Justin Maconochie Photography

Innovative Connections, Simple Solutions

Three unique glass-and-steel projects achieve success through highly engineered bolt systems—as well as through the universal principles of simplicity and constructability.

BY TERRY C. PETERSON

THE BENEFITS OF OPTIMIZING STEEL CONNECTIVITY WITHIN A PROJECT ARE ENDLESS. When innovative methods are introduced for joining steel framing members, the results can be phenomenal.

Increasingly, standard weld symbols on structural drawings are being replaced by creative details involving mechanical fasteners. Though bolted connections have been around for several years, exciting new ways of using them has led to a rapidly growing world of mechanical connectivity. As bolting technologies have advanced, they are becoming increasingly popular in solving the quality, aesthetic, time-line, and strength goals of the architect and engineer.

Following are a handful of projects illustrating the successful use of innovative bolting technologies and practices.

Careful Design for Steel Connections

As the last piece of prefinished steel was mechanically bolted into place atop the 208-ft-diameter, 50-ft-tall glazed dome at the Atlantic City Harrah's Resort and Casino's pool complex, Brad Swegles couldn't help but smile at its successful completion. Swegles is a project manager with Novum Structures, LLC, which designed and built the structure. The "hyper-track" time line allocated to design, engineer, fabricate, paint, and erect this 42,000-sq.-ft single-layer dome had seemed improbable when the contract was signed 10 months earlier.

"The great thing about these prefinished, bolted together systems is when the last piece goes in, you're done," says Swegles. "No nasty field painting."

The architectural firm of Friedmutter Group in Las Vegas set forth to accomplish the nearly mutually exclusive design objectives of high transparency combined with long-span. To make for an even more challenging project, environmental loading for Atlantic City's climate unites two of a structural engineer's worse enemies: hurricanes and snow. Had a conventional engineering approach been used in designing the dome, the combination of long-span and loading would have resulted in large, heavy mem-

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Atlantic City Harrah's Resort and Casino's pool complex (left) features a 208-ft-diameter, 50-ft-tall glazed dome framed with structural steel.

The 12-ft-wide, 200-ft-diameter glass walkway bridge at the General Motors Corporate Headquarters in Detroit, Mich. (right) is the largest glass walkway structure ever built in the United States, covering 17,580 sq. ft.

bers, thus compromising transparency. To solve the challenge, Novum engineering understood the need to think outside of the box.

In developing a structural grid geometry for the outer surface of any architectural form, Novum begins every project with an analysis of the cladding capabilities and related economics.

"While a geodesic grid surface is much more structurally efficient, it creates a need for triangular shaped glass panels, which cost about twice as much as rectangular glazing," explains Novum preconstruction engineer, Brian Vande Zande.

As a result, Scott Knoblock, project engineer at Novum, created a rectangular grid for the dome's outer surface while selecting a Novum system consisting of forged steel block nodes (joints) and rectangular strut elements. In order to generate a moment-resistant connection in a single layer, two concealed bolts are used to connect each strut end at the node. To generate enough stiffness to resist the loading and span challenges, eight lightweight triangular trusses framed out of the steel block node system were added down the slope of the dome, as well as three concentric circular rings. As it turns out, the triangular trusses provided a very logical raceway for the HVAC pipes in the humidity-challenged space.

"We really tried to minimize the visual impact of the stiffening trusses," adds Knoblock, "but it turned out to be a perfect conduit for the mechanical engineer in executing his work."

Yet another Novum system employing mechanical connections was used to affix the glazing directly to the rectangular-shaped top chord members of the steel block node system. Each glass panel was held by eight edge clamps (two per side) using Novum's edge clamp glazing system, which attached directly to the steel top chord and eliminated the need for costly aluminum framing mullions.

"Eliminating those aluminum framing mullions made the design a lot more transparent, which really pleased the architect," says Swegles.

