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USING 3-D LASER SCANS TO DEFINE PT LOCATIONS FOR TENANTS

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SUMMARY

This paper outlines the approach taken to document as-built tendon locations for a developer that was constructing their first post-tensioned office building. They were looking for a simple and practical method of communicating the post-tensioning in their project to potential tenants. We describe the steps taken to mark the boundary of tendons on the slab soffit, as well as a detailed three-dimensional (3-D) laser scanning approach.

HUDSON YARDS

According to its developers, The Related Companies and Oxford Properties, Hudson Yards is the largest private real estate development in the history of the United States and the largest development in New York City (NYC) since Rockefeller Center (Fig. 1). The project covers 28 acres (11.33 ha) on the West Side of Manhattan, and when it is completed in 2024, 125,000 people per day will work at, visit, or call Hudson Yards their home. The site will include more than 17 million ft^2 (1.6 million m^2) of commercial and residential space, state-of-the-art office towers, more than 100 shops, a collection of restaurants, approximately 4000 residences, 14 acres (5.67 ha) of public open space, and a 750-seat public school. Half of the project extends over an existing rail yard; the 30 active train tracks are slowly being covered by a massive platform that will hold three towers, a retail complex, a 6 acre (2.43 ha) public square, and a new cultural space. The construction is expected to be completed in 2019 and is taking place while the trains remain in operation.

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Fig. 1—55 Hudson Yards, Manhattan.

55 HUDSON YARDS

A prominent part of the project is a 51-story commercial office building, 55 Hudson Yards. One of the first fully concrete-framed high-rises of its class in NYC, the tower will include over 1.3 million ft^2 (120,773 m^2) of office space. The developers wanted the building to provide modern, efficient floor spaces uninterrupted by columns and with floor-to-ceiling windows. The solution comprises long-span post-tensioned flat slabs supported by a central core and perimeter columns. The architects are Kohn Pedersen Fox Associates plus Kevin Roche John Dinkello Associates, the structural engineer is WSP, and the contractor is Gilbane. ADAPT Corporation was consulted on the post-tensioned aspects of the design.

PROJECT CHALLENGE

As a commercial office building in NYC, the de facto structural system for 55 Hudson Yards would have been a concrete core with steel column and beam construction. Tenants and developers in NYC have become accustomed to the configuration of steel structures—in particular the large areas between girders that can accommodate new openings and other custom tenant improvements. As part of an initiative to diversify the type of buildings it develops, The Related Companies (the developer) carried out a study to evaluate the feasibility of a cast-in-place concrete structural frame for its upcoming building. A post-tensioned solution proved to be the most economical alternative. Despite the many advantages a post-tensioned solution offered, including lower cost, simplified construction, and lower floor-to-floor heights, the developer was concerned about how rentable an office building with post-tensioned floors would be in the competitive and conservative NYC market. Tenants walk into a space and expect to be able to make changes based on a typical steel girder grid.

Another major challenge facing the structural design of 55 Hudson Yards was that it was partially constructed over and supported by an existing structure. The design scheme required the columns of the existing structure to provide partial support for the new construction.[1]

How would they be able to make prospective tenants comfortable with something different—especially post-tensioned slabs? Working together with the design team, a two-pronged solution was developed to: (a) provide a design that would accommodate future openings; and (b) develop simple documentation for tenants to understand and work around the post-tensioning. In addition to their concerns about rentability, the developer wanted to make sure they could easily maintain their new post-tensioned structure.

DESIGN SOLUTION

From the beginning, it was clear that a traditional banded/distributed tendon layout would not be acceptable to the developer. They needed to keep their options open for future large openings—similar to what a steel alternative would have given them. The banded/distributed tendon layout would not have easily accommodated such changes to the slab. An acceptable solution for the developer was to be able to have predesignated areas, similar to what would have been expected in a steel building, that would not contain tendons and allow future openings. To achieve this goal, each level was split into regions as shown in Fig. 2. The zones most important to the developer were the areas marked for future openings. The design approach was to build these areas into the design by not running tendons through them. It was understood that a future opening would not cut any tendons but could require additional reinforcement. Figure 3 is an image of a slab under construction, showing the radial bands of tendons. Note the lack of distributed tendons which would typically run perpendicular to the banded tendons.

