plans plus
architectural and structural design
konstantin ashkinadze, p.eng.
consulting engineer

#202, 8704 - 51 avenue
edmonton, alberta
t6e 5e8

phone: (780) 719-4188
fax: (780) 468-0059
web: www.planspls.com

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Abarent Construction Ltd.
11472–156 Street
Edmonton, AB T5M 3N2

STRATEGIES FOR FOUNDATION UNDERPINNING AND THE MERITS AND DEMERITS OF SCREW PILE UNDERPINNING

By: Konstantin Ashkinadze, P.Eng., D.Sc.(Eng.)

Screw pile underpinning is an emerging technology, gaining popularity from day to day. This is notwithstanding the fact that the screw pile technology has been in use for almost a century now. One of the most promising applications of this technology is in repair of failed residential and commercial building foundations. The gain in popularity of underpinning is attributable to the following factors:

1. In residential construction built 50 and more years ago, the original foundations were very poor. Typically, they were built using low brand cement; no reinforcing; without proper embedment into the ground; with piles far short of the geotechnical and structural requirements; without any design and often by unqualified and unskilled builders. As these foundations age, the problems with them start to compound and cause settlement, differential settlement, and damage to the overlying structures.

2. In many regions of the country, Alberta being one of them, the native surficial soils are unstable and can give rise to local subsidence depending on the changing weather conditions, groundwater regime, desiccation by tree roots and drainage works, as well as subsequent construction activities in the proximity of the foundation. Sometimes these events progress slowly over decades, leading to greater and greater distress.

3. Booming economy of the latter years in Alberta caused an epidemic of expansion in industrial, commercial and residential fields alike. Building and structural additions have become a fact of life and exert additional loads on foundations that were not designed for these loads.

Underpinning allows to provide additional support to the foundation already in place, avoiding the costly and sometimes plain impossible changeout of the existing foundation. Among the systems of foundation underpinning, we will name the following:

- cast-in-place concrete pile underpinning;
- grouted-in anchor (Dywidag micropile) underpinning;
- jacked-in steel piles;
- screw piles, and
- pull-down micropiles.

The idea of all these strategies is to resupport the existing foundation, isolating it from surficial soil movements and transferring the load onto deeper soil strata, unaffected by seasonal moisture and temperature cycle. However, different systems accomplish this goal in different ways.

All the named strategies use piles that are friction type, except for the screw piles that are downward-bearing. There is a belief that the piles used especially in residential foundation repair are bound to be friction type piles and that bearing type piles cannot be relied upon. To understand the rationale of this position we need to take a closer look at the geomorphology of the soils encountered in Alberta and through most of the Prairies.

With all the local variations the main gradation is as follows. Most of the surficial soils in the Prairie region are high plastic clays of glacial origin. These are sedimentary and lacustrine clays which have a potential to swell when wetted, or shrink when dried. These soils are also frost-susceptible and can heave substantially with formation of ice lenses in cold winters. The soil cohesion, which is the main parameter governing its strength, can degrade suddenly due to either desiccation in summer or flooding in spring thaw. It is this instability that causes the foundations to settle. Also, previous construction and utility-laying activities may have disturbed the native soil and replaced it with fill, often poor quality and with little or no compaction.

Below these surficial clays, at a depth of 20-30 feet, lie hard glacial tills. These tills, although also of glacial origin, have been consolidated by the pressure of overlying soils and exhibit substantial bearing capacity. Still farther down are dense sands of pre-glacial (Saskatchewan) formation and (starting from depths 50 to 60 feet) the native bedrock of the Canadian Shield.

The reason for the adherence to friction type piles is that the piles used in residential and commercial foundation repair, are relatively shallow and do not reach the hard tills. Bearing type piles are advantageous when there is a stratum of very dense, hard soil that they can bear on. If there is no such stratum, friction piles that distribute the load over a long length appear more feasible.

However, this was before the advent of screw piles. Being extensible, the screw piles can be installed to reach depths of the hard tills and even the underlying sands to assure firm bearing. Even if at a particular site, the competent soils are out of reach and bearing on a single surface does not provide the required capacity, lead sections with three or four bearing helices can be used, and even more can be added in extensions. This allows to achieve much of the same effect as in the friction piles, namely distribution of the load over a long length, which is advantageous in weak soils.

Having said this, let's discuss advantages and disadvantages of the commercially available types of underpinning systems listed above:

Concrete pile underpinning would utilize a drilling rig to drill holes in the ground adjacent to the troubled foundation. Reinforcement is installed in the drilled holes and piles are formed out of concrete. Then, you need to sub-excavate the existing footing, reinforce and pour a specially designed concrete cap which would transfer the load from the footing to the pile.

Some of the drawbacks of this method are: (i) the need to operate a full-size drilling rig in a limited-space environment; (ii) the need for large excavation and reinforcement; (iii) the hardship of outdoor concreting if construction is done in winter; (iv) longer construction period as the concrete needs to cure before it can be put under load; (v) casing is required and the drilling becomes much more difficult if groundwater is encountered.

With special drilling equipment, it may be possible to drill the piles right under the existing foundation and avoid the need for the cap. However, in this variant the existing footing needs to be braced and sub-excavated to a depth of at least 5 feet at the location of the piles.