Maintaining the high-speed time line of the project started with the engineering process. The behavior of pretested systems is modeled in Novum's proprietary software, allowing for rapid structural analysis in a highly automated format. In addition, some modular components can be machined rather quickly using instructions generated by the software's output. Accuracy of the fabrication is greatly enhanced by the controlled environment that exists within the plant. Since field attachment doesn't employ any welding, all parts can be prefinished, and on the Harrah's dome project, that consisted of a hot-dip galvanized undercoating followed by an electrostatically applied powder in accomplishing the colored top coat. The parts can be shipped in logically assembled, protected bundles sequenced for installation, in order to minimize shake out time.

"While the challenges of construction always create a few hiccups along the way, the speed and relative accuracy of these prefinished bolted systems not only allowed us to keep our time line, but also provided the architect with the beautiful, lightweight, transparent dome that he had envisioned," reflects Swegles.

General Motors Houses Construction Breakthrough

The use of prestressed bolts to develop a high-strength connection was a key

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component of the successful execution of a 12-ft-wide, 200-ft-diameter glass walkway bridge at the General Motors Corporate Headquarters in Detroit, Mich. The bridge represents the largest glass walkway structure ever built in the United States and covers 17,580 sq. ft. Complicating the construction challenge, the mammoth glass bridge, referred to as the "Circulation Ring," was installed at the third floor of the preexisting Renaissance Center. At the building's ground floor was a very high-traffic retail center with many popular shops and eateries. As a result, access was very limited through a small entrance at the third level of the parking garage, and there needed to be high sensitivity to retail customers below. The combination of these elements resulted in a logistical nightmare.

"A challenge we faced with the General Motors project was incorporating a new structure and building systems within an existing building while providing minimal disruption during an occupied renovation," says Anwar Hakim, associate director at Skidmore, Owings & Merrill LLP, the project's structural engineer. "We worked around this by breaking the overall large project into smaller projects so that these components could be phased and sequential according to the construction schedule."

Surfaces of the Circulation Ring consisted of all glass with curved guardrails on each side and an acid-etched, triple-laminated floor below to enhance privacy. Initially, the structure was envisioned to use field-welded truss elements that would attach to existing concrete columns on one side of the bridge and suspend off cables on the opposite side of the walkway surface. Unfortunately, the logistical challenge of bringing in curved trusses through a small opening, welding them up above occupied space, and field painting pushed the pricing received from local bidders about 50% above budget. With time running out and a serious budget problem on their hands, the project's general contractor, Turner Construction, turned to Novum.

After reviewing the site, the Novum preconstruction team quickly understood the logistical peril that troubled the previous bidders. Converse to the original design of bringing in long members and welding them, Novum chose a completely different tactic in using its factory-finished beam-to-beam system, which consists of tubular steel profiles that are bolted together axially. The engineer of record was initially resistant to this approach because of the huge static and dynamic forces that exist on bridges when loaded with pedestrians, but Novum explained their research and testing that showed that mechanical fasteners could do the job. The elimination of field welding, field painting, and the use of easier-to-handle steel tubes allowed Novum to assemble a design-build proposal that was not only within budget, but also provided an even more aesthetically pleasing look.

The Future of Steel Support Systems

Looking through structures, not at them, has become an ever-increasing architectural trend in the U.S.. Transparency is king, and anything that can be done to reduce the size of structural sections while minimizing the integration required with cladding systems has come to the forefront of engineering and construction challenges. In reducing the size of a structure, tension-only elements, such as rods and cables, can be introduced. They have a much smaller diameter and are correspondingly less visible. Applications of tension-only (e.g., cable nets) and tension-assisted (e.g., grid shells) systems are being commonly used across the country. However, reducing the complexity of integrating glazing systems with a steel supporting structure has been a bit slower moving, even though the corresponding pay-off in improved transparency is similar.

The conventional methodology of "integrating" glass to steel is to utilize two completely independent systems. Typically, a large aluminum mullion (e.g., 5 in. to 8 in. deep) is set on top of the steel. In turn, the mullion receives the glass panels. As a separate system, the glazing mullion can be "shimmed off" the steel in transforming the AISC tolerances of the erected iron to the finer accuracy required for a well-functioning glazing system. Improving the integration of the two systems requires improved erected tolerances to be provided by the supporting steel.

