Soil Nailing Earth Shoring System
A Ten-Year Update

Southern Ontario Experience

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In the past forty years, one of the major trends in earth retaining structure design has been toward reinforcement methods which improve the internal strengths of soil masses sufficiently to make them self supporting. These methods include the New Austrian Tunneling Method (NATM), Reinforced Earth and Soil Nailing.

Soil Nailing and a number of related ground improvement methods are descendants of the NATM, which involves the use of rock bolts and reinforced shotcrete for support in tunnel excavations. Soil Nailing is an in-situ earth reinforcement method which enables an earth mass to achieve a state of self-support through the introduction of driven or grouted steel bars (called nails) into the mass during excavation and exposure. The excavation face is supported by a weather-resistant facing, most commonly shotcrete.

Origin

Soil Nailing has been used for excavation shoring and slope stabilization in France and Germany since the early 1970s. In Canada, its use has been predominantly in the temporary excavation shoring market in areas of western Canada. In Vancouver, a hybrid soil nail system referred to as Tied-back Shotcrete has captured the temporary excavation shoring market. The more conventional soldier pile shoring support methods, which dominate the Ontario industry, remain nearly extinct in Vancouver.

Soil Nailing techniques have been used for excavations to depths of 20 metres in Canada (Edmonton Light Rail Transit) and up to 30 metres elsewhere in the world. The deepest known cut in Ontario is 11 metres. Soil Nailing/ground improvement methods can also be used for shored excavations with large building surcharge loadings. This is common in Vancouver, but was inaugurated in Ontario only last year (see accompanying Brantford General Hospital project description).

This paper describes the fundamentals of the Soil Nailing method for temporary and permanent excavation support. It analyzes system strengths and limitations relative to conventional soldier pile methods, and the slow adoption by the Ontario market, with primary focus on the Metro Toronto market.

Reinforced Earth

In the late 1960s, gravity walls comprised of earth masses reinforced with metal strips were introduced as an alternative to anchored structures. This lateral retention technique,

called Reinforced Earth, is economical since the main structural component is the in-situ earth. Its limitation, especially in the case of temporary excavation shoring, is that the full excavation must be carried out first and the wall erected from bottom to top. Soil Nailing proceeds almost in reverse. By using the in-situ soil, it allows for the simultaneous construction of the shoring support as the excavation progresses downwards.

A Soil Nailed retaining structure is comprised of three main elements – the soil being retained, the artificially-introduced earth reinforcements, and the facing. Such a structure attains the capability of self-support from the shear and tensile strengths of the reinforcing, which increase the overall shear strength and self-supportability of the in-situ soil. These tension elements are typically steel reinforcing bars, driven or drilled and grouted into place.

The construction of a Soil Nailed wall proceeds from existing grade down in 0.5 to 2.0-metre steps depending on the soil type. Soil nails are installed at each lift and a facing, typically reinforced shotcrete, is applied to the exposed soil face. The installation specifics vary with soil type and stratigraphy, water conditions, site access, local material availability, contractor preference and intended structure longevity. The nail spacing and length (typically shorter than conventional tie-back anchors) depend on the in-situ soil properties. