THE NEWARK ARENA

Future Home of the New Jersey Devils

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Figure 1: Rendering of the Newark Arena-East view (Rendering by Morris Adjmi)

The Newark Arena, future home of the National Hockey League's New Jersey Devils, is a brand new $310 million dollar state-of-the-art sports and entertainment facility currently under construction in the city of Newark, NJ. With an area of 858,000 square feet and footprint dimensions of approximately 475 by 600 feet, the arena will include five levels, two of which will house luxury suites. The arena will have a 17,600-seat capacity and will offer a variety of amenities such as retail shops, theme restaurants and bunker suites. Two 120-foot tall cylindrical steel and glass structures will be prominently featured at the two main entries, and will straddle a giant video board display integral to the glass curtain wall façade of the main elevation. Two auxiliary structures, one a practice rink and the other a four-story office building, will complete the Arena complex. Construction of the arena began in early fall of 2005 and completion is scheduled for October of 2007. (*Figure 1*)

Site Description and Foundations

The urban site presented many challenges. On the west side of the site, neighboring structures included an historic church, a rail station structure and low rise buildings. At the three remaining sides of the site, roads underlain by a vital grid of underground utilities had to remain operable during construction.

The geotechnical investigation revealed that the site was on a landfill above abandoned rail tracks and miscellaneous substructures. The depth of this fill layer varied from 20 feet to 40 feet below grade. These findings had an immediate impact on the massing and foundations for the arena. Most conventional sports facilities of this type would have their main concourse at "street level", and would place the event level that houses the athlete facilities and locker rooms below grade. The prospect of a large excavation, within a tight urban site that would require the removal and disposal of large quantities of fill and other debris, was deemed non-economical and was quickly abandoned. The event level was therefore placed at "street level", which set the final height of the structure at approximately 156 feet.

Once this decision was made, a deep foundation system, such as driven piles, would have been the obvious choice. However, the engineers came up with an alternative system: a shallow foundation system to bear on dynamically compacted soils.

Dynamic Compaction is a process by which a heavy weight is dropped repeatedly from a specified height in controlled patterns in order to compact and densify the soil layers beneath the surface. Following precise specifications set by the geotechnical engineers and verified by an in-situ trial test, the existing soils were improved to an allowable bearing value of 3 tons/square foot. This process made the use of a shallow foundation system possible, and was significantly more economical than the pile option. To protect the nearby historic church and underground utility lines from vibrations caused by the compaction operation, isolation trenches up to 20 feet deep were excavated around the perimeter of the site. This approach was extremely successful, as no related damage was reported.

In order to control differential settlements between dissimilarly loaded columns and to evenly spread the pressures applied to the compacted soils, the foundation system incorporated concrete radial strip footings along the arena's bent lines and a continuous ring footing along the seating bowl's exterior columns. The footings ranged in thickness from 4 to 8 feet thick.

