Steel Trees

By Bryan Tokarczyk, P.E., and Julie Matsumoto, P.E.

Boca Raton, Florida is a spectacular city. Located on the eastern coast of southern Florida, it's Mediterranean and Spanish themed architecture is home to a fortunate group.

Central to the community is the Boca Raton Resort and Club (BRRC). Established over 80 years ago by the visionary Addison Mizner, the 350-acre "pink resort" is a prominent landmark, with a hotel tower that is one of the tallest structures for miles in all directions. Originally named the Cloister Inn, the resort has grown and modernized over the years to maintain its status as a legendary icon of elegance.

Recently, the resort undertook an ambitious renovation of one of the original areas of the hotel – the Palm Court. An area central to morning, afternoon, and evening activities, the Palm Court was positioned as an important connection nexus for the resort. When we first arrived at the site, we were introduced to a complex system of original construction and modern-day improvements that formed a functional hybrid of primary and secondary support systems. To maintain resort functions, these systems could only sustain minimal down-time throughout the design, exploration, demolition, and construction of the planned renovation.

As we found it, the Palm Court was a covered space with a hung ceiling – yet, big changes were planned. The project's lead design architects from the Office of Thierry Despont wanted to introduce more light and create an enlarged destination space for the resort. The design team took that as an opportunity for some radical changes and creative ideas.

Design Challenges = Design Opportunities

The Palm Court is surrounded and accessible on three sides by functional, active resort spaces. The fourth side, the East face, is a few yards from the active vessel berths of Lake Boca Raton, which actually has one of the few Atlantic Ocean accesses along the Intercoastal Waterway. That East face of the Palm Court was an original exterior wall of the resort and would integrate into the renovation.

Along with the resort geometry, the site presented some additional challenges with a very high watertable and saturated, sandy soils (both notorious in the Intercoastal region). Many improvements which changed and adapted the resort over the years were expected. The team found the Palm Court was likely on its sixth or seventh major alteration since inception – many of which they were about to investigate, locate, and remove as part of the new, deeper foundation systems.

As the conceptual geometry developed, the design increasingly relied on an efficient, strong support structure with a light, flexible canopy system overhead. The design team considered many options for construction materials, from conventional steel, concrete, wood, stainless, and glass to more unconventional fabric, titanium, aluminum, FRP, and ETFE systems. Weights, strengths, deformation characteristics, as well as fire ratings, flexibility of construction, erection qualities, and longevity issues were all considered.

The overhead canopy design concepts all needed secondary systems for functionality; these likely would result in active support systems inside the main structure. Early input from specialized subconsultants established the design requirements for primary and secondary drainage, fire sprinklers, intumescent coating, and potential for air supply, lighting, sound systems, and feedback loops.

An obvious challenge was the proposed organic geometry of the support and canopy systems. Early guidance from the architect also qualified all project exposed surfaces to AISC AESS+ finish standards, as well as specific radiuses on materials and details. Combining both demanded adherence to extremely precise 3D models. These models would form the basis for structural design and ultimately input schemes for the fabrication cutting hardware.

