The Grandstand's polytetrafluoroethylene (PTFE) fabric facade is composed of 486 panels over 26,000 square feet that were designed with computational solver software to streamline design and constructability.

USTA Grandstand

Part of a ten-year redesign of the entire Billie Jean King National Tennis Center campus, a new, relocated Grandstand plays with translucency with an innovative canopy of 486 PTFE-covered panels.

FLUSHING MEADOWS-CORONA PARK HAS come a long way from being the valley of smokestack deposits that F. Scott Fitzgerald described so evocatively in *The Great Gatsby*—as a "farm where ashes grow like wheat into ridges and hills and grotesque gardens." Before it became public open space in 1967, the site hosted two World's Fairs, a nascent United Nations, and highway infrastructure that remains vital to commuters today. The park itself took a big step forward in 1978, when the United States Tennis Association moved the US Open into an adapted World's Fair facility there. The transformation of Flushing Meadows from coal dust into community diamond continues to this day, with USTA's 2016 opening of a retractable roof over Arthur Ashe Stadium (see p. 2) and a new 8,125-seat Grandstand Stadium.

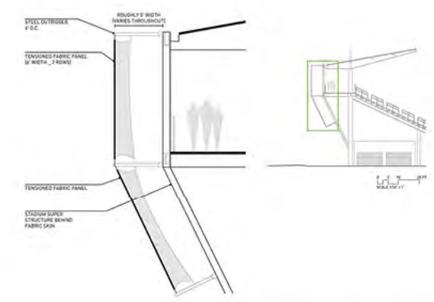
Grandstand is designed by Rossetti, and it forms the southwest anchor of the Detroit firm's own master plan for the Billie Jean King National Tennis Center. The multi-year scheme aims to remake this part of Flushing Meadows into an Olympic village–style campus, capable of accommodating an additional 10,000 visitors per day.

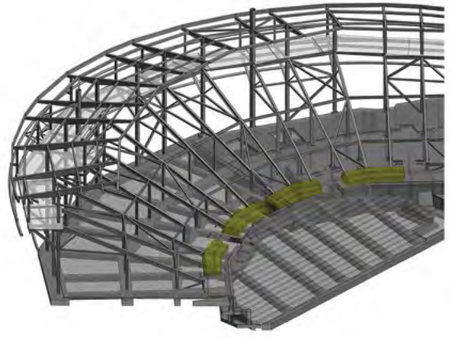
Grandstand's cornerstone location promised to unknot some existing pedestrian traffic and increase the overall capacity of the Billie Jean campus, explains Rossetti associate Matt Taylor. But Taylor, who served as design lead for Grandstand, also observes that siting placed higher aesthetic standards on the new 125,000-square-foot building. "We could have made Grandstand a much simpler design, but the site's relationship to surviving World's Fair buildings required sensitivity to that ambition," Taylor says. "We also had to take into account the orientation to campus, and make the stadium feel as open as possible to the northeast."

These considerations produced an oblong circle in plan, sectioned into 16 sides. In profile, Grandstand embodies a sloped bowl that reaches its peak in the southwest and tapers downward toward the Billie Jean campus to the northeast. Working in tandem, plan and section also maximize shade for eventgoers. A set of grand staircases spirits attendees to an upper walkway that provides vistas of the site under the cover of a cantilevered 23,000-square-foot polytetrafluoroethylene-coated (PTFE) fiberglass canopy. Inside the facility, the bowl is recessed into the earth to seat spectators closer to the play.

The Grandstand design also features a facade of 26,000 square feet of PTFE fabric divided into 486 panels fastened to an outward-facing cable structure. The design reinforces the curvilinearity of the stadium's footprint and lends a sense of movement to the volume. A sense of heritage, as well: Each panel resembles the motion of a tennis serve, or the fluttering of a park's tree canopy.

