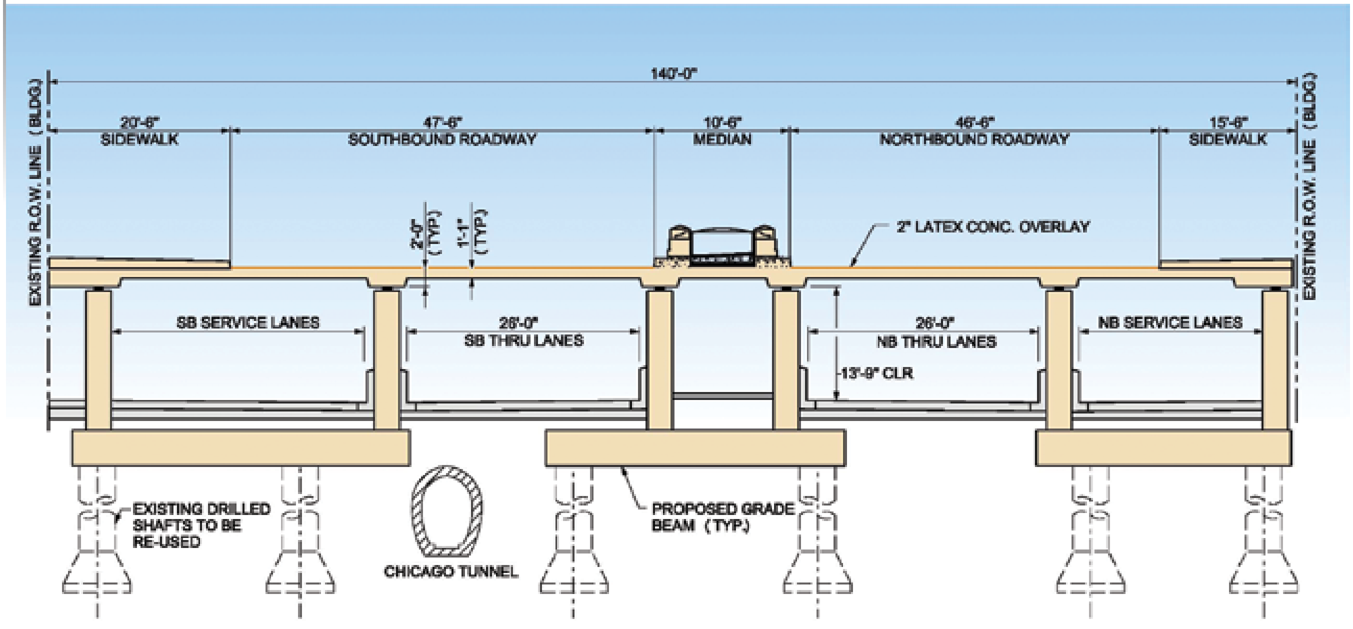
PROJECT

Reconstructing Chicago's Prized Wacker Drive

by Andrew Keaschall and Hossam Abdou, Alfred Benesch and Company, and Johnny Morcos, Chicago Department of Transportation



Typical cross section through the viaduct. Figure: Chicago Department of Transportation.

A critical downtown artery, Wacker Drive is home to several buildings that define Chicago's iconic skyline. The street is actually a multi-level viaduct structure with upper- and lower-level traffic that jogs along the Chicago River and borders the central business district. The Willis Tower (formerly the Sears Tower), the Civic Opera House, and the Chicago Mercantile Exchange are among those that claim a prestigious Wacker Drive address. An estimated 60,000 vehicles use the drive daily, along with 225,000 pedestrians and vehicles on the associated cross streets.

The north-south leg of the viaduct is being reconstructed to modernize the upper and lower levels, providing a safer, more-efficient roadway for motorists and pedestrians. The reconstructed viaduct is 2900 ft long and 140 ft wide, equaling more than nine acres. This project is an exceptional example of complex urban reconstruction with notable accomplishments in structural engineering, stakeholder communication, maintenance of traffic, and infrastructure security.

Substructure and Geometry Details

The upper deck is supported by individual columns located to accommodate the main travel lanes, service lanes, a median, and numerous building entrances on Lower Wacker Drive. The 3-ft-diameter columns are spaced roughly at 32 ft on center in the longitudinal direction. The transverse spacing varies to accommodate the different constraints as shown in the typical section. The columns at the expansion joints utilize a hammerhead cap in order to support bearing lines for

profile

WACKER DRIVE VIADUCT / RANDOLPH ST. TO MONROE ST.—CHICAGO, ILLINOIS

BRIDGE DESIGN ENGINEER: Alfred Benesch and Company, Chicago, Ill.

CONSTRUCTION ENGINEER: Parsons Brinckerhoff, Chicago, Ill.

PROGRAM MANAGEMENT ENGINEER: TranSystems Corp, Schaumburg, Ill.

