

Case histories on the use of helical piles for retrofitting and new construction

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ABSTRACT

The application of helical piles and anchors has expanded beyond lightly loaded and temporary structures to include medium and heavily loaded permanent structures subjected to both compression and tension. Helical piles provide an increasingly viable option in many different situations and offer benefits not available with more traditional foundation technologies. Several different instances where helical piles proved to be an effective solution to design challenges are examined and summarized.

RÉSUMÉ

Les applications pour les pieux d'acier vrillé et d'ancres ont répandu au-delà des structures temporaire à charge légère pour inclure, l'applications de structures permanente a charge moyenne ou lourde et en compression ou en tension. Les pieux d'acier vrillé son considéré de plus en plus, comme une option viable pour de nombreuses situations différentes et présente des bénéfices qui ne sont pas disponible avec la technologie traditionnelle de fondation courante. Plusieurs cas différents ou les pieux d'acier vrillé on prouve à être une solution efficace pour des design qui présente des défis, sont examiné et résumé.

1 INTRODUCTION

Helical piles and anchors have been used to support boardwalks in environmentally sensitive areas, to support tower foundations (new and retrofit), to support and lift existing structures, to augment existing foundations, soil nailing applications, heavily loaded piles in new construction, and retaining wall support and tiebacks (new and retrofit).

2 UNDERPINNING

Helical piles are often used in underpinning applications. They can be installed with minimal excavation around existing footings. Underpinning is useful for supporting foundations in close proximity to excavations and remediation, and for supporting and lifting foundations that have settled. The underpinning brackets can be used with hydraulic cylinders to raise foundations. The helical piles can also be sleeved to allow for excavation after installation without compromising the strength of the piles. A typical configuration including the bracket used in underpinning applications is illustrated in Figure 1.

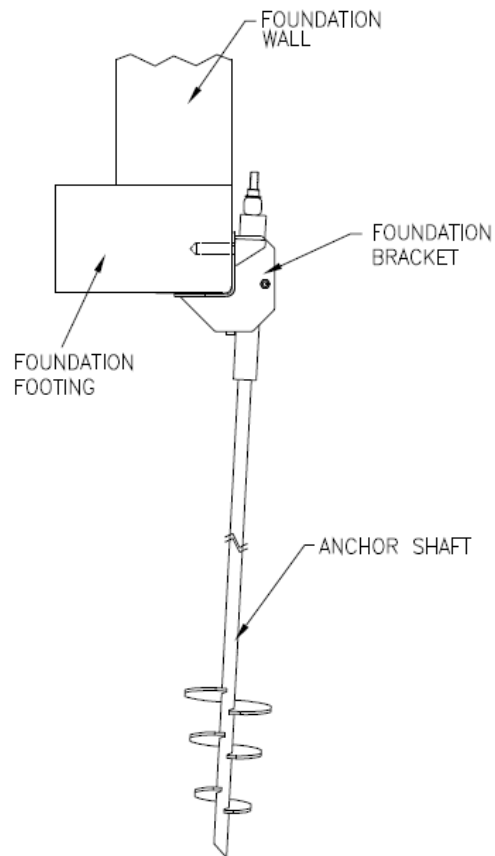


Figure 1. Typical underpinning assembly

The bracket is generally bolted to the concrete foundation using lag bolts. This can be modified to suit different situations including lumber and stone foundations.

2.1 Residential underpinning

Three residences were underpinned using helical piles. The buildings were constructed on structural fill, and within three months cracks were noticed. The movement was caused by a soft fill zone at the rear of the residences, and it was determined that movement was occurring both horizontally and vertically. These issues needed to be fixed without displacing the residents of the units.

A total of 50 solid steel, square shaft helical piles were utilized to stabilize the existing residential structure; 45 installed to resist 445 kN kips in compression, and 5 as tieback anchors to resist 356 kN in tension. The stabilization was completed quickly and effectively, and the homeowners were not required to move out during construction.

2.2 11-Storey residential underpinning, Richmond Hill, Ontario

In 1998, an 11-storey condominium was underpinned using square shaft helical piles. Figure 2 is a photo of the building.



Figure 2. Photograph of 11-storey residential building

The parking garage foundation walls, two columns and four shear walls of the building were undermined by dewatering efforts due to an artesian aquifer. The limited space in the parking garage and the presence of the aquifer meant more traditional support methods like driven piles or caissons were not viable.

