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Applications of the Press-in Piling Method to Emergency Bridge Foundation Repair

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INTRODUCTION

Increasingly frequent and severe flooding damages foundations of bridge piers and abutments all over the world. Repair of compromised bridge foundations often requires steel cofferdams to be constructed under low lying bridge girders in the face of hard soil without generating a high level of vibrations. The Press-in Piling Method can easily satisfy these project needs because of the way the method works. This article highlights the advantages of the method with two case studies of emergency bridge foundation repair; one in the United States and the other in Japan.

CSX BRIDGE PIER REPAIR WORK IN COLUMBUS, OHIO, UNITED STATES OF AMERICA

CSX Transportation is one of a few freight railroad companies based in the United States, which has more than 30,000 km of route track in the eastern parts of the U.S. and Canada. One of its rail bridge piers in Columbus, Ohio was heavily scoured around its foundation, needing emergency repair work in 2015 (Fig. 1). The original pier foundation was on timber piles with a concrete footing. The repair work was to drive micropiles around the original footing first with a larger concrete encasement footing to be constructed after a sheet pile cofferdam was built. See Figs. 2 and 3 for the structural details.

Fig. 1. Bridge Pier with Damaged Foundation

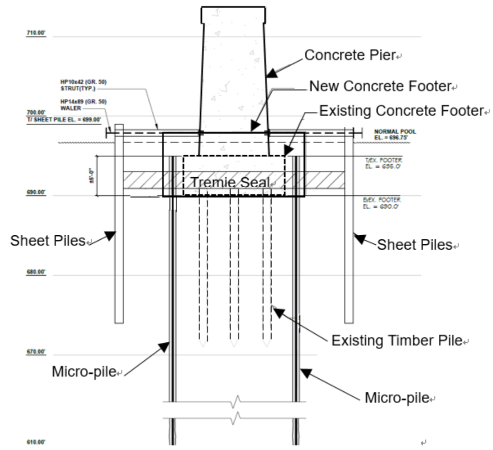

Fig. 3. Cross-section of Cofferdam and Pier Foundation (Source: Richard Goettle Inc.)

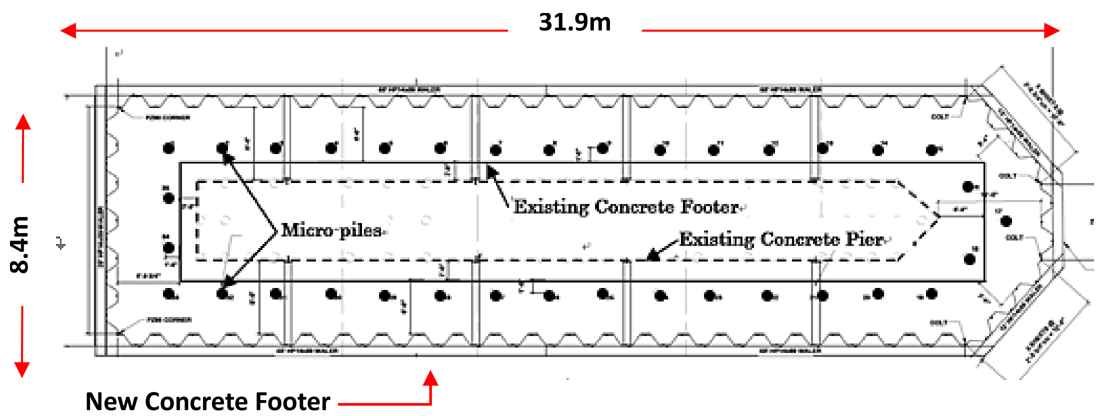

Fig. 2. Plan View of Cofferdam (Source: Richard Goettle Inc.)

The sheet pile cofferdam was to create dry working space around the damaged foundation to place tremie seal at the bottom and to construct a new larger reinforced concrete footing inside it. The construction of the cofferdam required careful planning because of the limited overhead clearance under the bridge girder (5.1 m) and proximity to the damaged foundation without generating a high level of vibration (White et al., 2002). For these reasons, the foundation subcontractor chose to press-in sheet piles for the cofferdam. Fig. 4 shows the soil conditions at the pier with N-values and the vertical location of the 7.5m long sheet piles. As can be seen, the soil was not very hard for the entire penetration except sand and silt mixed with stone fragments found between 3.6 to 4.5 m below the GL. A water jetting or auger attachment was not needed.

In order to work under the bridge girder, short sheet pile sections were brought over to the press-in piling machine by a small track loader with a special arm to hold the short sheet piles in position after their lower sections had been pressed in (Fig. 5). Each new section was then spliced by welding to the lower section in place. With the sheets spliced together, the press-in piling work continued. Approximately 9 sets of welded sheets were pressed-in per 10-hour shift. Fig. 6 shows the concrete pier with the existing concrete footing, lines of new micropiles, and steel bar reinforcement placed inside the sheet pile cofferdam.

