined directly from the model, eliminating the need for a traditional material take-off from paper documents. This approach allowed procurement of steel to begin before the designers had finalized details and connections on the final construction documents.

After being used to produce the mill order, the building models were transferred to the project's steel detailer, where they were advanced to include all connection designs and detailed information for shop drawing production. The entire design-build team relied upon the Tekla models during coordination meetings. They allowed team members to visualize complex connections three-dimensionally and were revised on the spot as decisions were made.

The use of BIM also helped the team fulfill the designers' aesthetic vision. Because the exposed trusses could be fully visualized early in the design process, the connections could be designed to satisfy the architects' desire to maintain a light appearance. The steel fabricator's preference for shop-welded connections was also incorporated into the design solution. Partial penetration shop welds of W14 wide-flange shapes created clean truss connections without gusset plates or other miscellaneous connection hardware.

Steel was the ideal material for the large clear-spans and significant cantilevers for the seating bowls.

The Tekla models allowed the team to design elements for ease of transport as well. Trusses and frames were preassembled in the shop in the largest possible shippable assemblies. They could then be quickly erected in the field, with minimal field-welded connections. The Tekla models were used to ensure that the weights and sizes of these prefabricated assemblies were within the shippable limits. The maximum out-to-out dimensions of all elements, including connection plates, were established in the model prior to finalizing

Q&A with Don Banker

AISC Senior Regional Engineer Tom Faraone chatted with Don Banker of Banker Steel to get a fabricator's perspective on the use of the design-assist role, rather than the traditional design-bid-build arrangement, on the new Nationals Park.

What's the advantage of design-assist?

We considered it an opportunity to participate at an early stage on making the design work for our unit prices, our shop, and our erector. We went to design meetings every two weeks as soon as we were released on the project. With the 3D model [developed using the Tekla Structures program] we were able to review and make adjustments to connections, material sizes, truss sizes due to shipping limitations, etc. [The benefit is] we are in control of our destiny. If you let the process roll over you, it can be very expensive. If you manage and participate at each stage, the ability to make money is in your control.

Did you use the 3D structural model to assist with pricing?

No. The engineer's 3D model was in too early a stage to be of use. The sketches and discussions on the design plan were useful in determining our unit prices.

Did you use 3D modeling and direct digital exchange of information?

Yes. It wouldn't have worked without the digital transfer of information. The timing of design input to design output, to material and detailing changes, to actual work in the shop was too short to allow any other method of communication. The use of 3D models provided enormous benefits to our shop. There were situations [where] we could not have built the component without having the model to view and determine its exact interface in the structure. The erector had similar instances, but was not as adept at using the model. The erector sees the opportunity of having the 3D model and is training staff to better utilize it. It can be used for piece counts, bolt orientation, how to access connections, productivity, etc.

How was the connection design handled?

Thornton-Tomasetti did the majority of the moment connections, and we did the remaining connections, such as the truss member and shear connections. Loading was obviously provided by Thornton-Tomasetti. All connections were given a final review by Thornton-Tomasetti—electronically, to expedite their comments. Mountain Enterprises and Banker Steel essentially developed the expansion joint details/connections as well.

Are you more profitable on design-assist projects or on traditional design-bid-build projects?

Design-assist projects, but with much greater exposure and risk. The risks were huge. Think about having very limited designs and creating a matrix for pricing that is used to the end of the job. Because it was a publicly funded project and our customer had a fixed price, we had to work very hard to make sure the design, utilizing our unit prices, was adhered to.

Did being at the table early help manage your exposure?

Yes. We went to design meetings every two weeks as soon as we were released on the project. With the [3D] model we were able to review and make adjustments to connections, material sizes, truss sizes due to shipping limitations, etc. We were the driving force if there were issues that impacted the unit prices, but without flexibility from the design team it would not have been successful. The difficulty, as with every job, is convincing everyone of the cost impact of changes.

