New "playbook" makes some tolerances uncommonly tight

—by Don Talend

Opened in September in downtown Indianapolis, Lucas Oil Stadium, the new home of the NFL Colts, is taking sports spectators and the Circle City's entertainment and convention business to new levels. With a capacity of 63,000 - 70,000 seats, and 137 Super Suites, each with its own 50-inch plasma TV and 24-36 seats with individual screens, Lucas Oil can accommodate the NCAA Final Four, the Super Bowl, concerts, conventions, and various other events

The stadium is part of the Indiana Stadium and Convention Building Authority owned by a group of Indiana businessmen and constructed by Hunt Construction Group, Inc., of Indianapolis. The architect, HKS, also designed Major League Baseball's Milwaukee Brewers' Miller Park and the Cowboys' Stadium in Dallas scheduled to be completed in August 2009.

Work on the Lucas Oil Stadium broke ground in September 2005 and by mid-August of this year, the stadium was ready for grand opening—just in time for the Colts' pre-season games and their nationally televised regular season opener against the Chicago Bears on September 7. Without doubt, Lucas Oil Stadium will boost business as well as the Colts' bottom line through new revenue streams.

The stadium is built on 1.8 million square feet of land of which 183,000 square feet are exhibit and meeting space. Flexible design rather than huge size distinguish the facility which boasts a state-of-the-art retractable roof, a large high-definition scoreboard, as well as other high-tech amenities to support upscale club seating and an overflow seating areas in times of high usage. The Colts' "new digs" are a civil engineering marvel, thoughtfully planned and executed.

Unique roof design

Lucas Oil is the first to use a SuperFrame Structural System with a moving, two-panel roof design. The Milwaukee Brewers' Miller Park is topped off with a retractable roof, and the new Dallas Cowboys stadium scheduled to open next year in suburban Arlington, Texas, will have one as well.

Gabled and peaked down the middle, when open the Lucas Oil roof provides 176,400 square feet of space—more than four acres; it opens by sliding its 600 x 175 ft panels on cable rails. Each panel has five upper transporters riding on two 36-inch-in-diameter steel wheels and supporting two lines of retractable roof trusses.

The three interior upper transporters are mounted with four cable drum drives and the two exterior transporters are mounted with two cable drum drives. Each cable drum drive is powered by four 7.5-horsepower AC motors, and each winds a 1½-inch-in-diameter cable that is anchored to the structure near the peak of the transverse trusses. The cable drum drives let out cable to slide the roof panels open and wind it up to close the roof.

This page: USI Consultants' Michel Baden [left] and Jason Deiwert [right]. Page 22: Deiwert and Bader in second and third top image.

Opening and closing the roof takes nine to 11 minutes. Each side of the roof performs 10 critical lifts of substantial weight. The roof panels weigh 2,900,000 pounds—the heaviest retractable roof built so far.

The roof support structure is also unique. A pair of 760-foot-long steel SuperFrames were constructed roughly along the edge of the playing area. They are made of traditional rolled steel shapes laced together into box elements and located parallel to each other about 300 feet apart. The engineered box elements vary the height of the lower chord, changing the frame depth from 58 feet at mid-span to 84 feet deep at the column support so as not to obstruct the view from any seat. The width of the SuperFrame column varies from 26.6 feet at the support to 61 feet 2 inches at the truss. The column is 217 feet tall and is supported at street level by 35-foot-high concrete shear walls.

The SuperFrames support five peaked, three-span transverse trusses spaced 144 feet apart. The trusses are 12 feet wide and vary in depth from 40 feet at the midfield apex to 30 feet at the SuperFrame. The outboard sections of the transverse trusses span 170 feet between the SuperFrames and perimeter columns, while the peaked interior section spans 300 feet between the SuperFrames.

Each transverse truss holds a steel rail box girder, and the girders each support a 175-pound-per-yard crane rail along which the wheels of the retractable roof panels move. Four bar linkages allow for movement between the roof trusses, the rails, and transverse trusses, allowing for normal structural deflections, differential thermal expansion and construction tolerance variations.

The design of Lucas Oil's roof is fundamentally different from those of both Miller Park and Cowboys Stadium. "Miller Park has a radial shape to match the shape of the baseball diamond," said Hutchings. "Here, we wanted the view on axis with the downtown and Monument Circle. The building is skewed on site, and the [north end] window opens so that the fans and the media and broadcast television can have a great view of downtown Indianapolis during the game. The Lucas Oil roof is the only one in the world that opens up down the centerline of the field toward the sidelines." In contrast, the Cowboys' Stadium roof opens end zone to end zone.

Tolerances for the Lucas Oil roof were extremely tight, given that the stadium was to host both open-air football and indoor events such as basketball. The surveying team, USI Consultants of Indianapolis, Indiana, thus had to bring its "A" game to the project and rely on Topcon's GTS-233W total station.

Surveying challenges

USI Consultants have provided surveying and engineering services for a number of road and bridge projects since its founding in 1976. Lucas Oil Stadium, particularly the retractable roof, presented new challenges.

Imagine a day in mid-July, when it's cooler in the morning and hot in the afternoon, and steel can move as much as half an inch due to heat expansion. The tolerances on the retractable roof structure had to be within an eighth of an inch. "This was about as close to "zero tolerance" as realistically possible," said USI Consultants' Tim Brown.