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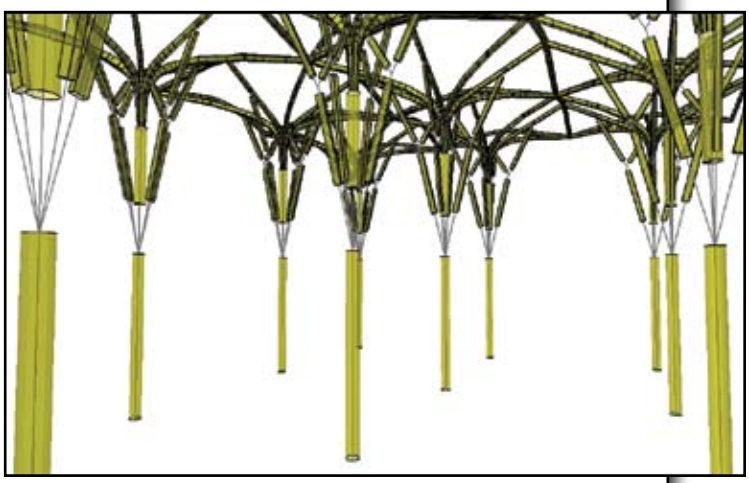
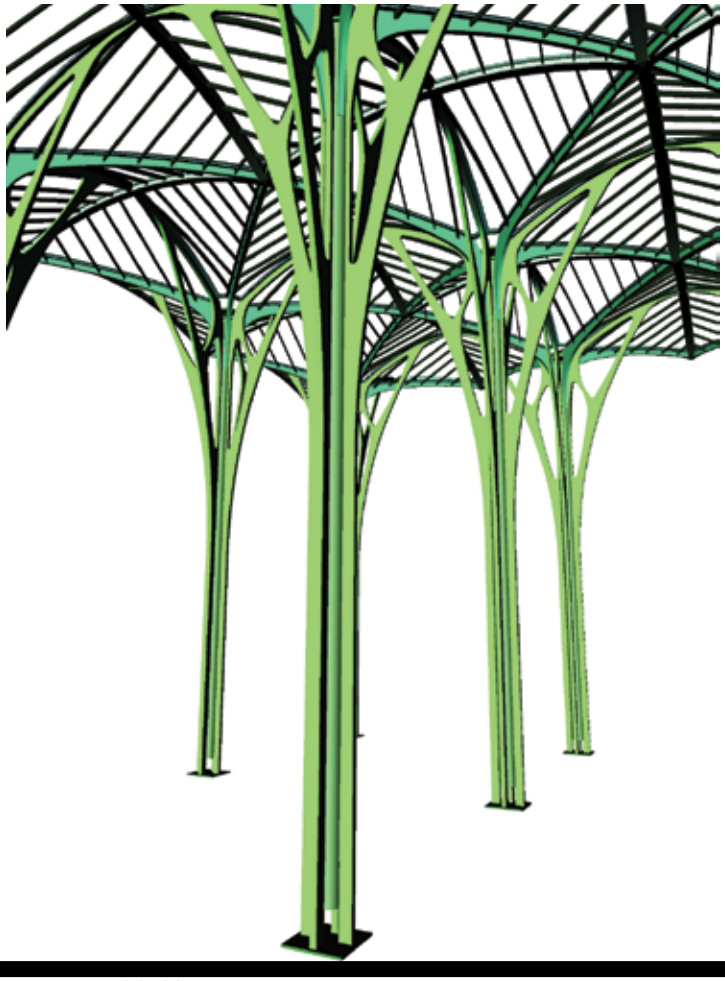


Analysis software for tree/forest.

Palm Court interior.



NURBS model of forest.

Concept, to Hand Sketches, to a Three-Dimensional Solid Model

A 3D solid model was first created during the introduction to the early canopy concept. A "Non-Uniform Rational B-Splines" (or NURBS) based solid model was used continuously throughout design, production, and fabrication. Literally, from a few concept ideas and sketches, a 3-space environment was used to store, manipulate, and create the overall design.

Initially, the NURBS model was used to export geometric information for structural design software and connection design. 2D drawings were produced from the model for consultant coordination, city review and project approval, early material take-offs, and to establish the Maximum Anticipated Construction Cost (MACC) for the project.

As refinement progressed, the NURBS model was expanded, developed, and layered with many variants, options, and ideas as other consultant information was added and coordinated. A precise model was created and used as the basis for the final structural design, connection design and coordination, conflict resolution for the internal system routing, and ultimately the direct plug-in for the Computer Numerical Control (CNC) fabrication hardware for support and canopy elements.

Ultimately, once the basic wire-frame and first round of design geometry alterations were reflected in the NURBS environment, design iterations began with the basic load cases. After initial sizing and design team coordination with geometry, more advanced loads were introduced, finalizing with some unique cases one might not expect in a more conventional structure.

A Multitude of Loads

Beginning with the code-based lateral and the gravity estimates, the loading conditions on the canopy concept quickly refined the project's material and geometric options – the trees began to take shape.

