Fulcrum

The Newsletter of the Deep Foundations Institute

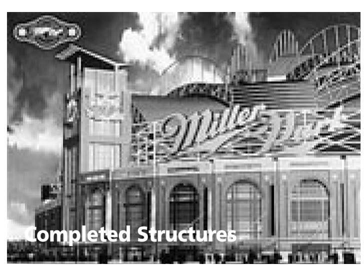
Winter 2001-02

Miller Park Stadium Receives DFI Outstanding Project Award

Pile Driving

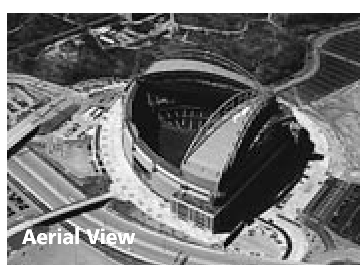
Installing Drilled Piers

Site



Completed Structures

Roof Model



Aerial View

Load Test

2001 Outstanding Project Award

Miller Park Stadium
Milwaukee, Wisconsin

The race for DFI's Outstanding Project Award for 2001 was hotly contested. The winning nominee was Miller Park Stadium in Milwaukee, Wisconsin, and Van E. Komurka accepted the award on behalf of his firm, Wagner Komurka Geotechnical Group, Inc. Twelve other projects were accorded honorable mention status (see article in this issue of **Fulcrum**).

Miller Park is a premier state-of-the-art baseball stadium, the new home of the Milwaukee Brewers. With its fan-shaped retractable roof, Miller Park weighs 500,000 tons, making it the heaviest structure in Wisconsin. Miller Park is unusual in that it is supported on a deep-foundation system consisting of both rock-socketed drilled piers and soil-bearing driven piles. Subgrade conditions consist of fill, underlain by a relatively thin deposit of organics, overlying medium dense to dense granular deposits to bedrock. Depth to bedrock varies beneath the stadium footprint, from approximately 35 feet (10m) behind home plate to 125 feet (38m) at the outfield wall.

Wagner Komurka Geotechnical Group, Inc. ("WKG^2") was the geotechnical engineer for the project, and was responsible for the value engineering and design of the deep foundations. An indicator pile test program was performed, including initial drive and restrike dynamic monitoring of both 12.75-inch-O.D. steel pipe piles and 16-inch Monotube® piles. To evaluate the relative performance of these two pile sections, pipe and Monotube test piles were installed in pairs, and two pairs were statically load tested. Based on support costs (normalized in terms of dollars per ton supported), results indicated Monotube piles to be the more-economical section.

Where bedrock was shallow, driven piles' resistance to uplift loads was inadequate, and rock-socketed drilled piers offered lower support costs than driven piles. Since installation cost, and therefore support cost, of rock-socketed drilled piers increases disproportionably with increasing depth to rock, driven piles offered lower support costs where rock was deep. Using the results of the pile test program combined with pile and pier cost information supplied by Edward E. Gillen Company ("Gillen"), WKG^2 recommended that a two-foundation-type system be used, and determined the optimal depth to rock along the baselines at which to transition from drilled piers to driven piles. The use of this two-foundation-type system saved $4 million compared to foundations consisting of all drilled piers.

Two full-scale drilled pier load tests were performed using Osterberg cells ("O-cells") which applied load at the base of the drilled piers: one test in a shallow rock socket to evaluate socket friction, and one test in a deep rock socket to evaluate end bearing. Design values of 45 and 500 ksf (2.15 and 23.94 Mpa) were recommended for rock socket friction and end bearing, respectively. Gillen offered the value alternative of extending the production rock sockets deep enough to support the entire design load in socket friction, saving money by reducing the need to clean the bottom of the rock socket. Full-scale "twin" lateral load tests were performed by jacking the two adjacent test piers towards each other.

A total of 325 drilled piers, with 5-foot-deep rock sockets, diameters ranging from 3 to 5 feet (914mm to 1524mm), and design loads of up to 1325 tons (11,787kN), were installed. During construction, the capacity of several production piers was confirmed using high-strain dynamic testing. A 40-kip (178kN) weight was used, with drops as high as 20 feet (6m) and dynamic monitoring confirmed desired capacities.

A total of 1512 Monotube piles, with a design capacity of 200 tons (1,779kN) each and accounting for a total footage of 104,351 feet (31,807m), were installed. Beneath the outfield track beams, which support the moveable roof panels, eight columns are supported by 100-pile caps. To model deflection of these track beam foundations resulting from variable loading conditions (from opening and closing the roof and from wind loads), the large pile groups were modeled as equivalent mat foundations. Pressuremeter moduli were used to estimate load-deflection behavior of equivalent mat foundations to develop "spring constants" for the foundation systems used by the structural engineer. Consistency of moment-induced foundation response around the centroid of support was evaluated by 3-dimensionally modeling the uniformity of production pile toe elevations.

The three concentric outfield track beams on which the roof panels roll are constructed of cast-in-place reinforced concrete; each beam is 3 feet wide and 8 feet high (0.91m wide and 2.44m high). During construction of these beams, the formwork and fluid concrete were supported by temporary shoring towers which were supported at-grade on cribbing bearing partially between new pile caps, and partially above new pile caps. Due to compressible organic soils, the cribbing bearing between pile caps was expected to settle more than the cribbing bearing above pile caps, and the pile caps were considered "hard spots" likely to attract load. WKG^2's analyses indicated that at some locations, the piles would be overstressed, and supplemental piles were driven to support the temporary shoring towers.

WKG^2 was also the geotechnical engineer for the infrastructure relocation and construction related to the stadium, which included 9 bridges, 4 retaining walls, embankments up to 22 feet high, pavements, and below-grade culverts. In-situ vane shear testing justified high enough design strengths in soft organic soils beneath a mechanically stabilized earth retaining wall to preclude previously