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THE ROLE AND PLACE OF SCREW ANCHOR TECHNOLOGY IN FOUNDATION REPAIR

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Screw pile underpinning is an emerging technology, gaining popularity from day to day. One of the most promising applications of this technology is in repair of failed residential and commercial building foundations. However, the problem of foundation repair is much older.

Most of the surficial soils in Canada are 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. Ravines, valleys, slopes, underground creeks, or other discontinuities which are abundant in most of Canada, cause the soil to move sideways, forming cracks and tearing apart the foundations. 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.

The foundations themselves are also not without a flaw. The National Building Code of Canada still allows to build residential foundations out of unreinforced concrete, although it is widely recognized that the resulting savings are pennyworth. The reason must be the common belief that "conventionally built unreinforced concrete foundations have historically performed well under field conditions". Yes, new foundations, on average, perform adequately (if properly built); but as they age, problems with their structural strength start to compound. Note that only a small percentage of foundation failures become known to the engineering community.

However, most of the failed foundations are old ones, built 50-90 years ago. The quality of concrete used in basement construction in Canada has historically been less than perfect. In the first decades of the 20^{th} century, river-borne gravel and sand with high silt content were widely used in concrete construction. These materials, besides being weak, have near zero adhesion to cement paste and could not produce a solid concrete. The concrete is routinely diluted with water on site to improve workability (at the expense of structural strength). With low brand cement; no reinforcing; foundations built at grade with no footings; inoperational or nonexistent drainage systems; and so on, there is an endless supply of work for engineers and contractors involved in foundation repair and rehabilitation.

One may ask: why repair? Why not simply demolish it and build a new house from scratch? The reason is cost. To construct a new house may cost 5 to 10 times more than to repair a foundation. Besides, in many cases there is nothing wrong with the above-grade structure, even in an old house. Typically, it features sun-dried lumber for studs and floor joists, huge solid timbers for posts and beams, lath and plaster on the inside, and stuccoed lath on the outside of the walls. This forms an extremely strong and rigid box which could potentially stand for another 90 years. Roof framing is typically not as good (mostly because of faulty covers and insufficient attic space ventilation), but is nevertheless salvageable. In short, there is considerable residual value in these houses (some are declared of historical value), if only their foundations could be repaired.

Until recently, the prevailing way of reconstruction of a foundation under an existing house was to lift the above-grade structure up, demolish the old foundation in its entirety, build a brand new foundation and place the house back on it. However, this method is a) very expensive and b) very disturbing to the structure, considering its age and condition. In many cases, it is simply not possible because the structure won't stand a lift-up. In such case, one has to repair the foundation where it is, while still carrying all the loads exerted by the house above and the soil on the sides.

Out of the whole variety of foundation failures, we can distinguish the following 5 types:

- Foundation settlement, uniform or differential;
- Leaning or racking of the foundation;
- Bulging and cracking of the walls under soil pressure;
- Structural failure due to insufficient support, and
- Leaks.

The following methods are most commonly used for repair of foundations without replacement:

- ♦ Construction of a new preserved wood foundation inside the existing foundation,
- ♦ Shotcreting,

- ♦ Epoxy injection of the cracks, with or without structural reinforcing, and
- ♦ The use of underpinning technology.

A preserved wood foundation (P.W.F.) inside the existing foundation uses conventionally framed wooden walls built with preservative treated PWF grade studs. The new wall is placed inside the original concrete wall parallel to it, with a gap which subsequently gets filled with grout to ensure reliable transfer of lateral soil pressure. The new P.W.F. wall would then pick up all the loads from the upper floors and the retained soil mass. The solid barrier of grout also seals the inside of the foundation against leaks.

This method saves excavation, old foundation demolition, temporary bracing, and backfilling. It offers exceptional drainage and insulating value and secure structural support. Its drawbacks are the more complicated construction procedures and the fact that it takes away more of the basement space than other methods. It is best applicable to repair bulged, cracked and leaking foundations; not as readily applicable if the original foundation is settling or leaning.