Eighty-three (83) 50.8-mm solid steel, square shaft helical piles with 152-mm diameter grout columns were used to support this building. A compressive load test was completed on site, prior to installation, and ultimate loads of 667 kN per helical pile were determined. These high loads required special, heavy duty foundation repair brackets which are illustrated in Figure 3.

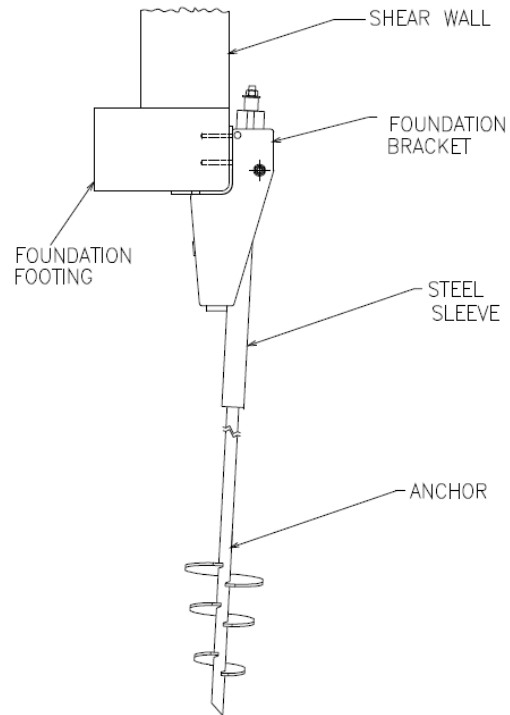


Figure 3. Heavy duty foundation bracket assembly

The bracket is significantly larger than that illustrated in Figure 2, and rated for ultimate loads up to 667 kN.

2.3 13-Storey residential underpinning, Toronto, Ontario

In 2003, a furnace oil tank leaked in the parking garage of a 13-storey apartment building in Toronto, Ontario. The building is shown in Figure 4.



Figure 4. Photograph of 13-storey residential building. After an investigation, petroleum hydrocarbon contamination was found in soils underneath the building, and immediate action was required. Multiple environmental remediation techniques were considered for this project, but in the end a remedial excavation where the soils could be removed safely and treated offsite was deemed the most effective solution in this situation. Traditional underpinning methods were considered, but column loads in excess of 2669 kN and limited head room in the parking garage made these options very expensive and time consuming.

Fifty-one (51) 44.4-mm inch solid steel, square shaft helical piles were installed, complete with 4.9-m steel sleeves and a 127-mm diameter grout column. Figure 5 is a drawing of the support of a column on this site.