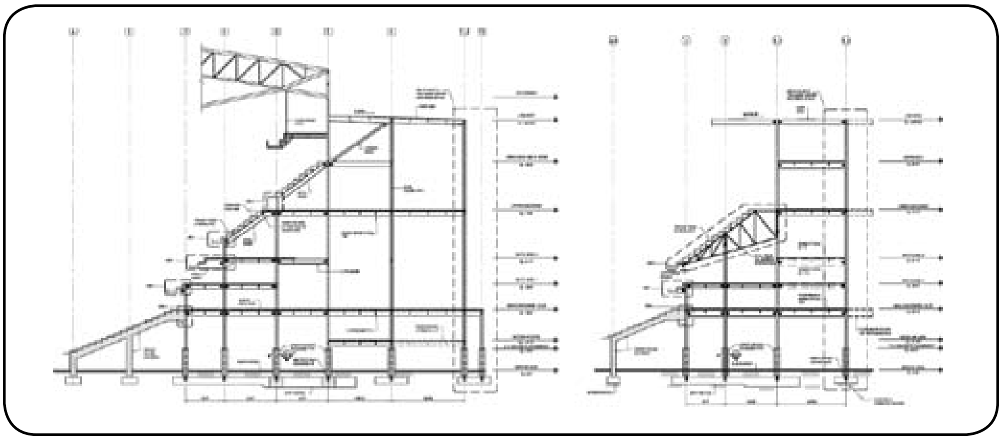

Figure 2: Typical Bent Sections

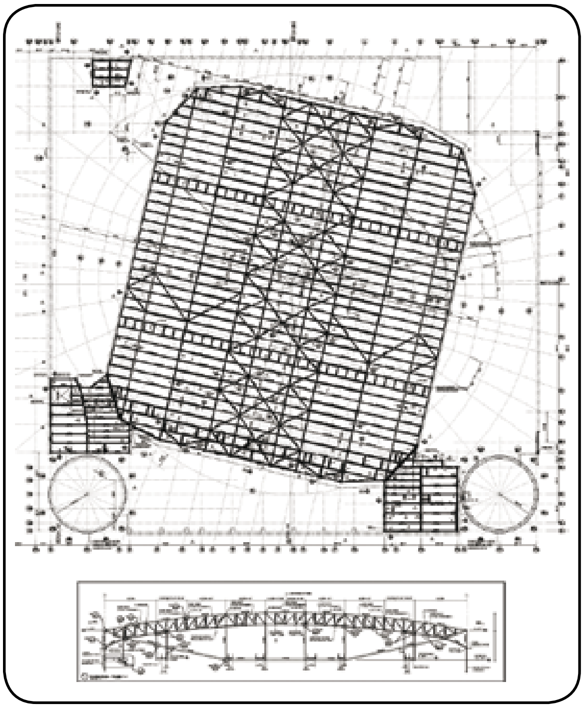

Figure 3: Roof Plan and Typical Truss Elevation

Materials Selection and Superstructure Description

The compressed construction schedule, in combination with existing local market conditions, was the driving force in choosing an all-steel structural scheme as the most suitable for the Newark Arena.

The overall structural concept for the facility was envisioned so that optimally designed structural elements could be integrated into a rapid, repetitive construction cycle by overlapping horizontal and vertical elements in a sequence that started with foundation elements and continued with frame elements, floor elements and seating elements. This sequence can start at any location in the facility, and can be repeated and overlapped progressively in either direction both horizontally and vertically. It enabled the early structural completion and enclosure of each progressing section, and thus allowed for the early start of follow up trades.

The main structural system consists of 40 frames (bents) that are spaced at approximately 30 to 36 feet on centers, along the circumference. The columns are arranged along a radial direction and are spaced from 18 to 40 feet on centers. They form the main gravity as well as the lateral load resistance system of the facility. The frames consist of wide flange rolled steel columns and girders and extend from the footings to the underside of the roof's long span trusses. (*Figure 2*) The floor system consists of a 6½-inch composite slab, reinforced to control shrinkage cracking and to support heavy concourse loads. Floor beams, varying in depth, are spaced approximately 8 feet on centers and span between radial bent girders. Steel columns are typically wide flange sections, of varying weight. The stadia units of the seating bowl are made of precast concrete double or triple units, with 6-inch thick risers and 4-inch thick treads, that span to the steel raker beams. These raker beams are part of the radial bents. The entire lower seating bowl was designed as precast concrete so that it could quickly be erected out of sequence after the roof erection.

Lateral Load Resisting System

Braced frames in each principal direction resist lateral wind and seismic loads from the high roof and transfer these loads down to the upper deck level. The sloped steel raker beams act as diagonal braces, delivering the loads from the upper deck down to the upper concourse. Moment frames were used below the upper concourse level to accommodate the architectural layouts and the desired unobstructed circulation. These frames proved to be a very efficient lateral system, due to small column spacings in the radial bent direction and deep girders that were required to support gravity loads and to control floor and cantilever seating vibrations. In the longitudinal direction, a continuous ring frame that wrapped around the entire arena was used from the lowest floor level to the upper deck floor level, beyond which the braced frames took over. The balanced stiffness nature of the moment frames at each bent, in combination with the longitudinal ring frame, was instrumental in resisting lateral loads, as well as thermal loads, efficiently. This efficient resistance to thermal loads allowed the building to be constructed without expansion joints, a huge benefit with regards to function and cost.

One challenge of the moment frame solution was the 28-foot tall first story. The stiffness of the steel columns alone was not enough to control drifts. To remedy this, cast in place concrete encasements, measuring 32 x 32 inches by 10 feet tall, were constructed around the steel columns to supplement the column stiffness. These encasements solved the drift issue and helped reduce the weights of the first story steel columns.