Do you have advice for other fabricators who are considering this type of delivery method?

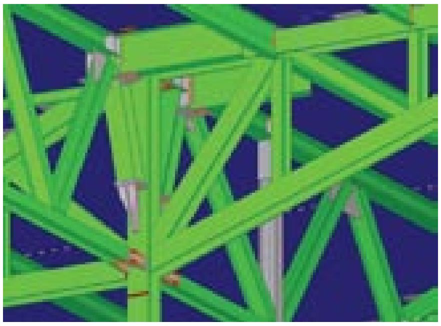
Make sure you have clearly understood the designer's intent with the structure. Make sure there is a clear matrix of pricing that everyone agrees to. Make sure that it's clear who is doing connection design and what the basis of that design will be. The fabricator, rather than the EOR, should make every effort to develop the connections and to get actual loads. These projects move so quickly that if you are not on top of them, it could cost you significantly if the EOR is more conservative with his connections than your estimate.

What was different about this project?

The biggest surprise was the architect's flexibility. You just don't see that happening in bid-build project delivery. The architect understood the need to get answers quickly. HOK, in most cases, either made decisions as we asked them or within a few days. It also helped that the architect was experienced in sports arenas. There were architectural features that the A/E included originally to define the project. A number of these features were dropped because of the budget constraints. The difference from normal bid-build work is that there is no discussion about "sacred cows," or if there is discussion it's how to keep them. On this job, the team [GC, fabricator, erector, precast contractors, etc.] discussed what was best for the project.

Any other advice for others contemplating design-assist?

This process requires a level of trust from the customer to the fabricator team and the fabricator team to the customer. It's important for fabricators to have a high level of integrity and to have an open-book policy that will withstand scrutiny by the customer. This project demonstrates that when the team works together with mutual trust and open communication, we can provide our customer a cost-effective and accelerated delivery project. We see this as the future of our industry.



3D modeling played a significant role in the stadium's design. The Tekla model (left) allowed designers to visualize complex connections (below).

the design and well before shop drawings were generated.

It is estimated that the release of early mill orders and design packages through the use of BIM shortened the overall project schedule by six months.

Construction Phase

The exceptionally aggressive schedule dominated all aspects of the project. A construction budget averaging one million dollars per day was put in place to meet the deadline. As the project progressed, design, detailing and shop drawing review, and construction were all taking place simultaneously on different sections of the ballpark. To manage this complex process, the design-build team implemented several strategies for avoiding conflicts and quickly resolving problems:

The team used the Tekla model to illustrate erection sequences in relation to calendar dates. The information was used to determine where conflicts in crane travel would occur between different cranes erecting steel and structural precast elements. Several portions of the bowl levels required the interruption of steel placement to set precast stadia units, with steel erection then continuing above. The fact that all lifts had to take place from the playing field area of the ballpark added to the complexity. The steel erector used two cranes simultaneously to negotiate the large radius and far-reaching picks necessitated by other work going on in the playing field.

Pre-installation of non-structural components. The design-build team worked together to identify opportunities for non-structural trades to pre-install equipment before the erection of large elements, such as the roof canopy. Sports lighting was built on the ground and then flown into place with the erection of the structural steel. Lights, handrails, gratings, etc. had all been added to the building model to ensure proper fit-up and eliminate construction coordination issues in the field.

Design-build team morning meetings. The design team attended daily meetings with project superintendents, creating a forum for the swift resolution of disputes and the coordination of construction issues. RFIs were thus limited, and most were used to confirm on-site direction provided by the architects and engineers. Total RFIs related to structural steel numbered less than 100.

Despite the speed of design and construction, the use of BIM technology and the collaboration between the designers and builders eliminated many potential problems. The new Nationals Park was made possible by the design-build team's ability to work together in innovative ways to bring about the construction of 9,000 tons of structural steel in time for the park's late March 2008 debut. **MSC**

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