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MARK TAMARO/THORNTON TOMASETTI

NATIONALS PARK

Mark Tamaro, Jeffrey D'Andrea and Lucas Nisley, structural engineers with Thornton Tomasetti, Inc., discuss the design-build process for the new Nationals Park in Washington DC.

The new Nationals Park — a 41,888-seat Major League Baseball (MLB) venue totalling 1,000,000sqft — opened on March 30, 2008, just thirty months after the design start date.

WAYNE STOCKS/THORNTON TOMASETTI

The new Nationals Park — a 41,888-seat Major League Baseball (MLB) stadium totalling 1,000,000sqft — opened on March 30, 2008, just thirty months after the design start date. The aggressive schedule required exceptional performance and collaboration from the design team, driven by the development of creative delivery strategies, and fostered a design process that put a premium on efficiency and buildability.

In April 2005, MLB agreed to move a team to Washington, D.C., with the stipulation that the city government would construct a new ballpark in time for Opening Day in the spring of 2008. Innovative delivery methods, the use of three-dimensional (3-D) Building Information Modelling (BIM) software for design and detailing, and design-build collaboration made Nationals Park the fastest Major League ballpark construction project ever completed.

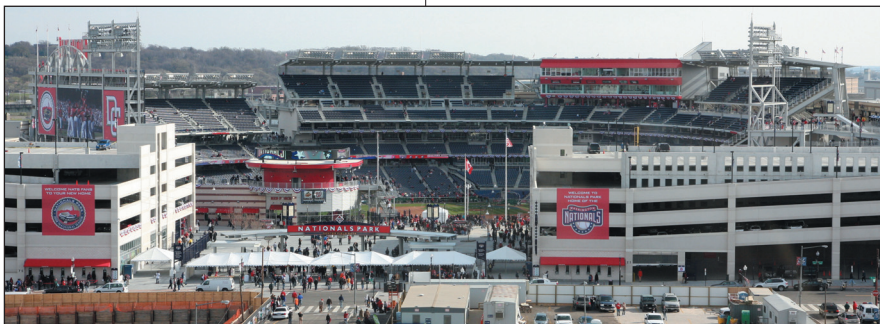
The ultra-fast-track schedule required the structural design of the stadium to be completed far in advance of the final

architectural design. Thus structural engineers, ReStI and Thornton Tomasetti (in a joint venture), played an enhanced role in the early stages of design.

Design Development

During the conceptual design phase, the design-build team determined that a predominantly steel superstructure was best suited for the ballpark. 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 real 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. By the time workers got to the main concourse level, fabricated steel would be ready and would quickly surpass concrete in 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 the areas comprised two different structural systems. Large structural bents, located 50ft on-centre 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 pre-cast seating and a combination of moment frames and braced frames in the



bays support the concourse levels and suites. The bents are then tied together along the circumference with four 'belt 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 analysed 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 upsized. Engineers used virtual work methods to determine which members had the greatest potential to reduce vibration, minimising the need for additional material, while optimising the response of the structure.

