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Proof Testing Push Piers

There may be times when you want to document the capacity of a push pier beyond the capacity information obtained during a typical installation. This can be done by performing a proof test at the installed pier location by monitoring pile movement at various loading conditions. Before we get into how to do a proof test on a push pier, let's do a brief overview of how a push pier system gets its capacity, and how the capacity is verified during a typical installation.

Push piers are installed with side load retrofit brackets that are set against the structure's footing via a hydraulic drive cylinder temporarily attached to the bracket. The pier sections are "pushed" through the bracket to a suitable load-bearing stratum. Push piers utilize the weight of the structure and the surrounding soil as the reaction to drive the piers. The drive forces are measured as the pier sections are advanced by monitoring the hydraulic pressure. To determine the final drive force needed, the service load (or working load) at the pier location is multiplied by a factor of safety, typically between 1.5 and 2.0. The push pier is driven until this final drive force has been achieved. At this point, the pier is unloaded and the drive cylinder is replaced with a lift cylinder. The load is then reapplied until the pier is at a specified "lock-off" load, which is typically at or near the service load. If further documentation of pier performance is needed, it is relatively easy to perform additional proof testing before the lock-off operation.

The Method:

Since push piers are used as retrofit systems on existing structures, proof testing is done with the retrofit bracket in place. To monitor movement of the pier during testing, a dial gauge can be set up similar to a standard load test, which has the gauge supported on a reference beam and movement monitored at the pier head (Figure 1).

A calibrated hydraulic cylinder and pump are connected to the bracket. Before the start of the test, an alignment load (typically 5-10% of the service load) is applied to take the slack out of the system. The loading and hold times required during the test vary from project to project, but for a proof test, you want to capture about 5 or more loading increments and about 3 or more unloading increments. Proof testing usually has a maximum load of 1.25 to 1.33 times the service load. The loads are applied and held constant at each increment for a specified period of time. Dial gauge readings are recorded at the start and end of each increment before proceeding. Additional dial gauge readings can be taken to monitor soil creep during the loading phase of the test.

Figure 1

The Issues:

The challenge with proof testing retrofit piers is that even after application of the alignment load, the bracket is often still not fully seated against the structure. During the early load increments, the bracket tends to move slightly upwards and rotate toward the structure. Given the geometry restrictions that prevent the use of a second gauge, it is difficult to capture accurate load versus total deflection data during the test. It is instead more feasible to monitor creep movement at specific load increments as an indication of pier performance. A common method of evaluating creep for grouted anchors or micropiles is to measure movement over a log cycle of time as verification of capacity. A portion of the data from this type of proof test is shown below. The log cycle measurements during this test were taken from 0.5 to 5 minutes, 1 to 10 minutes and 2 to 20 minutes.

The Analysis:

Since the deflection over a log cycle of time is an indication of how much soil creep is occurring at a specific load, it may be used to compare against an allowable creep movement as a failure criterion. For example, many grouted anchor and micropile proof test specifications allow 0.04 to 0.08 inches of movement between log cycles of loading. The pier data indicates less than 0.006 inches of creep movement between any log cycle of time (Figure 2). Using a specified maximum deflection over a log cycle of time as a failure criterion removes the measurement irregularities associated with bracket rotation and any elastic deformation effects in the pier shaft.

The theoretical elastic deformation of the shaft is determined from the traditional equation PL/AE. The elastic deformation is often compared to the load-deflection data from the proof test to quantify deflections associated with soil movement. For example, the load-deflection curve is almost parallel to the elastic deformation line and offset by about the same amount of deflection indicated from the bracket rotation (Figure 3). This indicates that the pier movement during loading and unloading is primarily from the elastic movement of the shaft, with very little soil movement at the pier tip.

In Summary:

Given the fact that push piers are installed exclusively in retrofit bracket systems, any pier testing needs to be performed with the bracket in place, which can lead to complications from bracket rotation upon loading. Despite this challenge, the log cycle of time creep method removes the effects of bracket rotation and elastic deformation from the analysis. This method allows the design professional to document pier performance beyond what is normally obtained during a typical push pier installation. If you have any questions regarding push pier testing, please feel free to contact the Foundation Supportworks engineering department.

Gauge Pressure (PSI)	Applied Load (kips)	% Of Design Load	Hold Time (min)	Gauge Reading (in)	Total Defection (in)	Log Cycle Defection (in)
3600	22.8		0.0	1.594	0.222	
3600	22.8		0.5	1.594	0.222	
3600	22.8		1.0	1.594	0.222	
3600	22.8	100%	2.0	1.594	0.222	
3600	22.8		5.0	1.590	0.226	0.004
3600	22.8		10.0	1.590	0.226	0.004
3600	22.8		20.0	1.589	0.227	0.005
4500	28.5		0.0	1.518	0.298	
4500	28.5		0.5	1.518	0.298	
4500	28.5		1.0	1.518	0.298	
4500	28.5	125%	2.0	1.518	0.298	
4500	28.5		5.0	1.517	0.299	0.001
4500	28.5		10.0	1.517	0.299	0.001
4500	28.5		20.0	1.517	0.299	0.001