PRIME CONTRACTOR: McHugh Construction, Chicago, Ill.

READY-MIX CONCRETE SUPPLIER: Ozinga Concrete, Mokena, Ill.

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International USA Inc., Bolingbrook, Ill.

the up-station and down-station deck segments.

New grade beams are typically 5 ft wide by 4 ft deep, but increase to 5 ft by 5 ft at expansion joints to accommodate increased torsional loading from the hammerhead columns. Adjusting the column locations required reconstruction of the existing grade beams, which were supported on belled shafts extending approximately 60 ft below the surface to a hardpan clay layer. The revised column arrangement caused some existing shafts to bear substantial additional loading. In certain locations, pressure-meter testing was conducted to justify increasing the allowable bearing pressure from the 12,000 psf, used in the original design, to upwards of 20,000 psf. All told, 254 of the 264 existing 4-ft-diameter belled shafts were able to be reused, and only eight new shafts drilled.

Another main goal of the reconstruction was to upgrade the alignment of both the upper and lower levels. Re-aligning the Lower Wacker Drive service and travel lanes proved to be the greatest geometric challenge because it affected the locations of the columns previously mentioned. The main geometric modifications to the Upper Wacker Drive Viaduct involved reducing the number of access points between Upper Wacker Drive and Lower Wacker Drive to improve and control the flow of traffic. Another key constraint of the Upper Wacker Drive geometry was that the sidewalks on the edge of the viaduct had to be level with adjacent building plazas. This made for very tight vertical constraints, while still ensuring the viaduct would drain efficiently during a rainstorm.

Bridge Deck Design

The viaduct deck is a cast-in-place concrete slab that is post-tensioned

View from adjacent skyscraper looking down on the existing Madison Street intersection prior to completing deck demolition. Photo: McHugh Construction.

CITY OF CHICAGO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Cast-in-place concrete slab, post-tensioned in both horizontal directions. This portion of the viaduct is 1400 ft long by 140 ft wide and is split into seven segments with 44 spans in the longitudinal direction and five bays in the transverse direction. The average longitudinal span length is about 32 ft. The beam slab is supported on pot bearings that sit on individual columns.

STRUCTURAL COMPONENTS: High-strength, high-performance, 6 ksi concrete, post-tensioned with 0.6-in.-diameter, Grade 270, low-relaxation, post-tensioning strands and 2-in.-thick, latex-modified concrete wearing surface

BRIDGE CONSTRUCTION COST: Total project cost \$300 million; North Viaduct Cost: \$60 million (\$306/ft^2)

Looking south along Wacker Drive with the new columns in place and waiting for the decking. Photo: Alfred Benesch and Company.

Example of the close proximity of the adjacent buildings to the viaduct. Photo: Alfred Benesch and Company.

in both directions. High-strength (6 ksi), high-performance concrete with reduced chloride permeability was specified as another means of ensuring the structure will withstand the harsh Chicago winters. Typically, a 2-ft-deep, 4-ft-wide longitudinal rib runs along each of the six column lines with a 13-in.-thick deck between the ribs.

This design concept required an increased effort to accommodate the post-tensioning tendons along with conventional epoxy-coated reinforcement, while avoiding conflicts. This issue was solved by banding the profiled tendons in ribs in the longitudinal direction with straight tendons in the slab between adjacent ribs. Banding of the profiled tendons allowed for providing uniformly distributed profiled tendons in the transverse direction. In this manner, the deck acts as a one-way slab spanning in the transverse direction, supported by post-tensioned concrete beams formed by the ribs with their banded tendons. At the end of each deck segment is a transverse rib that is also 2 ft deep that accommodates the anchorage blockouts and the expansion joint.

The structural slab was designed for zero tension under all service loads for both the top and bottom surfaces. This design objective was accomplished through the use of three separate post-tensioning systems using 0.6-in.-diameter, Grade 270 low-relaxation strands. The primary system consists of the banded tendons in the longitudinal ribs. Each rib has between five and eight 3-in.-diameter profiled ducts, which contain nine post-tensioning strands. Each tendon was stressed at each end to a force of 370 kips.

The secondary system is in the transverse direction and extends along the entire length of the viaduct with profiled four-strand flat ducts. The ducts are spaced at 1 ft 6 in. or 2 ft on center, depending on geometric variables. These tendons are single-end stressed to 164 kips with a monostrand jack.

The third element of the system consists of non-draped distributed tendons in the longitudinal direction. These are five-strand tendons, single-end stressed, to a force of 205 kips each, and spaced roughly 2 ft on center between the ribs. All ducts were grouted after the stressing operations were complete.

Designing the system to a zero-tension criteria involved quite a few challenges. The geometry and loading were always varying, meaning several different profiles and spacing adjustments had to be made within each system. A nineteenth-century trolley tunnel beneath Washington Street eliminated the possibility of columns for that bay and created an abnormally long span (over 50 ft) between column bents. This was accounted for by using additional tendons in the ribs and modifying the drape to adjust the magnitude of the balance forces.