When surveying the retractable roof, Jason Deiwert, crew chief, carried a reflector up a stairwell to the top level at the southwest end of the stadium, and Michael Baden, instrument operator, carried a Topcon GTS-233W total

station. Then, having moved to opposite sides of the transverse trusses via catwalks, the crew ran a control line across each transverse truss to check the alignment of the panels at each truss. Because the roof operates with multiple motors and they all have to be running at the same speed, USI Consultants put a line across each truss so that the panels could be monitored during movement. The surveyors also aligned the railing system.

"Not even close," Deiwert says with a laugh when asked if he had ever done so much to get into position. "We've never had to work at an elevation of 270-feet, that's for sure," he continued. Using a control traverse at the base of the structure, the crew set the alignment on the ground. After verification, the alignment was transferred at both ends of the roof to the higher levels. Finally, the crew moved their instruments to the very top and verified the alignment from above.

The GTS-233W total station—which USI Consultants purchased from Positioning Solutions Company's Indianapolis branch office in 2004—is easy to set up for leveling. The wireless Bluetooth capability of the instrument in particular boosted productivity on this project.

"We set it up, turned the collector on without plugging any wires in, and started the surveying," said Brown. "The Bluetooth range is about 25 feet, which makes it possible to move the instrument about without losing connection. If one has to go back to the truck to read the plans, one can take the controller along to do additional computations. There are no cables to lose, or trip over, or break."

Inside the stadium, USI Consultants surveyed concrete walls and floors as each of the seven levels were constructed. The plumbness of the south walls was checked before installing the large glass panels.

Brown looks out onto the playing field where workers were stitching yard markers and end-zone lettering onto the artificial FieldTurf. Along the field, his crew were setting control lines for luxury suites and a press box for drywall and plumbing contractors; the field and goalposts were surveyed too. Control points were set in front of the base of the steel SuperFrames at the north end of the stadium; corresponding control points were set at the other end of the stadium and just south of the 50-yard line in the middle of the playing field.

Final touches

By mid-July 2008, USI Consultants" work on Lucas Oil was nearly complete. The last task was to survey the position of concrete planter walls in front of the stadium's north entrance.

Bader sets up the total station on the north side of the street and Deiwert levels the reflector near the north façade of the ballpark. Holding a log book listing the coordinates for one of the planters, Bader peers through the lens on the GTS-233W and verifies with Deiwert via walkie-talkie that they are plotting out the same coordinate. Bader instructs Deiwert to move forward, back, or to the side.

When Deiwert's position is on target, the total station sends a laser beam that bounces off of the reflector and records distance by measuring the amount of time it took for the laser beam to bounce back.

The horizontal and vertical angles between the total station and reflector are also measured and the location data

Lucas Oil Stadium Facts

- Seating: 63,000 for football; 70,000-plus for other events such as basketball and concerts
- Cost: $715.4 million - $719.6 million (est.)
- Seven levels (vs. three in RCA Dome)
- 1.8 million square feet
- 183,000 square feet of exhibit space
- 137 luxury suites (vs. 104 in RCA Dome)
- Retractable roof opening: 176,400 square feet (more than four acres)
- Time to open and close roof: nine to 11 minutes
- Total roof weight: 14,000 tons-plus
- 130,000 cubic yards of cast-in-place concrete
- 16,000 tons of steel
- 700 pieces of structural precast concrete
- 1,440 pieces of architectural precast
- 9,100 pieces of exterior glass
- Operational large north window (six panels, 88 feet tall and 244 feet wide) providing view of downtown
- Public concourses minimum 30 feet wide, up to 80 feet wide
- 148 concessions stands (vs. 80 in RCA Dome)
- 14 escalators and 11 passenger elevators (vs. no escalators in RCA Dome and six elevators)
- Two slightly graded pedestrian ramps inside the building giving access to each level of the stadium (vs. none in RCA Dome)
- No bleacher seats (vs. all bleacher seating in RCA Dome upper deck)

are saved. Later, the data are downloaded into a computer equipped with AutoCAD software to produce a drawing of the planter and produce relative measurement data from other structures on the site for the contractor to set form work for the planters and pour concrete in it.

Thanks to meticulous, accurate surveying and data processing at real time, the stadium boasts several spectacular architectural features—an unusual, retractable roof, a huge, movable window wall system providing spectacular views of downtown Indianapolis, and architecture inspired by the building designs of old Indianapolis.

"We liked the laced steel pattern that we saw on older structures in Indianapolis and decided to use it for the SuperFrames," said Hutchins. The exterior of Lucas Oil, an amalgam of steel and glass skylights, reminds one of an old warehouse and locals will no doubt see some resemblance with the nearby Butler University's Hinkle Fieldhouse.

The Colts' "new digs" are an architectural and civil engineering marvel, thoughtfully planned and executed. Both the Colts and their fans are very happy with their new stadium. Surveyors have done what they always do—deliver accurate, high-quality work.

Don Talend of Write Results, West Dundee, Ill., is a publicity and communications project manager specializing in construction technology and innovation. All images courtesy of Topcon, except opening night image, which is courtesy of http://www.lucasoilstadium.com, and third image on p. 22, which is courtesy of USI Consultants.