Moving forward in design with a steel support structure (the "tree"), the canopy system was still in refinement. A multitude of attributes were considered for the canopy selection. The aesthetics of light quality and spatial depth were discussed, as well as the structural characteristics of strength and weight for each variant. Additional options included variable opacity, availability of colors and patterning, and possibilities of designed heat gain. All options considered, the team was excited at the selection of an ethylene tetrafluoroethylene (or ETFE) foil membrane to serve as the canopy and the environmental barrier for the Palm Court.

Due to the complex surface area of the canopy, water ponding forces were determined at theoretical maximums for both single tree and forest (multiple tree connections in series) configurations. Loading conditions for primary and secondary drainage malfunctions were estimated for single and multiple tree configurations. Temperature loading was also considered for both tree configurations; this was particularly important due to the restrictions of loads imposed on the surrounding resort structure and the material stresses across inter- and intra-tree connections. Also, single and multiple tree configurations had unique loading considerations due to their variations in constraint boundary conditions and duration of loading.

Design Tweaks Answer to Loading Conditions

In response to some more refined loading cases and construction details, key areas were redesigned. Addressing refinements in water flow and loading, alterations to the tree drainage systems, the top flared portion, or "trumpet", and the main support branches were made. Additional ponding forces from ETFE creep factors also impacted the final branch design.

Tree connections to the ETFE foil system transferred diaphragm loads to the branches via upstand brackets, or "butterflies". The butterfly design was altered for the increased panel forces and the resultant foil diaphragm loads. Diaphragm loads across canopies also impacted intra- and inter-tree connections. Additionally, the connections between complete forest and the existing resort structure were also customized for slip and fixity issues resulting from temperature and lateral wind directly off the water.

As the design finished and the bid process began, the introduction of some value engineering options were considered from an interesting source.

Overseas Value Engineering

The selection of the steel fabricator for the trees led the team to Europe. The entire design package was then altered to adapt to metric dimensions, differences due to material thicknesses, material availability and grades, and differences in erection techniques.

Major advantages were realized from the selection of the German steel fabricator. A full-size, fully functional mock-up was constructed to test the fit-up and detailing from the fabricator. The mock-up would additionally serve as a permanent test-bed for the EFTE surfacing options and functional dry run for the foil pillow attachments. Secondary benefits from the mock-up fabrication led to a refinement of the fabrication process and staging. Starting with the first shipment, the entire upper section of each steel tree was assembled in a controlled environment, trued, numbered, and then staged for shipping as a customized unit.

Assembled, numbered, primed, and packed, the trees started their journey from Bremen, Germany to Miami, Florida.

A Forest is Planted

Arriving by sea, containers holding tree trunks, branches, and twigs cleared US customs and traveled up the coast into Lake Boca Raton, right to the back door of the resort – the same seawater that created some interesting foundation challenges now paid the project back as a creative solution to a tight working/staging environment.

The first three steel trees arrived together; they were assembled, lifted, and erected within days. Some lessons were learned, but largely the prototype efforts overseas allowed each tree to be recreated, connected, and adjusted with minimal effort and time.

The ETFE foil pillows arrived and installed quickly. Final connections were made for the system operation and, after initial pressure adjustments, the court was skinned and flashed to become a conditioned air enclosure.

With a fully operational resort, a very tight workspace, multiple trades requiring equipment and space, the forest was "planted", aligned, coated, painted, and covered – all while flooring, finishes, and resort function systems were installed.

See the Forest through the Trees

Opened to the resort patrons last Spring, the reception was extraordinary – people entered the space and immediately warmed to the surroundings, the views, and the light pouring in from above. It was a time that the design, construction, and management teams all looked forward to – it didn't disappoint.

The Palm Court is literally a destination within a destination, an excellent example of organic design, and a successful marriage of both form and function.▪

Project Team

Owner: Blackstone/Boca Raton Resort and Club
Design Architect: the Office of Thierry W Despont, LTD
Local Architect: Garcia Stromberg
Structural Engineer: KPFF Consuting Engineers
Local Engineer: Bliss and Nyitray
Local MEP: KAMM
Steel Fabricator: Stahlbau Lamparter
ETFE Fabricator: Foiltec NA

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