DETAILED AS-BUILT DOCUMENTATION

Once the developer agreed to move forward with the project and the No-PT Zones, they wanted to make sure they had accurate as-built documentation and could easily communicate the presence of these zones to tenants. The agreed-to approach was to implement a simple tendon marking procedure with a more accurate measurement of actual tendon locations using three-dimensional (3-D) laser scanning.

TRADITIONAL TENDON MARKING

To mark the location of tendons in the slab, the concrete contractor drilled holes in the formwork and suspended colored nylon rope along the outer boundary of each tendon band (Fig. 4). This was a simple but rough method of capturing the general location of tendons. After removal of formwork, these nylon ropes could be used to identify the tendon locations (Fig. 5). To mark the location of tendon bands even more clearly, the contractor painted in the location of bands and marked those areas as PT Zones (Fig. 6). Each tenant package would include a description of the post-tensioned slabs and alert the tenants of PT Zones that should not be drilled into.

DETAILED 3-D LASER SCANNING

Even though the marking of tendon bands on the slab soffit provided reasonable data on the possible location of tendons, the developer wanted more accurate as-built information. After reviewing different data-capturing methods, including newly developed photogrammetry technologies, it was decided that 3-D laser scanning would provide the most accurate option for the site conditions

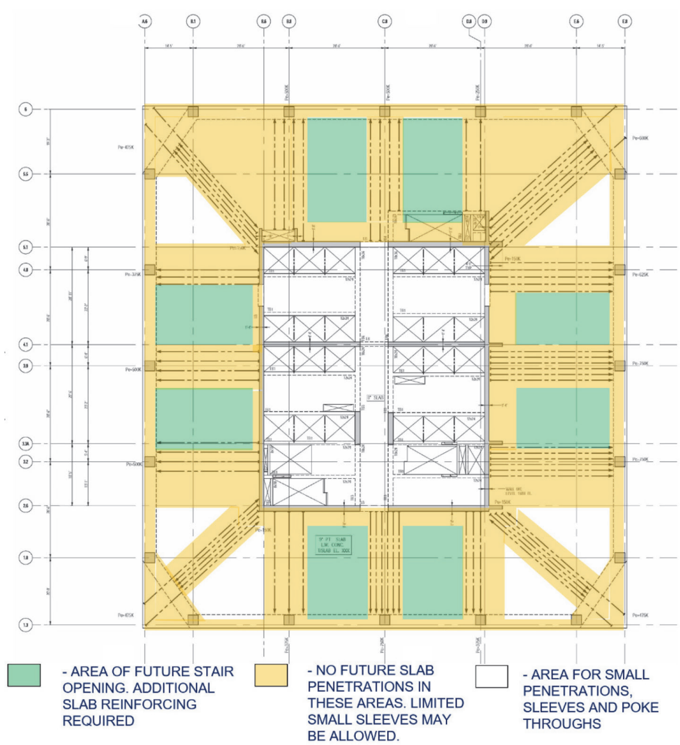

Fig. 2—Layout of typical slab showing designated areas without post-tensioning.

Fig. 3—Slab under construction showing layout of tendons.

of this project. ADAPT was hired to carry out the laser scanning of all tower levels. Each level was constructed as a single pour with a targeted 4-day construction cycle. Figure 7 shows a technician on the jobsite with the FARO laser scanner that was used.

Our initial planning assumed we could capture the required level of detailed tendon data using approximately 16 scans, one positioned at each end of a band. Laser scanners can be configured to take longer, more detailed scans that capture data at greater distances versus shorter scans that only capture details relatively close to the device. We quickly found out that the accelerated construction

Fig. 4—Nylon rope used to mark outer boundary of tendon bands.

Fig. 5—Nylon ropes showing underneath slab.