Just as local history informed Rossetti's design of Grandstand, so the site's past life as an ash dump compelled partner engineers at WSP USA to devise an innovative engineering solution for the foundation. Company vice president Craig Tracy explains, "Normally, you might break a stadium of this size into two or four pieces to allow it to expand and contract with the seasons and prevent settlement from building up stresses inside the structure. Here we just have terrible soil, and because budget eliminated pile foundations, we created a much more economical net of shallow footings." Set just below the frost line, the net's grade beams vary between 3 to 8 feet in width and measure approximately 2 feet in thickness. Even then, Tracy says, Grandstand faced significant movement due to soil settlement. "Every subsequent decision would have to make Grandstand lightweight and flexible."





The superstructure has two parts, consequently. A lower bowl interconnected with the foundation is reinforced cast-in-place concrete that can absorb the gentle movements of settlement. The upper bowl eschews traditional precast concrete seating risers for a Sandwich Plate System divided into 14 wedge-shaped structures linked by custom expansion joints that can withstand movement. Each wedge is supported by a row of 16x16-inch HSS columns located on Grandstand's perimeter. To each column, a W21 raker beam is field welded. These raker beams support the SPS stadia and bolt to the foundations via massive concrete abutments that project above grade and form the first two rows of elevated seating. The expansion joints required precise location and fabrication of slotted holes and seated connections to accommodate the required axial releases, with some drilling performed on site.

Raker beams both carry vertical loads and act as concentric braces for lateral stability. This multitasking allowed WSP to simplify the column base supports, which did not require moment connections. Circumferential lateral stability is delivered by the concentric braced frames, with additional stability provided by framing for the pedestrian walkway and a box-girder system that forms the canopy.

All photos: Rafael Gamo; section drawings: Rossetti; raker beam diagrams: WSP

This page To the casual viewer, the building assumes a uniform single-radius arc, but its shape is a hexadecagon (16-sided form).
Facing page from top Due to the non-linear behavior of the tensile membrane structures, Rossetti used special software to determine the forces delivered to the structure. A section detail of the grandstand canopy. Raker beams support the SPS stadia and bolt to the foundations via massive concrete abutments (highlighted) that project above grade and form the first two rows of elevated seating.

Many nodes where the bracing members meet feature exposed pin connections, which Tracy again deems out of the ordinary: "In a typical building, you can bolt everything and cover it up. But here, structure is exposed, and we need it to be flexible. Twenty bolts can be replaced by just one pin that also allows the joint to change over time."

The project team further leveraged Grandstand's HSS perimeter columns to hang the fabric facade. Three tubular ring beams support this membrane; they join to all 14 wedges via a lattice of struts and 4-inch-diameter pipes.

Curved armatures challenged the project team to modularize the PTFE panels, so that they could be fabricated efficiently while maintaining proper tension on each membrane. "When you zoom into a spline, it has an infinite number of radii," explains Rossetti technical designer Pierre Roberson, "so every instance along a spline curve has a different radius, which then had to be translated into something buildable." Rossetti divided the spline curve into 40 unique segments in Rhino, and used Grasshopper's Galapogos platform to test possible radii for the optimal radius that could be applied to all the segments.

"We used an evolutionary solver, to orient the panels and attach to the ring beams," Roberson says of the computational approach.

Taylor says that employing parametric design on Grandstand's facade initially seemed like a leap of faith, commenting that the result "offered us a lot of confidence to challenge ourselves to do things that are quite complex." Considering that Rossetti singlehandedly changed the way sports venues are designed with its introduction of luxury suites in the 1990s, Grandstand's combination of efficiency and innovation may get the industry ready for another tectonic shift.

Above The new stadium helps accommodate an increasing number of visitors to the US Open, which draws more than 700,000 fans to Flushing, Queens, each year.
Facing The Grandstand's oblong, sloping bowl gently bows to provide a vantage of the USTA campus and ensures that no two pieces of the structure are the same and no two angles are repeated.

USTA GRANDSTAND

Location: **USTA Billie Jean King National Tennis Center in Flushing Meadow-Corona Park, Queens, NY**
Owner: **United States Tennis Association**, *White Plains, NY*
Architect: **Rossetti Architects**, *Detroit, MI*
Structural Engineer: **WSP USA**, *New York, NY*
Membrane and Mesh Facade Fabricator and Erector: **Birdair, Inc.**, *Amherst, NY*
Structural Steel Erector: **Northeast Structural Steel, Inc.**, *Yonkers, NY*