Figure 2

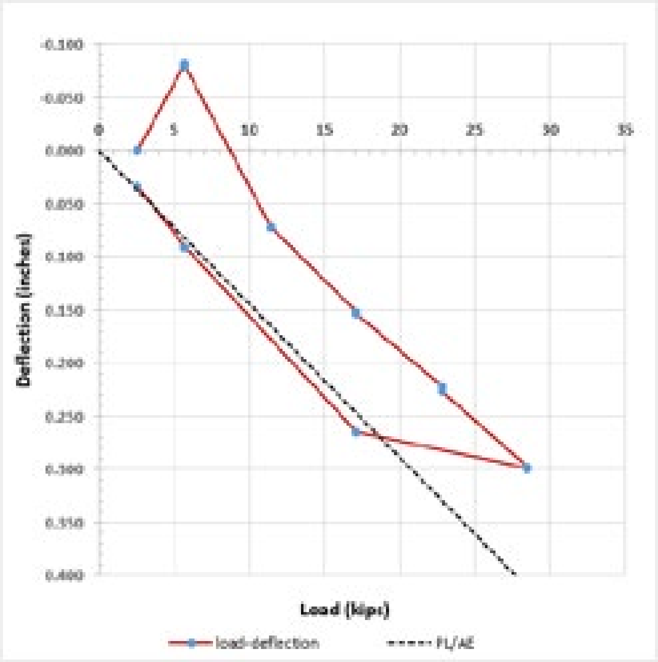

Figure 3

DON DEARDORFF, P.E.

Project: **Industrial Building Underpinning**
Location: **Phoenix, AZ**
Pile Installer: **Arizona Foundation Solutions**

Piers installed along the east wall

Lift cylinders attached to brackets

Lifted structure with brackets locked in final position at Southeast corner

Challenge: A 279,000 square-foot industrial building, constructed in 2013, exhibited significant wall and floor slab settlement, with more than 12 inches of movement at the southeast corner. Before the building was constructed, the site was initially used for mining sand and gravel. It was later used as an inert debris landfill for about 13 years. Records from the landfill operations indicated that the fill was composed primarily of soil, rocks, gravel, concrete and asphalt debris. A geotechnical investigation performed in 2007 identified about 50 feet of debris fill east of the subject property. Based on the recommendations in the report, deep dynamic compaction was selected for soil improvement before construction, to allow the use of a shallow foundation system. After the settlement had occurred, another geotechnical investigation performed in 2018 showed about 60 feet of debris fill at the southeast corner of the existing structure.

The building construction consisted of exterior concrete tilt-up panels and interior steel columns, both supported on shallow foundations. As a result of the settlement, the tops of adjacent tilt-up panels separated by as much as 8 inches, and their connections to the roof joists were compromised. A temporary shoring system was then required to support the walls and roof, in case of further misalignment. Given the amount of settlement and misalignment of the tilt-up panels, the ideal remedial method would first stabilize the structure and then potentially lift the walls back toward the original elevation. The interior column pads and floor slab in the southeast corner of the building would also require stabilization and minor lifting. Underpinning was required beneath 43 of the wall panels, with each panel being 26 to 41 feet long. Estimated service loads of the panels ranged from 7 to 14 kips per lineal foot.

Solution: Compaction grouting was chosen for the slight lift and stabilization requirement at the selected interior column pads and slab areas. Micropile and push pier systems were both evaluated as possible solutions for underpinning and lifting the exterior footings and tilt-up panels. Micropile installation would be difficult in the debris fill and would require casing to prevent grout loss within the anticipated void space. Casing would also be required to minimize downdrag forces on the micropiles, should consolidation of the fill continue to occur. Additionally, the micropile capacity would be dependent upon the bond strength below the debris fill, which was not well identified, and capacity could not be verified during installation. Push pier system capacity, on the other hand, is primarily dependent upon end bearing and can be easily determined by monitoring the drive pressure during installation.

The Model 288 (2.875-inch OD by 0.165-inch wall) push pier system with side-load retrofit brackets was ultimately selected to support and lift the tilt-up panel foundations. Given the installation challenges posed by the debris fill, installation would also include predrilling with a 3.5-inch diameter down-the-hole hammer to a minimum depth of 60 feet. Due to the cavity created by predrilling being larger than the outer diameter of the pier sections, each section of pier tubing would require field welding to connect them as they were lowered into the predrilled hole. The push piers would be installed on both sides of the footing (inside and outside) at the heavier panels to meet the service load requirements and to also maintain stability during the lift process. Before the lift, compaction grouting would be performed around the piers to densify and stabilize the soil mass.

Pier installation was completed in two phases; first to install enough piers to stabilize the exterior panels and minimize further movement, and then to install additional piers to have sufficient capacity for the lift process. After the second phase, the 303 push piers were generally spaced at 3- to 5-foot centers. The push piers had a 60-foot minimum depth requirement (to bear below the estimated debris fill depth) and a minimum final drive force of 54 kips to achieve a factor of safety of 1.7 or greater. Piers were required on both sides of the tilt-up panel foundations in most areas to achieve the required factor of safety. Pier depths generally ranged from 65 to more than 100 feet. The lift operations recovered most of the initial settlement; however, a fair amount of finesse with minor adjustments was required to bring the tilt-up panels to plumb. The work was performed over two years, between the initial evaluation, pier installation, grouting and lifting operations.

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