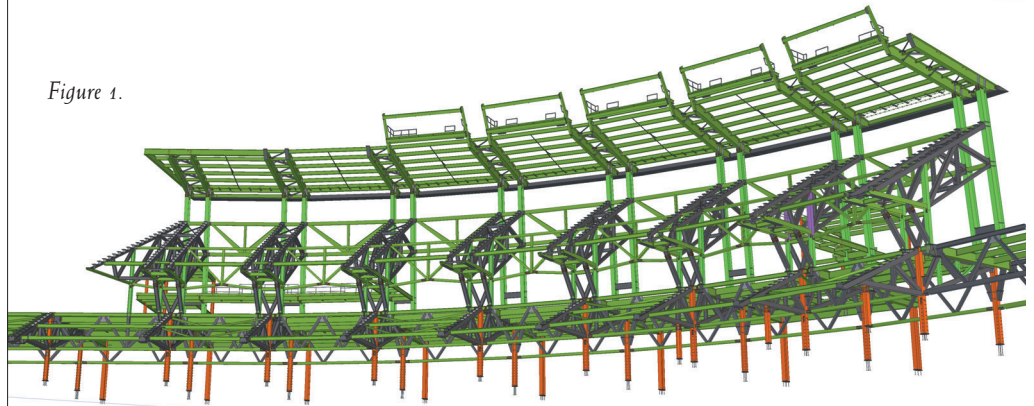
Design-Build Phase

As soon as the general contractor — a joint venture between Clark Construction, Hunt Construction Group and Smoot Construction — was selected by the owner, they began searching for a steel fabricator to perform a 'design-assist' role with the engineers and architects: HOK/Devroux & Purcell, PLLC. 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, Banker Steel Company LLC, 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 time-frame necessitated a unique design approach: the structural team produced ten consecutive design packages, one for each of the independent areas of the ballpark (see Figure 1 above right), which were used to place five separate mill orders. Based on early and extensive input from the steel erector, Bosworth Steel Erectors, Inc., these design packages were laid out in the order in which erection would proceed (clockwise from right field). The entire ballpark was designed, detailed, fabricated, and erected in this order.

Figure 1.



The structural design and coordination process for Nationals Park was streamlined by the use of Building Information Modelling (BIM).

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On Schedule & Within Budget

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, the general contractor, fabricator, detailer, steel erector and the structural pre-cast 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 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 pre-cast seating stadia units using Tekla Structures software. The models, which included basic geometry, 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 the procurement of

steel to begin before the designers had finalised details and connections on the final construction documents.

After being used to produce the mill order, the Building Information Models were transferred to the project's steel detailer, Mountain Enterprises, 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 visualise complex connections three-dimensionally and were revised on the spot as decisions were made.

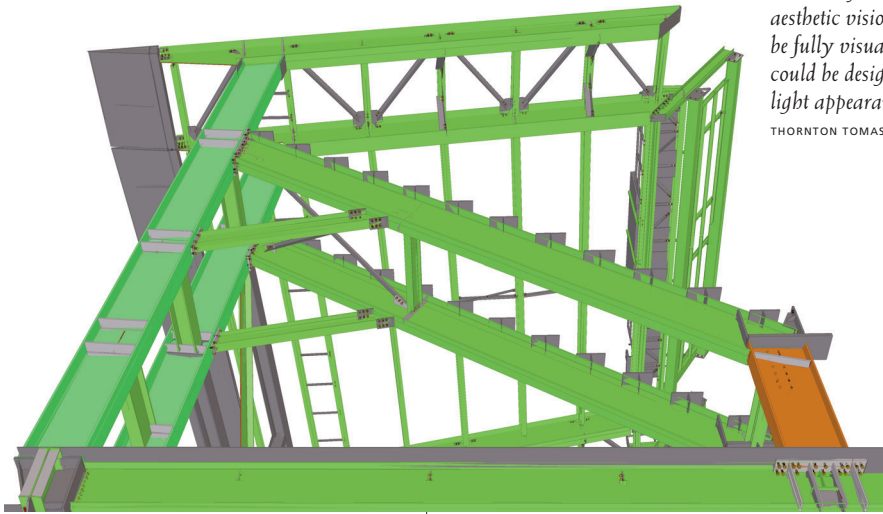
Building Information Modelling (BIM)

The use of BIM also helped the team fulfil the designers' aesthetic vision. Because the exposed trusses could be fully visualised 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 were 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. The Tekla models allowed the team to design elements for ease of transport as well.

Trusses and frames were pre-assembled 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

The use of BIM also helped the team fulfil the designers' aesthetic vision. Because the exposed trusses (see Figure 2) could be fully visualised early in the design process, the connections could be designed to satisfy the architects' desire to maintain a light appearance.

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weights and sizes of these prefabricated assemblies were within the shippable limits (see Figure 2, below). The maximum out-to-out dimensions of all elements, including connection plates, were established in the model prior to finalising the design, and well before shop drawings were generated.

Figure 2 — The 14 inch by 6 inch high typical upper seating bowl prefabricated shippable raker trusses, which were designed to maximise shop assembly and simplify erection.



The use of BIM provided a host of benefits to the project. 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, and it also provided additional advantages during construction.