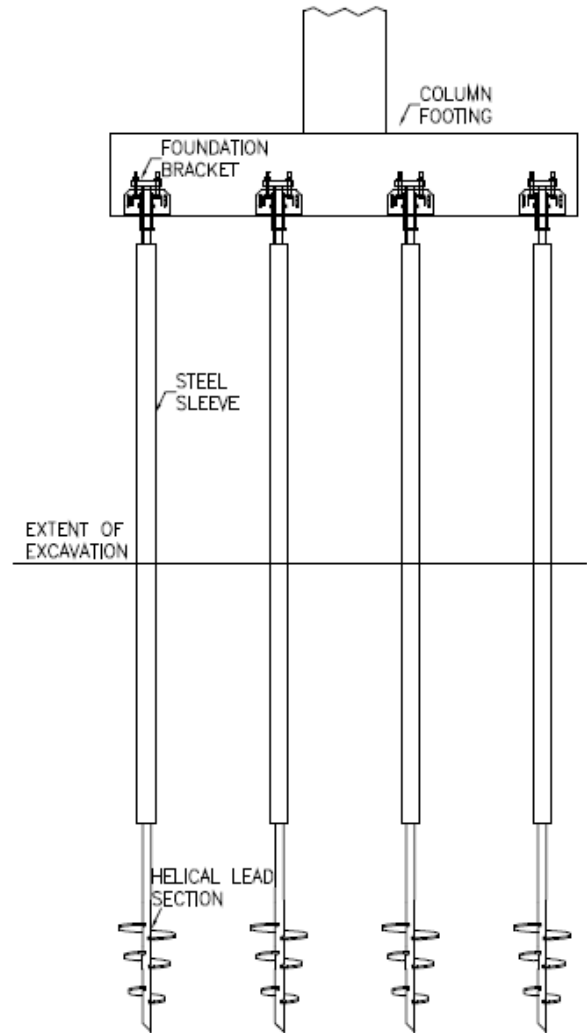


Figure 5. Underpinning and supporting during environmental excavation

Column footings as well as foundation walls were supported with the piles during excavation. The excavation was completed to a depth of 2.7-m below the base of the footing, and the contaminated soil was removed. This was completed with most of the parking garage remaining operational, and no residents were displaced. In order to minimize corrosion on these piles, the steel helical piles were hot-dipped galvanized. The grout column, as well as the steel sleeve, provide additional corrosion protection for the pile.

3 NEW CONSTRUCTION

Helical piles have traditionally been considered for light and medium loaded structures as well as in temporary applications. Original concerns with this technology for new construction applications included inefficiency due to load capabilities, and unacceptable deflection values. Load test data continue to indicate large load capabilities for helical piles with low deflection values. As a result,

helical piles in new construction applications are becoming increasingly viable. Projects have been successfully completed using helical piles in residential, commercial, institutional, and small and large scale industrial applications. Typical terminations for new construction projects are shown in Figure 6.

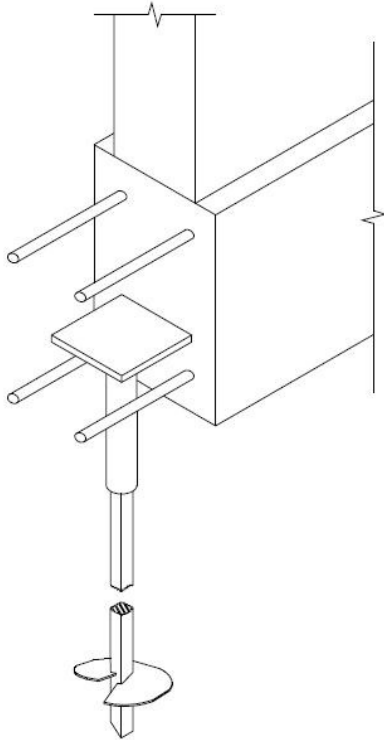


Figure 6. Typical new construction bracket termination

The bracket consists of a solid steel plate, and a round steel sleeve that fits over the helical pile. In tension situations, this bracket is either bolted to the shaft, or a steel plate is used instead and is welded to the shaft.

3.1 Mausoleum, Toronto

In 2008, a construction project took place at a cemetery in Toronto, Ontario. Construction involved large shoring walls, a pumping station, a masonry wall and a mausoleum. A photo of the completed mausoleum is shown in Figure 7.



Figure 7. Completed mausoleum

Space was limited and very valuable in the urban location, and construction noise and vibrations were a major concern due to the close proximity of residential areas.

The soils investigation revealed a deep foundation was required because surface soils did not have the strength for bearing the design loads on shallow foundations. Load tests on helical piles proved they were capable of resisting design loads. Nearly 200 solid steel, square shaft helical piles were installed on site for four different projects. The versatility of the piles combined with no spoils or vibrations made them the most efficient solution for many parts of this project.

3.2 Tiebacks for shoring, London, Ontario

In 2007, an access manhole for a sanitary trunk sewer was installed in London, Ontario. This required a deep excavation, and shoring had to be installed to support the surrounding soils. The site was in a forested area along the side of a creek, so minimizing the environmental impacts was important. Figure 8 is a photograph of the manhole after installation.



Figure 8. Fox Hollow sanitary trunk sewer manhole

A geotechnical investigation revealed the underlying soil consisted of a layer of 1.5 m layer of topsoil with a large layer of compact silt underneath. Installation of helical piles as soil anchors to tie back steel sheet piles was determined to be the most efficient method of shoring. They were capable of being installed with minimal environmental effects and they could resist design loads immediately. Thirty-three (33) 57.1-mm solid steel, square shaft helical anchors were installed and certified to resist working tension loads of 333 kN. The anchors were preloaded and terminated with threaded rod adapters.

3.3 Hotel and convention centre, Windsor, Ontario

In 2007, a large construction project including a five-storey underground parking garage in Windsor, Ontario was completed. The water table on the site was very high due to the close proximity of the Detroit River, subjecting the foundation to significant buoyancy forces. These forces meant the raft slab had to be tied down to adequate load-bearing soil below the bottom of the slab. Figure 9 is a photo of the project during construction.