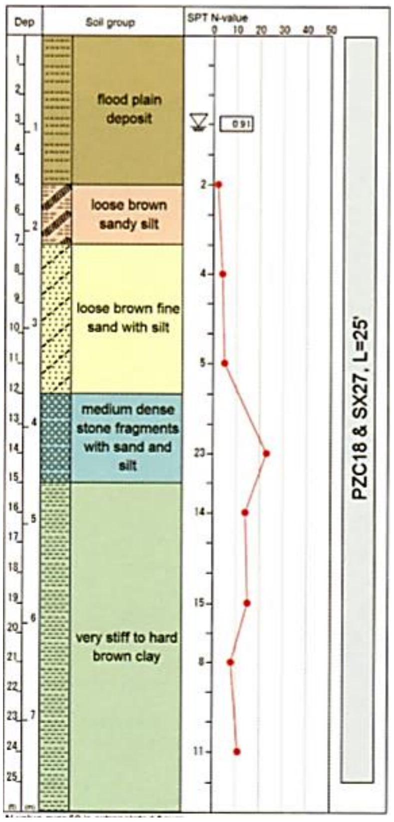

Fig. 4. Soil Conditions and Sheet Pile Location

Fig. 5. A Short Section Being Placed on Top of the Lower Section for Splicing Under the Rail Girder

Fig. 6. Sheet Pile Cofferdam and Micropiles for Larger Encasement Footing

The cofferdam construction was finished within a short period of time without affecting the weakened pier foundation or the rail girder above it. Although this project did not encounter very hard soil, emergency bridge foundation repair often faces gravel, cobbles, and boulders brought over by flooding. The auger attachment becomes essential for safe and efficient installation of sheet piles in these cases (Takuma et al., 2018). Additionally, sheet piles have been pressed in an extremely low headroom (1.0m) situation in fast running water on a different project (Takuma et al., 2015).

UTO BRIDGE ABUTMENT EMERGENCY REPAIR IN KAGOSHIMA, JAPAN

The Kyushu region of Japan experienced very heavy and continuous rain in a short period of time on June 20, 2016 and the following couple of days. More than 250 mm of precipitation was recorded during a 24-hour period in the City of Kagoshima where the Uto Bridge was located. The bridge section was immediately closed when deep erosion of the slope just in front of its abutment was reported. See Fig. 7 for the degree of erosion nearly exposing the abutment's foundation at the beginning of the project.

The highway agency in charge determined that a pressed-in pipe pile retaining wall would be the only safe and reliable solution to expediently protect the abutment because of the very steep and unstable slope created by the flooding right underneath it in addition to extremely difficult construction access.

Fig. 8 shows the concept of Giken's proprietary GRB System involving a Gyropress piling machine with its power unit, a Clamp Crane, and a Pile Runner; all working and moving on top of already installed piles while using the line of installed piles as a construction staging area as well as an access road. The Pile Runner hauls piles from a faraway access point by travelling on the piles to the Clamp Crane which then picks up one of the piles and brings it to the Gyropress piling machine. Once these pile sections are fully unloaded, the Pile Runner goes back to the access point for the next batch of piles. This system enables pile installation on projects even where construction access is impossible or extremely difficult to secure such as this project.

Fig. 7. Severe Erosion in Front of the Abutment

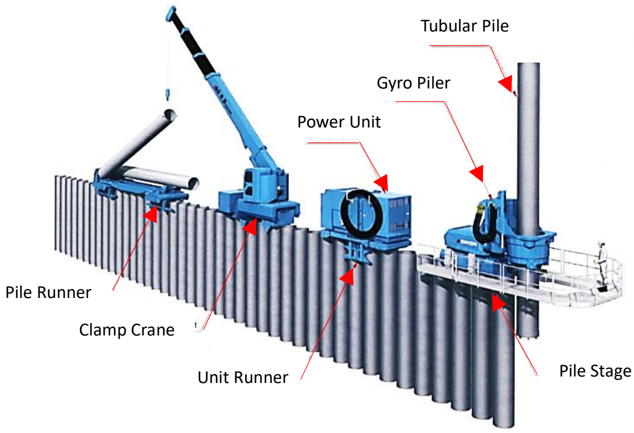

Fig. 8. Concept of GRB (Giken Reaction Base) System

Uto Bridge has a slightly curved 42-meter-long single span with a two-lane highway supported by its concrete girder. Fig. 9 shows the plan view of this emergency repair work to prevent further erosion around the foundation. 15 of 1,500mm diameter pipe piles were pressed in to form a very solid earth retaining structure. The pile's length varied from 15.5 to 24.5 meters with the wall thickness from 15 to 21 mm. Each pile was spliced once, twice, or three times depending on the pile's location and its overall length. The pile driving was planned to start from the downstream side because of easier access compared to the other side. The soil condition was from weathered to fresh sandstone covered with a thin surface clay layer spared from the storm water. The sandstone was expected to have an average equivalent N-value of 275. See Fig. 10 for the cutting shoe of the pile that enabled the pile installation into the sandstone. The Gyropress piling machine rotated and simultaneously pressed pipe piles into the ground (Takuma et al., 2013). Fig. 11 shows the installation of one of the piles in the middle of the heavily eroded and unstable slope.