The Upper Wacker Drive median was also required to support planters requiring a design loading of over 400 psf. The geometric layout of the deck and the congestion created by the post-tensioning ducts, eliminated the ability to provide spare ducts in case field stressing data did not achieve the required results. Designing the post-tensioning tendons to be stressed to 70% of the ultimate strength solved this problem. Once in-place, and after evaluating friction test data, the stressing value could be increased to 75%, if necessary. The additional capacity would also be available if a particular strand was lost. Both of these contingency plans were implemented, on occasion, during construction.

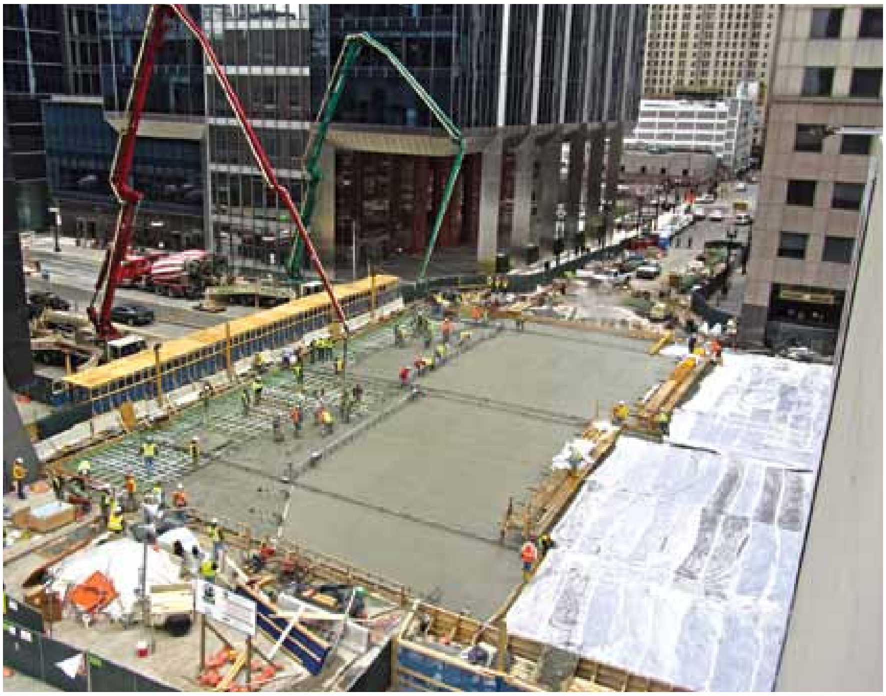
Urban Challenges

The dense urban setting was a fundamental constraint under constant consideration during both design and construction. The viaduct footprint on the east and west is bordered by buildings with the gap between the viaduct and adjacent property set at $^7/_8$ in. During the design phase, significant effort was required to develop details to allow for transverse stressing at the edge of the viaduct when the facade of a high-rise building may only be inches away. During construction, the contractor preloaded the strands in the transverse ducts prior to installation to avoid threading.

The contractor also had to deal with difficult scheduling. Work activities were limited or restricted during performances at the Chicago Civic Opera, which occupies an entire city block, in the middle of the project. The Madison Street intersection could not be closed until all other side streets were re-opened. This constraint was implemented because the closing of Madison Street diverted 50,000 pedestrians a day that mostly come into the city through Chicago's Union Station and walk across Wacker Drive into the central business district. The contractor was also responsible for maintaining access 24 hours a day to all loading docks and parking garages in the Lower Wacker Drive service drive. Maintaining continuous access for pedestrians to all buildings and businesses was perhaps an even larger challenge.

Overall Project

The overall Wacker Drive Reconstruction project is a remarkable example of a massive urban construction undertaking.



View of first placement of concrete for the deck. Photo: McHugh Construction.

The number of stakeholders and coordination involved becomes much greater when working with skyscrapers lining both sides of a ½-mile-long viaduct.

The north viaduct deck, which consisted of seven deck segments, was completed in December of 2011. The south viaduct contract (Monroe Street to Van Buren Street) includes the remaining eight deck segments of the viaduct and is scheduled for completion by December 1, 2012. The interchange project, which links Wacker Drive to the east-west expressway, is due to be completed in October 2012. As of press time, the remaining contracts are on schedule. The anticipation of a full opening is growing, especially for the hundreds of thousands of people who have been displaced throughout the 2.5-year construction period.

Andrew Keaschall is a project manager and Hossam Abdou is a vice president and structural practice leader, both with Alfred Benesch and Company in Chicago, Ill. Johnny Morcos is the acting chief bridge engineer with the Chicago Department of Transportation.

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