



DID YOU KNOW?

Fyffe House, Built in NZ in 1860, by people in the whaling business, rests on whale bone piles.



The Marquette Interchange, Milwaukee, WI

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The confluence of Interstate Highways I-94, I-43 and I-794 immediately southwest of downtown Milwaukee, Wisconsin comprises the Marquette Interchange. The original interchange opened in 1968 and was supported on low-capacity H-pile and pipe pile foundations. By 2000, the interchange handled over 300,000 vehicles per day, or roughly twice the intended capacity. The Wisconsin Department of Transportation (WisDOT) had the interchange completely reconstructed from 2004 through 2008 to meet the increased traffic demands and to improve traffic safety.

The reconstructed five-level interchange occupies the same general footprint as the original one, and is supported by more than 120 km (77 mi) of 32, 36 and 41 cm (12.75, 14 and 16 in) outside diameter closed-end pipe piles. These pile sections were installed at a cost of 19.3 million dollars to support maximum design loads of 1334, 1779 and 2224 kN (150, 200, and 250 tons), respectively. Maximum design loads of this magnitude had never been previously used by WisDOT.

Early in the design process, Milwaukee Transportation Partners LLC (MTP), the designer, determined that high-capacity pile foundations were the most cost-effective foundation solution for this project. High-capacity pipe pile



Marquette Interchange, completed project.
Photo by WisDOT Marquette Interchange Project Team

foundations were chosen over a lower capacity pile foundation design because of the reduced substructure size, the reduced utility impact, and the significant cost savings provided. The use of higher capacity piles also meant that there were fewer piles to drive, which contributed to maintaining a very aggressive project schedule.

The interchange covers a large area with highly variable soil conditions and high soil set-up potential. On average, a nearly six-fold increase in shaft resistance occurs between the end of initial driving and one month later. To achieve cost-effective foundation construction, the soil set-up was quantified and incorporated into the production pile installation criteria. Wagner Komurka Geotechnical Group (WKG²), working with GRL Engineers, used the results from an extensive 2003 design-stage test program during which 88 indicator piles were driven at select locations throughout the interchange footprint. Those indicator piles were dynamically tested by GRL during initial driving and during multiple restrike events to quantify



GRL's APPLE system was used on re-strike Dynamic Load Tests.

both the time rate and magnitude of soil set-up. GRL used a Pile Driving Analyzer[®] (PDA) for the dynamic tests and performed CAPWAP[®] analyses on the collected data. GRL's 15 ton APPLE system was used to effectively perform the long-term restrike tests on the indicator piles and to mobilize the large soil resistances. The design stage test program also included six axial compression load tests and six lateral load tests so MTP could optimize foundation selection.

During production pile installation, GRL Engineers performed dynamic pile monitoring with the PDA on the initial production piles driven at each substructure location. These production piles were also dynamically tested during restrike after a period of one to three days. GRL once again performed CAPWAP analyses on the collected data from end of drive and restrike. Approximately 10% of the production piles were dynamically tested in this manner. WKG² compared the long-term soil set-up information quantified in the design-stage test program with the short-term soil set-up information gathered from the production piles, and then established driving criteria for the remaining piles at each substructure location. WKG² used depth-variable driving criteria that considered the reduced end of driving capacity required as pile penetration depth increased, and the additional capacity achieved with penetration depth through soil set-up. Incorporating set-up and depth variable criteria into the pile installation criteria meant driving the piles as short as possible. Individual driving criteria was thus developed for each of the 254 substructure locations that comprised the Marquette Interchange.

The contractor, Marquette Constructors LLC, routinely operated 6 pile driving rigs at the same time and at one time had as many as 10 pile driving rigs operating concurrently. Single acting diesel hammers with rated energies of 54,500 to 223,200 Joules (40,200 to 164,600 ft-lbs) were used to install the over 5000 production piles. These hammers were significantly larger than those typically used on other WisDOT projects. The use of the larger hammers resulted in improved production installation rates.

The dynamic pile testing program contributed to an efficient foundation installation during the rebuilding of the congested interchange. The project was completed in August 2008 ahead of schedule and below the estimated cost of 810 million dollars.