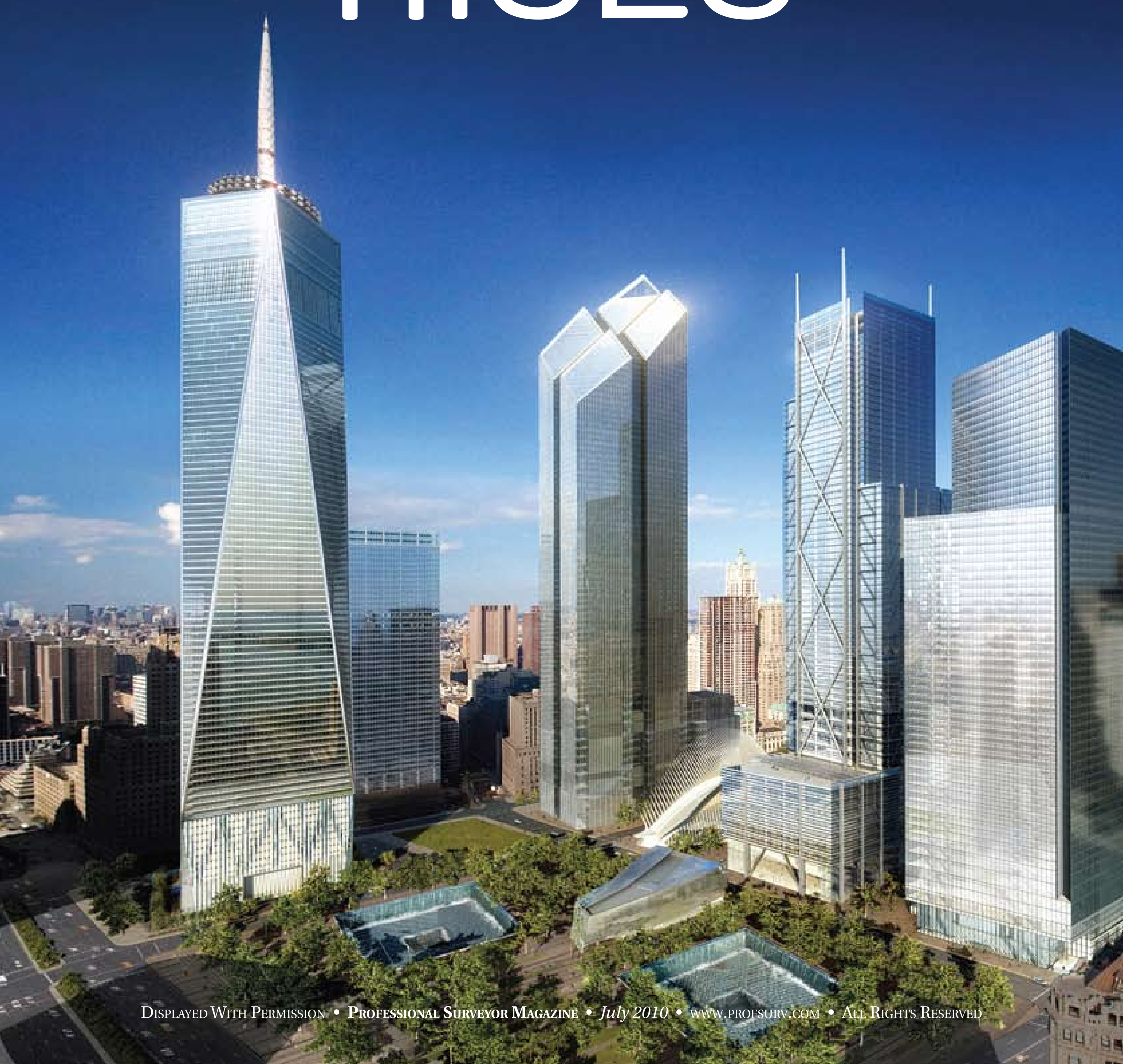
PROFESSIONAL

SURVEYOR *Magazine*

July 2010 Vol. 30 No. 7

FLATDOG MEDIA

ONE WORLD TRADE CENTER RISES



Clockwise from left:
The new conceptual downtown skyline with the One World Trade Center at left and the September 11 memorial in foreground —*courtesy dbox, Silverstein Properties, Inc.*

Conceptual site plan showing the World Trade Center site redevelopment—*courtesy Foster & Partners, Silverstein Properties, Inc.*

Perry Pettinato of Garden State Engineering Surveying & Planning is one of dozens of surveyors working on the World Trade Center project.

An innovative survey system is at the core of reconstruction in New York City.