Figure 9. Project during construction

Tension tests showed helical piles installed to approximately 21.3 m below the base of the slab were capable of resisting required loads. Helical piles proved to be the most viable solution in this situation, and 259 helical anchors were used on this project. 57.1-mm solid steel, square shaft helical piles complete with a 152-mm diameter grout column were used to resist ultimate tension loads between 444 and 734 kN. The piles were preloaded and terminated with custom designed brackets that were able to be installed after the raft slab was poured.

4 BOARDWALKS, WALKWAYS AND PEDESTRIAN BRIDGES

The use of helical piles to support boardwalks, walkways and pedestrian bridges is becoming increasingly popular. Helical piles are often the most effective system for this application for many reasons. Helical piles require no

soil excavation and installation can be completed with portable equipment. This is a key factor when boardwalks are being installed in wetlands or parks, where heavy machinery can have negative impacts on the environment and aesthetics of the site. In these situations they can easily be installed without a grout column, leaving the piles capable of fully supporting the ultimate load immediately after installation. This significantly reduces the duration of the project, and also provides increased opportunities for installation in situations that would normally not be feasible. Figure 10 illustrates the typical pile termination for boardwalk and pedestrian bridge walkways.

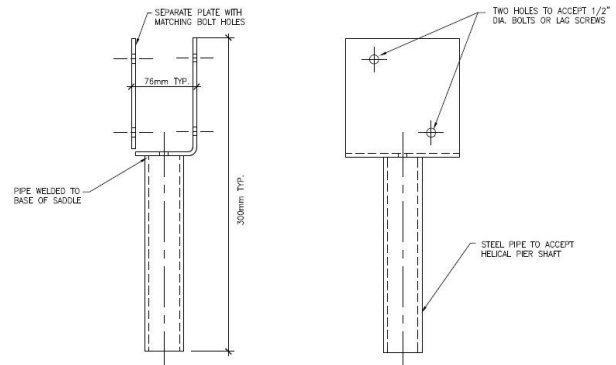


Figure 10. Boardwalk bracket termination

These brackets are designed for compression loads only and are ideal for attaching pressure treated lumber or other construction materials.

4.1 Boardwalk, Waterloo

In 2000, a boardwalk was built using helical piles as support in Waterloo, Ontario. The 3-m wide boardwalk was built around Silver Lake, as part of the park's trail network and supports multiple benches and gazebos. Figure 11 is a photo of a boardwalk supported using helical piles.



Figure 11. Boardwalk supported using helical piles

Based on the soil and site conditions, required loads, and project type, helical piles were recommended as the most efficient method of supporting this project.

A series of 117 helical piles were installed to a depth of 3.65 m below grade. 12 of these were 88.9 mm round, hollow steel shaft helical piles, with a 203, 254, and 305-mm triple helical configuration. These piles were installed to resist compression working loads between 78 and 201 kN, as specified by the design engineer. The remainder of the piles installed were 38.1-mm solid steel, square shaft piles with a double helical configuration of 203 and 254-mm diameter helices. These piles were installed to resist compression working loads between 44 and 122 kN, as specified by the design engineer.

5 LATERAL LOADING

Helical piles are an effective method of resisting lateral loading in many different applications. They can be installed on an incline/batter as required with no added installation equipment or difficulty.

5.1 Billboard support, Toronto, Ontario

In 1999, seventy-eight (78) 44.5-mm solid steel, square shaft helical anchors with a 254, 305, 356-mm triple helical configuration were installed to support a series of billboards as seen in Figure 12.



Figure 12. Billboards supported using helical piles

The billboards were located at the edge of an enclosure for a transformer station. The compression loads of the billboards was minimal, however, wind loadings resulted in high lateral and over-turning moments. Helical piles were used because installation could be completed in close proximity to the transformers, and the lateral loading could be resisted by installing them on 10° to 15° batters. Each pile was certified to resist an ultimate load of 400 kN.

6 CONCLUSIONS

As the number of projects successfully completed using helical piles increases, the level of familiarity and confidence also increases. Load test results continue to prove helical piles effective at resisting tension and compression loads, making helical piles an option for many different foundation designs. The many advantages of using helical piles, including no vibration

or spoils, the potential for installation without heavy machinery, and the load capabilities that were previously not considered with this system, present efficient foundation solutions for countless construction projects.

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