Dywidag micropiles (GEWI® piles) are drilled micropiles with a steel core made of the GEWI® Bar with hot-rolled, continuous thread deformations on both sides. The steel core is sheathed by cement grout which acts both as corrosion protection and load transfer into the soil or rock. Some of the advantages of this system is that it can be installed with very compact equipment, under existing structures and inside buildings. This pile can be cut off and spliced at any point. Load transfer into concrete structures is arranged by means of special anchoring elements. It can be used to transfer tensile, compressive and alternating loads with equal ease. Continuing settlements can be prevented by the use of preloaded piles.

The drawbacks of this system are primarily cost – it is probably the most expensive underpinning system on the market, used mostly for heavy industrial applications – and the need to grout the anchors, which takes time. Also, this system gives no indication of the achieved capacity of the pile, which has to be correctly estimated at the design stage.

Jacked-in steel micropiles, instead of drilling, use downward hydraulic pressure to force cylindrical steel piles into the ground. The foundation is sub-excavated and an L-shaped bracket is bolted under the foundation. A pile is then formed out of hollow pipe steel sections and placed through the bracket. Connectors are set and hydraulic pressure applied to force the pile into the ground “until it hits bedrock or equal load bearing strata” (the last phrase was taken from a commercial pamphlet on these piles). The weight of the structure itself is used as a reaction to drive the pile to refusal.

Once the pile is loaded, it is locked off with high strength bolts. A rebar is inserted in the centre of the column, the column is filled with concrete and the excavation backfilled.

An advantage of this method is that the achieved downward pressure, to some extent, serves as an indication of the installed pile capacity. It is fairly fast, economical and can be accomplished using compact equipment, both outside and inside the building, although it is better suited for exterior installation. However, the drawbacks are many. First of all, since the piles are pushed down by compression, there is no guarantee that the pile remains straight in the ground. If it encounters a hard spot, it will have a natural tendency to deflect and bypass the hard area, thereby defeating the capacity.

When installed in clay, the phenomenon of “rest” of the soil, well-known to contractors installing drop-hammer-driven piles, will come into play. The very high capacity achieved today, may completely disappear tomorrow when the excess pore water pressure dissipates. Thirdly, last but not least, the use of the weight of the structure to force the pile into the ground, may jack the structure itself out of the ground, with secondary foundation and structural damage resulting.

The **Screw pile underpinning** technology is free from most of the drawbacks of other systems. These piles can be installed using compact equipment, thus the disturbance to the surrounding structures and the soil is minimized. They can be used to underpin interior bearing walls and column footings as well as the exterior walls. They utilize a pre-manufactured steel bracket to transfer the load from the footing to the screw anchor, with a minor need for sub-excavation and no need for concreting. Drilling through water bearing soils poses no problem at all.

The attained capacity of the pile is controlled by recording the installation torque, which is a more direct indication than is possible with any other type of pile. The installation is self-correcting: if soft soil is encountered at depth, then a longer pile will be installed to still attain the required capacity. This correction is not possible with conventional piles.

The straight shape of the pile is guaranteed regardless of the length and “rest” of the native soil is not a factor because the pile is not pushed into the ground – rather, the lead section, cutting through the soil, pulls the pile behind, sometimes with such a force that it drags the rig towards the hole! The pile, therefore, is always in tension, which is advantageous for steel performance. The strength or weight of the existing ailing foundation is not used for installation in any way.

The distributed nature of bearing of the screw anchors makes them akin to friction-type underpinning piles. However, if you are still not satisfied and want to add the power of the actual skin friction to bearing, you may use **HELICAL PULLDOWN™ Micropile** technology. It is essentially the same screw anchor underpinning but in addition to it, a grout column is constructed around the shaft of a helical (screw) anchor. A displacement plate is added to the anchor to form a void in the ground, which gets filled with pumped-in flowing mix grout.

Benefits of this system include: (i) additional capacity by combining end-bearing on the helical plates and skin friction along the surface of the grout column; (ii) resistance to buckling in weak surface soils; (iii) stiffer pile which deflects less at a particular load; (iv) additional corrosion protection in aggressive soils. However, in the opinion of the writer, structurally it is a less clean solution than a pure helical anchor. Not only the need for the grout to cure will slow down the installation, but also the “skin friction” part of the resultant capacity cannot be readily determined from the installation data, which is probably one of the most important advantages of the “pure” screw piles.

Conclusions:

The discussion above suggests that the screw pile underpinning is every bit as reliable as other, friction-pile-type underpinning strategies for supporting foundations in typical Alberta soils, and has important structural and technological advantages. However, to use it correctly, an engineer must be retained to assess the condition of the existing foundation. The former concrete wall which used to bear along its whole length on a strip footing, after the underpinning turns into a deep grade beam, which it wasn’t designed to be. The engineer must assess, based on the construction and the condition of the wall, how far it can span between the adjacent screw piles. He should also, based on the analysis of framing patterns of the house, calculate loads upon the screw piles. This information is necessary for the supplier of the screw pile system to correctly design the anchors. Often the design goes the other way: based on the available array of anchors, the engineer determines their allowable spacing under the tributary loads.

The choice of the strategy of repair, as well as the actual design of the repairs, should be left to a qualified Professional Engineer. This applies equally to any choice of the underpinning method.