By James Fleming, LS

In lower Manhattan, adjacent to the site of the original World Trade Center North Tower, the steel framework of the new One World Trade Center now rises more than 20 stories above the intersection of West and Vesey Streets. When ready for occupancy in 2013, the building, planned to tower a symbolic 1,776 feet above the site of the September 11 attacks, will redefine the iconic New York City skyline as the centerpiece of the area's redevelopment.

Designed by architect David Childs of Skidmore, Owings & Merrill, LLP, One World Trade Center when completed will consist of a 60-foot-high public lobby, 2.6 million square feet of office space on 69 office floors, an observation deck 1,265 feet above ground, and a glass parapet that marks 1,362 feet and 1,368 feet, the heights of the original Twin Towers.

When the workers from DCM Erectors, Inc. prepare to set columns for the next floor, a unique system is being used for the first time in the United States. The Leica Geosystems' Core Wall Survey Control System was initially developed for the construction of the Burj Khalifa skyscraper in Dubai, United Arab Emirates (at 2,717 feet, it's the tallest man-made structure ever built) by Joel van Cranenbroeck, business development director at Leica Geosystems, and Douglas Hayes, chief surveyor of the Burj Dubai Tower. It was used subsequently during the construction of the Al Hamra Tower in Kuwait City and The Landmark Tower in Abu Dhabi, United Arab Emirates.

High-rise buildings are subject to tilting, caused by environmental factors such as wind pressure and the thermal effects caused by exposure to sunlight. In addition, during construction factors such as crane loads will cause the building to move from the theoretical vertical axis, and subsequent resonance will cause it to oscillate about this offset position. This movement of the structure creates several

problems for correct set out of control; at any given time the surveyor needs to know exactly how much the building is offset from its design position to determine the precise position at his or her instrument setup.

The Core Wall System uses a network of conventional on-site GPS observations, remote reference stations, and precision inclinometers. Surveyors are, for the first time, generating reliable coordinates for construction layout where they are needed—at the top of the steel superstructure—rather than having to repeatedly transfer them from control on the ground.

Prior to the start of the project, DCM invited Leica to demonstrate their fieldPro stakeout software, which performs construction stakeout directly from CAD files for use in the assembly of the intricate steel parts of the project. It was at this meeting that Larry Davis, president of DCM, first inquired about the system in place at the Dubai project and its possible use to ensure that the One World Trade Center tower was plumb during construction.

Over the next four or five months a series of meetings were held among Leica, DCM, the Port Authority of New York & New Jersey (the owner of the World Trade Center site, formerly a terminal of the Hudson and Manhattan Railroad), Tishman Construction (the construction manager for the project), and others. Gerard Lamarre, product/project manager, and Gerard Manley, vice president of engineer solutions for Leica Geosystems, began work on the DCM account in February 2009, and all the agreements were signed in September 2009. Since then they've been supplying the hardware, software, and training. "We have to pay our respects to DCM because

they were willing to push the envelope and try something new, as we have to pay our respects to the Port Authority. It took both of these guys to make it happen," says Lamarre.

Establishing Ground Control

The first step in the process is the establishment of a network of ground control around the site. Surveyors, under the direction of Scott Zelenak, the chief of parties World Trade Center construction for the Port Authority, set a series of control stations at every intersection in the project area. In addition, the Port Authority surveyors mounted prisms on adjacent buildings that can be sighted directly from inside the project's perimeter fencing. Only one adjacent building owner who was approached refused to allow the prisms to be mounted on his property. "It's surprising," said Zelenak, "when you show up with a handful of guys, drills, extension cords, etc. and say 'We're from the Port Authority and need to get out on your roof' how many people just say okay."

Left to right:
Using equipment from different manufacturers makes keeping track of prism constants on the permanently mounted control difficult. Pictured is Tim Ptak, Layout Inc. (foreground) and Shaun McQuilken, Hirani Engineering & Land Surveying.

Contruction is complicated by the fact that there is a fully operating PATH rail station in the middle of the site.

Each of the individual construction projects on the 18-acre site, including 1WTC, has its own project datum based on the building control lines. These all have a different correlation to the overall site datum, the New York State Plane Coordinate System, Long Island Zone. With multiple companies providing surveying on the site, the Port Authority surveyors at times have to play the role of "datum cop."

The GNSS component of the system is twofold: "active GPS," which is Leica's terminology for the receivers placed on the actual building under construction, and Continuously Operating Reference Stations (CORS) located off site. A minimum of three active GPS antennas are set on the top deck of the structure. Each of the antennas has a 360° prism mounted below it, and the antennae height is corrected to the center of the prism. All the satellite information is fed into onsite computers using Leica GNSS Spider, a software suite designed for operating and controlling single reference stations or networks of stations.