Fig. 6—Extent of tendon bands painted on slab soffit and labeled "PT Zone."

schedule would not afford us the luxury of longer scans. Instead, we had to adjust our scanning approach to a maximum of 2.5 minutes per scan so that we could get out of the way of active construction on the deck. Our only time frame to scan a slab was between 4:30 am and around 2 pm the same day when the last concrete would have been poured. To access secured tendons and reinforcing bar that was ready for scanning, we would show up 1.5 hours before the concrete pump would start at 6 am. At that time, approximately half of the slab would have already been laid out and tied down the previous afternoon. Work to complete the tendon and reinforcing bar layout on the second half of the slab would also start at 6 am. We were essentially being chased by a concrete pump on one end of the slab and waiting for reinforcing bar installers to complete their work on the other end. Sometimes the pump was ready to pour concrete as the last top bars were being fastened. Our biggest challenge was staying clear of all of the activity and trying to find a few minutes of uninterrupted view to scan each square foot of the slab. In the end, we adjusted our process to be as agile as possible

Fig. 7—FARO 3-D laser scanner used on project.

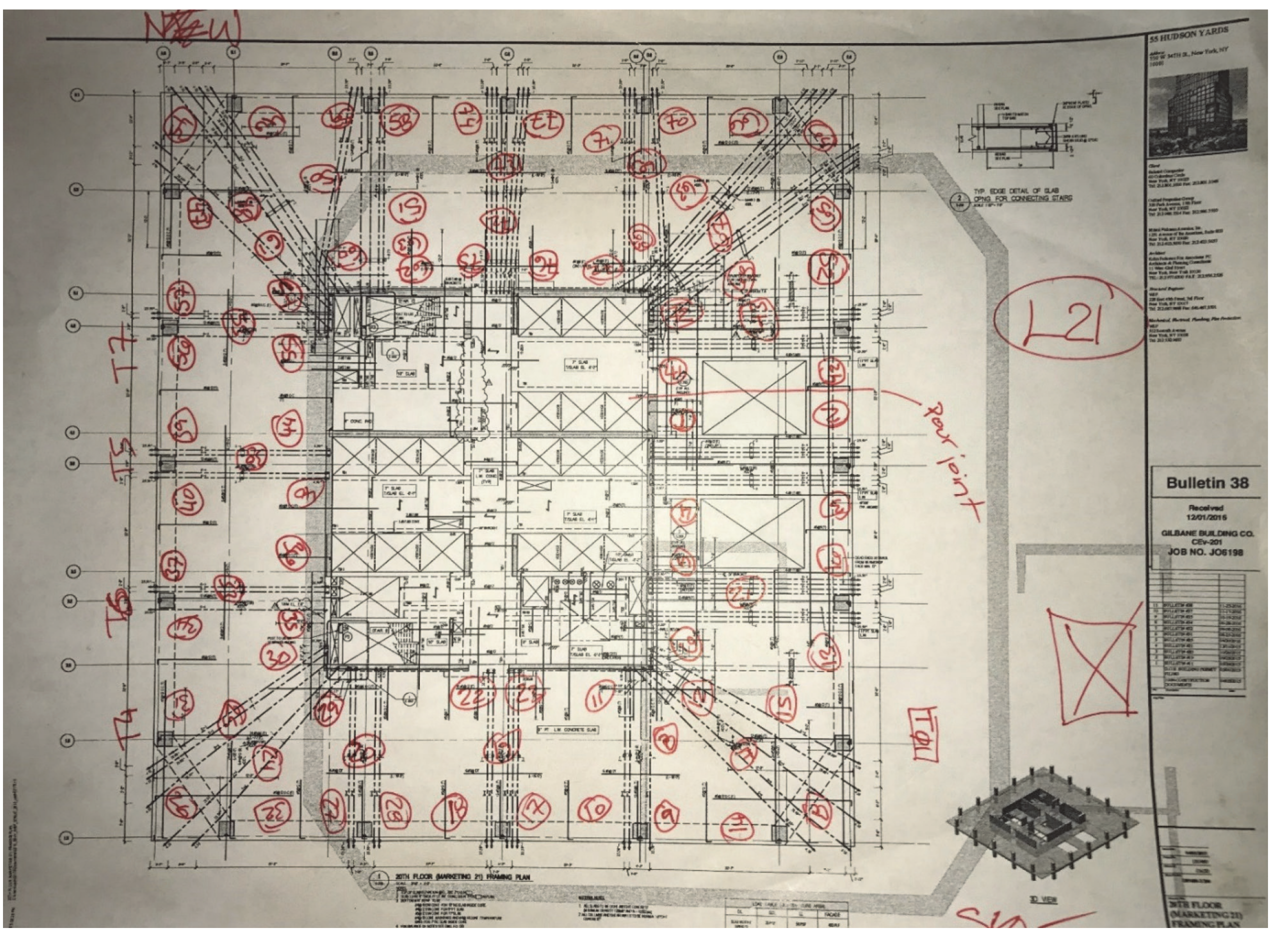

Fig. 8—Worksheet showing location and number of scans needed to capture one level.

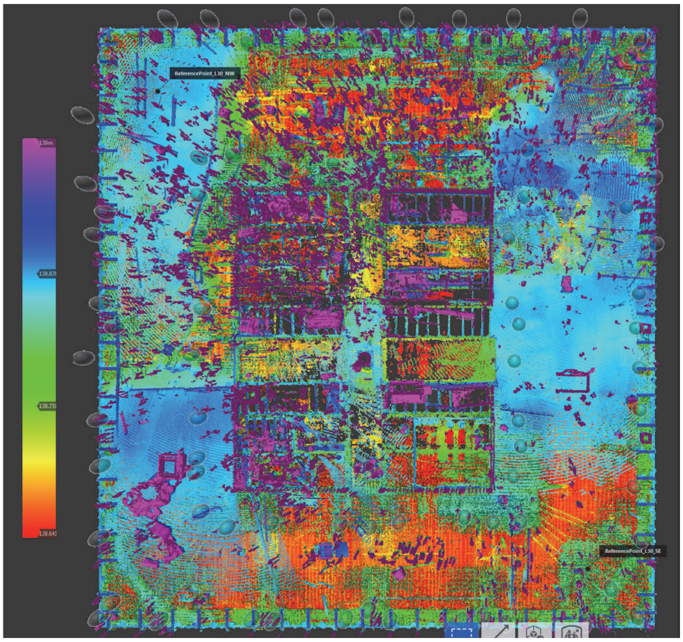