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Figure 4: Roof Truss Erection

Arena Roof

The dimensions of the arena's main roof are 366 by 426 feet. Several options, both economical and functional, were investigated to support the arena's long-span roof. Truss economy is measured by tonnage and quantity of shipped pieces. Therefore, maximizing the amount of shop-fabrication would be key to achieving this goal. The design produced an efficient tied-arch truss system that also provided for an open rigging and catwalk level area. The system consists of two queen posts at the third-points of the clear span, supporting a shallow 3-span truss. The queen posts are supported by tension ties that slope up at the ends to the truss bearings, thus supporting the majority of the gravity load in direct tension. The catwalk and rigging level is located at the tension tie elevation, resulting in an unobstructed layout. Engineers modeled the proposed roof system using three dimensional computer models that enabled the design team to visualize the functional advantages of this open system and thus, choose this system. (*Figure 3*)

The tied-arch truss is 48 feet deep at the center. All chord members are W14 wide flanges and have their webs horizontal in order to minimize the out-of-plane slenderness effects. The upper shallow truss is only 12 feet deep, which allowed it to be shop-fabricated and shipped in approximately 40-foot segments. (*Figure 4*)

This roof structural system concentrates the web members in the upper shop-fabricated segments, and combines the advantages of a deep truss with the shop-built economy of a shallow truss.

The shop-fabricated truss members are light because of the shallow depth and the 3-span condition of the trusses. Truss verticals consist of W14 members and diagonals consist of double angles members. The verticals were welded directly to the chords with full-depth partial-penetration welds. The diagonals were fillet welded to small gusset plates, which, in turn, were welded to the web of the chords and verticals. Further economy was realized in the chord splices of the shop-fabricated trusses. Since the top chord is in compression, its splice was designed with end plates. Since the bottom chord of this segment is near the neutral axis of the overall system, resulting in a small tension force, its splice was designed with flange plates.

Bridging trusses were provided between all primary trusses at approximately 40 feet on centers at the panels closest to the chord splices. They provide primary stability bracing for the trusses, distribute unbalanced loads between trusses and provide a level of redundancy for the roof system. Horizontal bracing in the plane of the truss top chord was used to resist diaphragm loads. This bracing was connected to the truss top chords at 40 feet on centers at the location of the bridging trusses. Roof purlins, typically 14 inches deep, were spaced at approximately 10 feet on centers at the truss panel points.

Roof lateral loads in the east-west direction are resisted by braced frames at the east end of each truss which deliver the load to the upper deck rakers. Each truss collects its tributary load and transfers it through its bearing into a braced frame. This reduces the demand on the diaphragm bracing in this direction. In the north-south direction, lateral loads are resisted by a horizontal diaphragm bracing system spanning between the ends of the trusses. These loads are then transferred through the ends of the trusses down to the braced frames on each side of the roof.

Figure 5: Aerial view of arena during construction

Fast Tracking and Steel Procurement

The tight construction schedule, made more difficult by problems with the timely acquisition and delivery of the construction site, forced the project into a fast track mode from the start. The foundation package was awarded before a construction manager was on board. Construction started in September of 2005. The steel fabricator/erector team was then brought on board in a design-assist role to help with the preparation and procurement of the steel mill order. Cives Steel Co. and their erector, Cornell & Co., joined the team before the completion of the design development phase. This decision was instrumental in meeting the tight schedule. The steel mill order packages were issued in sequences; the first mill order was placed approximately five months prior to the issuance of any construction documents. Thornton Tomasetti worked closely with the fabricator and erector in determining connection type preferences, sequences of mill orders, erection schemes, and other details to simplify, optimize and expedite the steel construction. Thornton Tomasetti also designed and documented the vast majority of the connections, a practice that is not common in the eastern part of the country. This helped tremendously with expediting the shop drawing approval process. (*Figure 5*).

Conclusion

Innovative engineering solutions, from the foundations, to the superstructure, to the roof, were the constant themes in the design of the Newark Arena. Engineers working closely with the rest of the design and construction team, not only delivered an efficient structural design for a world class sports facility, but did so while meeting an extremely aggressive schedule in a difficult urban environment.▪

Project Team Members

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