"We're using feed from one CORS station along with the two reference stations installed on Port Authority property, so there is a live feed coming into the spider software system over the internet," said Lamarre. "Instead of getting RTK regular broadcast corrections, we get the raw data so that the onsite computers can reconstruct the RINEX files. And then the three receivers on the top feed their position by modem to the same system. So we have six data feeds, three essentially CORS and three onsite active control points, and every hour the Spider software reports the positions. We have an hourly fix and a 24-hour fix that publish coordinates. So when the surveyor at the top logs into the computer he sees the latest position. It's not RTK. Spider creates all the RINEX files, and every hour we post-process, and that's how we get a good coordinate we can use for plumbing steel. The steel requires between 1/16 and 1/8 of an inch tolerances, and with the GPS after one hour of observations we're within that range."

Solving Unique Problems

Even though the site is surprisingly open, there are unique problems involved in using a GNSS system in an urban environment. Prior to the start of construction, obstruction surveys were performed to map the adjoining buildings and other obstructions that may interfere with the line-of-sight satellite signals. This information is used during processing to explain signal losses and multipath.

Lamarre explains, "We added to the system obstruction survey planning so the guys know the time of day they can rely on the positions, and we added some QA/QC information so when they log into the system they see they have a good fix and I can use the coordinates. Sometimes at the lower elevations they can't use the coordinates from the GPS, but as we start going up the problem of multipath will disappear." When the building is still at its lower levels, the GNSS component can be augmented by using traditional resection, using the control established by the Port Authority.

As the building rises and the external tilt effects come into play, precise inclinometers are installed on the building core wall (the inner concrete wall that remains constant while the exterior face of the building varies based on the design). The Core Wall Survey System uses Leica Nivel200 Series dual-axis inclinometers to measure the displacement of the tower alignment from vertical. The inclinometers, that can measure absolute tilt to +/-0.2" arc, are installed approximately every 20 floors up the tower as construction proceeds. The inclinometers are installed and leveled during a period when external stresses to the building are at a minimum to ensure that the initial position is aligned to the gravity vertical. With the inclinometers' measurements integrated into the system, the surveyor is able to continue to set control, even when the building has moved "off center," and can remain confident that he or she will construct a straight structure.

Computation of the surveyor's position for layout is carried out as a resection. The Spider software transforms the WGS84 antenna coordinates first into the site datum then into the individual buildings coordinate system, adjusted for tilt. The accuracy benefits of the Core Wall Survey System are obvious, but

Above:
Prior to the installation of the GPS system, Bobby Himble of DCM Erectors transfers control by traditional methods.

as Lamarre explained, one of the most important benefits is the time savings. "Without the GPS you have to imagine that today they would be sitting at the bottom of this building trying to square up a line, while that building moves. The tradition method would be to transfer the locations from the ground on all four sides and box it—try and do a best fit. The minimum time to try to do it the traditional way is three to five hours, sometimes more by the time you go down to the ground and back up. With the GPS, every hour you have a good position."

Surveyors at the Core

In the end, any technological system is only as good as the people who use it. And at the One World Trade Center site, the surveyors using the Core Wall Survey System are more than up to the task. Says Lamarre, "The ironworker surveyors are very good at what they do. They're very thorough surveyors, because the steel has to be right, but working with GPS was something they had never done. They usually work on lines and offset lines; now they have to work with resection, but they learned really fast. These guys are very accurate; 0.01 of a foot is not good for them—they like to have 0.005 of a foot. The steel will contract and expand with the weather, and they all know this—they have an intimate knowledge. There's about ten surveyors doing the work on the top, and they're the cream of the crop. It's very nice to be able to work with such good surveyors."

One World Trade Center is just the first in a number of projects that are now simultaneously under construction on the site. The steel is already up for Tower 4, with two more high-rise buildings to follow. The "Transportation Hub" is planned to be comparable in size to Grand Central Station and will serve more than 200,000 daily commuters, along with millions of annual visitors, connecting the Port Authority Trans-Hudson (PATH) rapid transit system that links New York with New Jersey to the New York City subway system.

At the heart of the reconstruction lies the National September 11 Memorial and Museum. Built to encompass the footprints of the original Twin Towers, it will be both a public space for contemplation and remembrance with a museum to teach future generations about the events of both February 26, 1993 and September 11, 2001.

At the center of this beehive of activity, some of the best construction surveyors in the world are using some of the most modern surveying equipment and software developed to rebuild the site of one of the worst days in recent American history, which, as often happens, brought out the best in all of us.

James Fleming, LS, *is editor of this magazine.*