Fig. 9—Raw scan data with elevation color coding.

and reduced our scanning times to 2.5 minutes per scan. This resulted in the need to carry out between 95 and 100 scans per level, as shown in Fig. 8. To create a complete data set for each level, we merged and aligned each of the individual scan data sets. Sample scan data captured for a level are shown in Fig. 9 and 10.

One of the developer's major concerns was the ability to survey the exact location of tendons from our scan data. The issue with only scanning the reinforcing bar and tendons before casting concrete is that all identifiable markers will get covered up. One ends up with a very accurate and detailed laser scan of what is inside the slab, but not how it relates to the outside world. To overcome this issue, we decided to install a steel bolt at each corner of the slab that would penetrate above and below the finished concrete (Fig. 11). The location of these bolts and their relative position to all reinforcement was being captured in our scan data. After the concrete was cast and the columns and walls above the slab were constructed, we could go

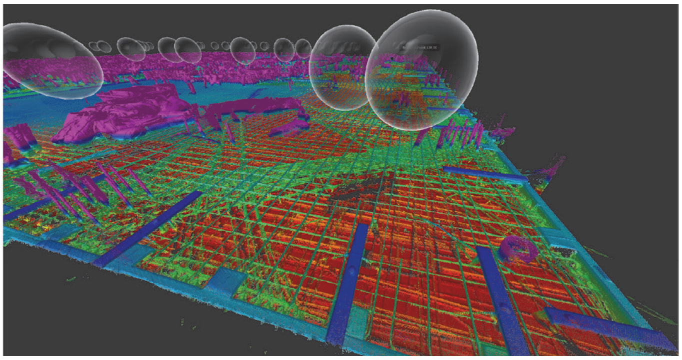

Fig. 10—Detailed scan data showing corner of slab; each sphere represents a scan location.

Fig. 11—Bolt used to mark relative location of scan data after tendons are covered in concrete.

Fig. 12—Top of anchor bolt visible and available for measurement from columns.