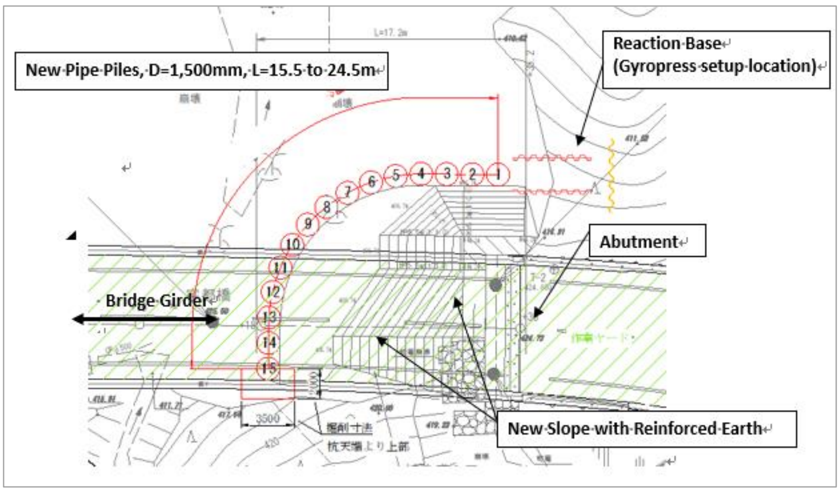

Fig. 9. Project Plan View

Fig. 10. Cutting Shoe of Pipe Pile (Sacrificial)

Fig. 11. Pile Installation on Heavily Eroded

The highest self-standing height of these piles was as much as 12 meters. Since there were no other practical ways to bring the piles to the Gyropress piling machine for the piling locations under the girder, a Clamp Crane was mobilized to supply the sections to those locations. The crane was equipped with a Y-shaped boom end, allowing it to lift and hold one end of pipe section in the minimal overhead clearance as shown in Fig. 12. The heaviest section lifted by the crane on this project was slightly more than 5.0 metric tons.

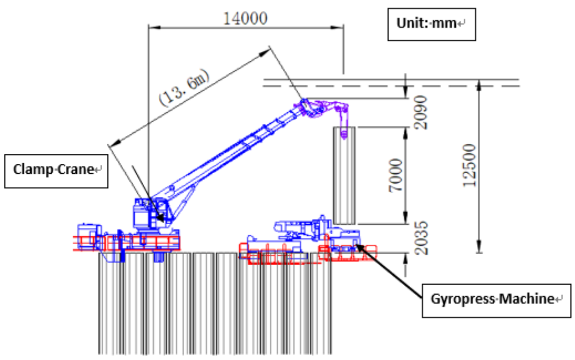

Fig. 12. Pipe Section Supplied by Clamp Crane

Fig. 13 shows installation of the last pile under the girder with the pile supplied by the Clamp Crane. Once the pile installation was completed, both the Clamp Crane and the Gyropress machine were walked backward to the reaction stand next to the side of the abutment and dissembled there for demobilization. Fig. 14 shows the completed pipe pile wall after the equipment was removed off the piles. 200 mm wide steel strips were welded onto both sides of each pile to fill the 80 mm wide gaps between piles as designed.

The press-in force and torque were closely monitored real time for smooth installation with minimal vibration. Thanks to the combination of the rotating cutting shoes and the press-in force simultaneously exerted on the piles, the necessary press-in force for installation was relatively small, considering that the piles were installed deep into fresh sandstone. The piles were not for carrying vertical load so the vertical loading capacity was not calculated or tested.

Fig. 13. Last Pile Supported by Clamp Crane during Splicing

Fig. 14. Pile Installation Completed

Finally, a reinforced earth embankment was placed against the abutment inside the retaining wall for its stability. The pressed-in pipe pile wall provided a highly reliable earth retaining structure to secure the once threatened abutment.

CONCLUSIONS

Press-in piling can provide very safe and highly reliable bridge foundation repair solutions even in the face of extremely difficult site conditions, such as low headroom, steep and unstable slopes, and very hard soil. A watertight cofferdam can be built quickly with pressed-in sheet piles even in running water.

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