Unfortunately, one of the contributors to reduced tolerances of erected steel is field welding. Heat applied from welding, as well as the installation methodology, can limit how accurate the supporting members can be. One method to tighten tolerances has been the mechanical attachments used in the Novum systems. Tolerances can be significantly improved by machining parts in the factory and welding, when required, under plant-controlled conditions. Parts with higher accuracy are then shipped to the site and connected mechanically without inducing any heat that can warp members during the installation.

Installing a much more accurate steel supporting structure allows for true glazing integration and a greatly downsized and simplified transition from top of steel through top of glass. When executed appropriately, you can begin to view the top chord of the steel system as replacing the standard aluminum glazing mullion referenced above. In doing this, transparency is greatly enhanced, as you have reduced the thickness of the envelope by 5 in. to 8 in., or the thickness of the removed aluminum mullion. To substitute for that bulky mullion, there are a number of highly transparent ways to affix or "glaze in" the glass panels. Some systems included point-supported, edge-clamped, corner-clamped, and line-supported.

Innovative Steel System for Transparency

Line-supported glass is the most challenging system of all, as the top chord of the steel literally functions as the aluminum mullion that it replaces. A thin, EPDM rubber glazing strip is used atop the steel to receive the glass panel. Therefore, the steel has to be virtually perfect. That challenge was placed on Novum by Pelli Clarke Pelli Architects (New Haven, Conn.) when designing the rotunda element at the Overture Performing Arts Center in Madison, Wis., an octagonal structure in plan with a 45.2-ft corner-to-corner dimension and overall height of 25.3 ft.

"We basically had [Novum] sitting with us at the design table," says Robert Mangas of Potter Lawson Architects, Madison, Wis., who served as project architect. "They heard the aesthetic goals that were trying to be achieved and they offered solutions which was very valuable. They really were part of the design team."

Pelli Clark Pelli wanted an incredibly transparent dome to draw in natural light at a very key location of the beautiful facility.

"[The architects] really wanted this to be as slim as possible," says Lou Olson of J.H. Findorff & Sons, Inc, general contractor on the project. "The design team definitely challenged us to minimize the design. "

Initially, the structure was minimized by introducing tension rods along with tubular steel profiles. In regard to the glazing, PCP wanted a completely smooth outside glass surface that eliminated any point support or clamping mechanisms for glass attachment. To accommodate a glazing system that really challenges the supporting steel, Novum turned to its mechanically attached BB-system in order to deliver the appropriate tolerances.

"I think one of the challenges was to keep the profiles as small as possible," says Mangas. "They were looking for as much transparency as could possibly be achieved."

"One of the unique things about it is we had to hide all the fasteners," says Olson of using the BB-System in the design. "I've never before used a system like what was incorporated into this specific structure."

The final "tension-assisted" structure, equipped with a fully integrated glazing system, resulted in substantially smaller steel profiles while eliminating the aluminum mullions. The transparency was breathtaking. And the project was a huge success. MSC

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Why Use Mechanical Connections?

Reduced engineering time. Modeled behavior of pretested systems has resulted in proprietary design tools that reduce structural analysis time, and automates much of the complex shop and fabrication drawing work for both cladding and structure.

Faster installations. Bolted connections lend themselves to more consistent quality and faster assembly than field-welded solutions and the inherent testing.

Reduction of costly and messy field painting. Minimal field welding reduces damage and better allows for pre-applied factory finishing.

Higher-quality finishes. Structures can be factory-coated under tighter controls, yielding better quality and variety. In addition, an "undercoat" of hot-dip galvanized protection can be applied before the paint system to withstand more corrosive applications.

Lighter-weight structures. Hollow sections and joint design philosophies can reduce weight and cost. Lower weight reduces structural reactions to support boundaries, which can yield additional economies.

Increased accuracy from the shop. Tighter tolerances can be provided by shop fabricated and assembled components. Factory machined parts combined with attractive connectivity result in highly aesthetic structures.