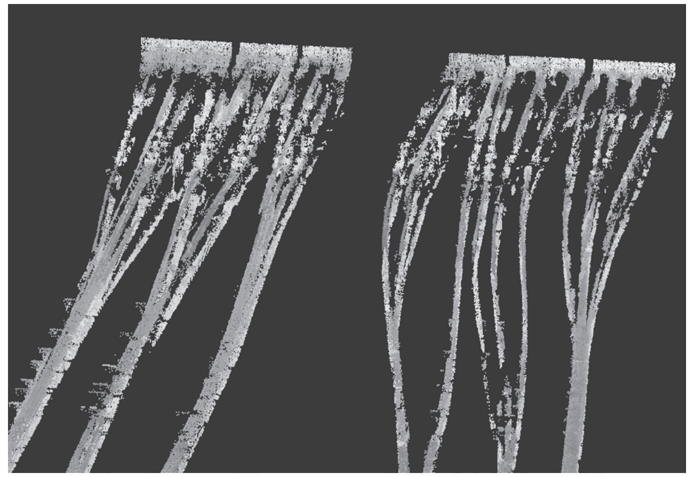

Fig. 13—Details of tendons that have been cleaned out of scan data.

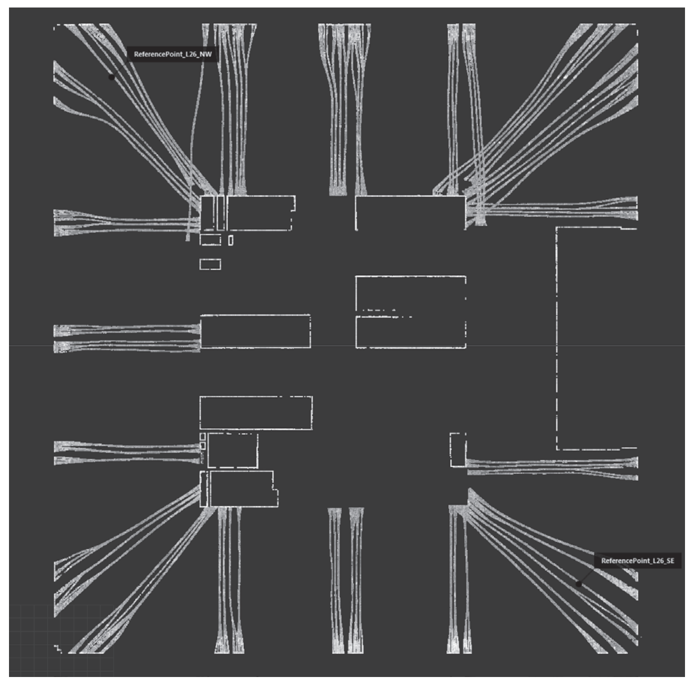

Fig. 14—Cleaned scan data only showing location of core walls and tendons.

back and measure the location of these bolts from an easily identifiable location. Figure 12 shows one of these bolts sticking out of the slab and how we would dimension it against a column.

SIMPLE, BUT ACCURATE AS-BUILT TENDON LAYOUTS

As mentioned at the beginning of this case study, the developer wanted a very simple method of communicating the placement of post-tensioning to its tenants. Even though detailed 3-D laser scanning was used to capture the as-built information, the developer did not want to hand