Shotcrete ("gunite") is a method of application of concrete by conveying it through a hose and pneumatically projecting onto a surface. There are two systems in use: wet mix (shotcrete) and dry mix (gunite). The advantage of these systems is that forming is not required; the resulting concrete is stronger and denser than conventional concrete and reaches a high strength in a short period of time. When used for foundation rehabilitation, shotcrete or gunite is applied over a wire or rebar mesh secured to steel dowels driven into the existing concrete. This reinforcement and added thickness of concrete help supplement the strength of the original wall, level its irregularities and infill cracks.

This method is quick and highly technological. Among its drawbacks, we should mention the unknown degree of achieved success. Although many providers of shotcreting service claim that their system is "fully engineered", we haven't yet seen any engineer's report or investigation of its strength and performance. The existing concrete remains part of the wall section, forming its compression zone against the lateral soil pressure. The condition of this concrete often is such that it can hardly perform this role. Also, there is a concern that the blast-shot concrete will over time separate and spall off the original concrete. If used, this method can remedy bulged, cracked and leaking foundations, but again can't help if the foundation is settling or leaning.

Patching with epoxy mix injection is the least expensive but also the least effective style of repair. It does not restore the structural function of the walls, and after a while, the cracks usually reappear. The structural performance of this system can be greatly enhanced by using it together with gluing-on strips of fibreglass reinforced plastic which will then act as external reinforcing to the wall. The technology and materials are available but to the best of our knowledge, haven't been used in residential construction yet (although they are common in commercial construction). This method of repair, again, works best for local bulges, cracks and leaks, but it is not suited for settled or leaning foundations.

Screw pile underpinning is an answer to the market request for repair of the great number of settled foundations, built on fill or on unstable soil. Before them, underpinning of existing settled foundations, as well as failed grade beams and other foundations less than adequately supported vertically, was accomplished by conventional drilled concrete piles. This method utilized a drilling rig to drill holes in the ground adjacent to the troubled footing or (with special drilling equipment) under the footing or grade beam. Reinforcement was installed in the drilled holes and piles formed; then, the existing foundation was subexcavated and a specially designed concrete cap constructed to transfer the load from the foundation to the pile.

This method entailed many problems, namely: (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) the need for casing and the hardships of drilling when groundwater was encountered. Most importantly, it was suitable for exterior walls and grade beams only.

Screw pile underpinning eliminated most of these concerns. The screw 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 premanufactured steel bracket to transfer the load from the footing to the screw anchor, with a minor need for subexcavation and no need for concreting. Drilling through waterbearing 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, which the designer had no way of knowing without a geotechnical investigation, then a longer pile will be installed to still attain the required capacity. This correction is not possible with conventional piles.

Therefore, screw pile underpinning is suited ideally for supporting settled foundations on unstable soils or fills. 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 their 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.

For leaning foundations, which are not sufficiently braced to remain vertical under differential soil pressure or due to internal distress, a feasible solution is **screw anchor tieback system**. In this case, the screw anchors are installed essentially horizontally or with a slight inclination to the horizon, reaching stable soil in the base of the hill to counterbalance the soil pressure. A similar solution can be used for bulged walls, although in our opinion it is not as efficient as stabilizing from the inside by PWF framing, shotcreting or external reinforcing.

Conclusions:

– The screw pile underpinning strategy is best suited for supporting settling foundations on unstable soils, when the foundation itself is in a relatively solid state, and for supporting foundations in structural distress by reducing their spans.
– The screw anchor tieback system is best when the foundation as a whole is leaning.
– In case of local bulges, cracks, or leaks, other methods such as inside PWF framing, shotcreting or external reinforcing, are more efficient, although screw anchor tieback system can also be applied to reduce bulges.
– The choice of the strategy of repair, as well as the actual design of the repairs, should be left to a qualified Professional Engineer.

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