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:

- ◆ **USE OF FOUR-DIMENSIONAL BIM OUTPUT TO PREVENT CRANE CONFLICTS:** 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 pre-cast elements. Several portions of the bowl levels required the interruption of steel placement to set pre-cast stadia units, with steel erection then continuing above. The fact that all lifts had to take place from the field side of the ballpark added to the complexity. The steel erector used two cranes simultaneously, a 300 tons Manitowoc 2250 crawler and a 330 tons Demag CC1800 crawler, to negotiate the large radius and far-reaching picks necessitated by other work going on in the playing field area.

- ◆ **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. The 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 Information Model to ensure proper fit-up and eliminate construction coordination issues in the field.

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Nationals Park was designed for sustainability. The ballpark secured LEED Silver Certification from the United States Green Building Council — the first professional sports facility in the U.S. to meet these criteria.

Nationals Park - Washington, D.C. Playing Ball at a Green Park

Nationals Park has made history as the first professional ballpark in the country to achieve LEED Silver Certification. The U.S. Green Building Council originally created its LEED rating system for heavily used buildings such as offices and schools - it wasn't intended for something as unique as a ballpark.

Located at the base of the Anacostia River, Nationals Park gives back to its beautiful surroundings by protecting the river, using energy-efficient and recycled materials and by providing easy access to public transportation. The result is a ballpark that is respectful of its environment and will stand the test of time.

- Lighting:** High efficiency field lighting for projected 2% energy savings
- Roof:** High efficiency roof materials minimize heat gains
- Energy Savings:** Optimized energy performance through exterior wall design and commissioning
- Interiors/Suites/Clubs:** Low emitting materials, carpet, paint and adhesives
- Green Roof:** 6,100 M² planting above concourse area will minimize heat gain
- Water Sampling:** Playing field sampling methods to test runoff quality
- Transportation:** Access to mass transportation, Metro Bus and Metrolink systems, parking for bikes
- Toilet Rooms:** Water conserving plumbing fixtures save a projected 1.6 million gallons of water per year
- Recycling:** Storage and recycling of glass, metal, plastic, cardboard and paper products
- Stormwater Management:** Enhanced facilities to screen organic debris (leaves, twigs, etc.) and recycled food waste into sanitary systems
- Underground:** in six locations throughout ballpark
- Site Remediation:** brownfield redevelopment site
- Up to 30% recycled content:** in construction materials used for ballpark

HOK

HOK/DEVROUAX & PURCELL, PLLC

NATIONALS PARK

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.

Success & Sustainability Assured

Nationals Park was designed for sustainability. The ballpark secured LEED Silver Certification from the United States Green Building Council — the first professional sports facility in the U.S. to meet these criteria. The structural designers contributed to the sustainability of the project by the

Design-Build Team

Architect: HOK/Devroux & Purcell, PLLC
Structural Engineer: ReStI/Thornton Tomasetti Joint Venture, PLLC

General Contractor: Clark/Hunt/Smoot, a Joint Venture

Steel Fabricator: Banker Steel Company LLC

Steel Detailer: Mountain Enterprises

Steel Erector: Bosworth Steel Erectors, Inc

Miscellaneous Steel Fabricator: American Iron Works

Structural Precast Subcontractor: Sidley Precast Group

Concrete Subcontractor: Clark Concrete Contractors LLC

use 100% recycled steel and fly ash and slag cement substitute products in the concrete. Efficient design helped to reduce the total volume of building materials used, while also minimizing costs, and reducing fabrication time.

During all aspects of design and construction, creating the best value was a primary concern. Because the budget was mandated by municipal legislation, the entire team made every effort to create the very best facility possible for the available funding. Schedule constraints meant that things had to be done right the first time around. Despite the speed of design and construction, the use of

BIM technology and the collaboration between the designers and builders eliminated many potential problems.

Major League Baseball's new US\$611 million Nationals Ballpark was made possible by the design-build team's ability to work together in innovative ways to deliver a great ballpark on time and on budget. 🌟

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Building Solutions

Thornton Tomasetti is the premier structural engineering firm for sports and entertainment facilities. We are committed to creating the best building solutions through technical ingenuity.

By integrating 3-D building information modeling into our design and analysis work, we improve efficiency and enhance team coordination. It's one way we meet our clients' needs and achieve excellence in every aspect of our work.

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Soldier Field, Chicago
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