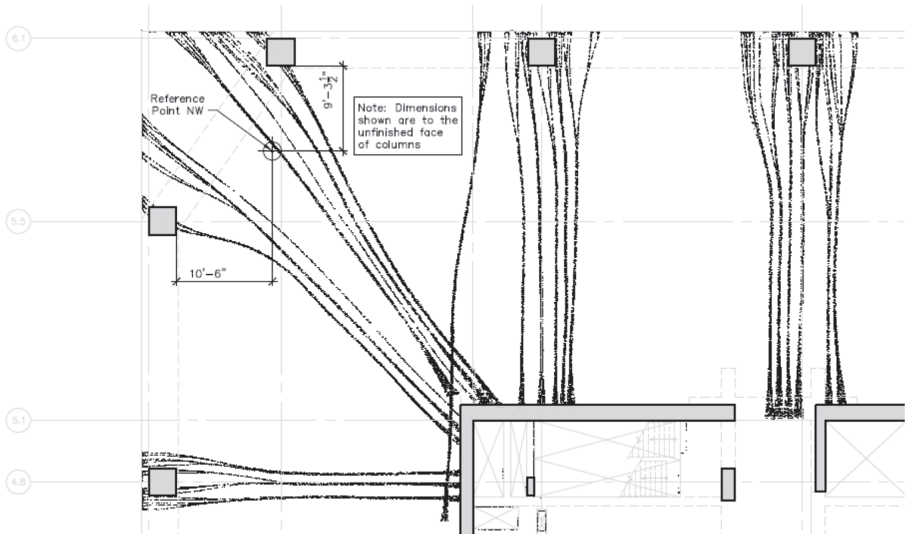

Fig. 15—Structural drawing updated with tendon and reference point locations.

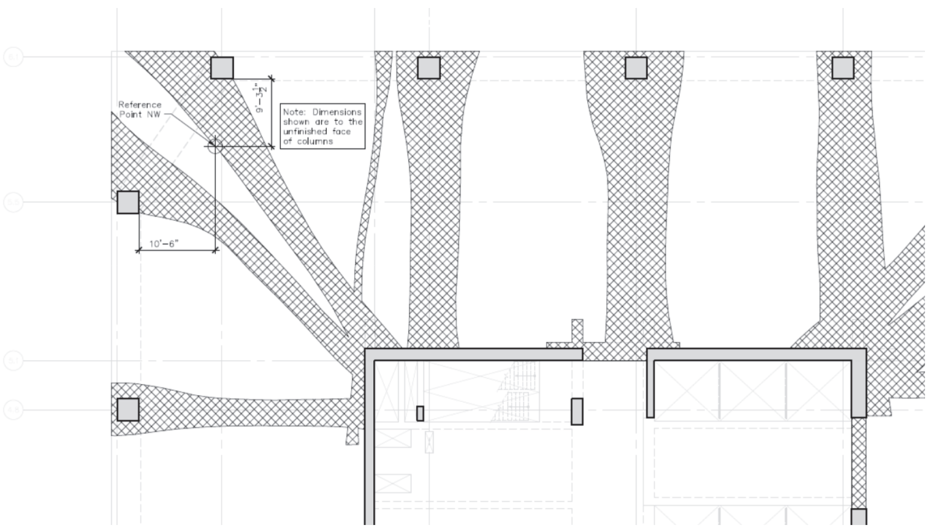

Fig. 16—Structural drawing updated with PT Zones.

Location: New York, NY
Owner: The Related Companies and Oxford Properties
Engineer: WSP USA and ADAPT Corporation
Contractor: Gilbane Building Company and Cross Country Construction, LLC
PT Supplier: AMSYSCO, Inc.
Submitted by: ADAPT Corporation

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over potentially overwhelming 3-D data to tenants. Instead, they asked us to produce a simple, two-dimensional (2-D) drawing. Once the scan data for each level was merged, we had another team post-process the data to isolate the tendon information (Fig. 13). Once the tendons for each level were isolated, we ended up with a clean representation of the as-built tendons (Fig. 14). This information was then transferred back to the original structural drawings to produce two sets of documents: one for the owner and maintenance team that included actual tendon locations, and a simplified version only showing tendon zones for tenants (Fig. 15 and 16, respectively).

ADDED BIM BENEFITS OF 3-D SCAN DATA

The traditional tendon markings carried out by the contractor and the sets of 2-D drawings we submitted for each level satisfied our client's requirements. They were able to completely rent out the office building and the project is projected to be a major financial success for them. In addition to the core business need we addressed for our client, the presence of 3-D scan data for every inch of their project turned out to provide many added benefits. For example, the main contractor was able to use our scan data to coordinate the placement of new openings needed to accommodate changes to the MEP system. We are certain the developer will find additional value in the wealth of information we captured throughout the life span of this project.

REFERENCE

1. Aalami, F., 2017, "55 Hudson Yards" PTI Journal, Post-Tensioning Institute, Farmington Hills, MI, Dec., 4 pp.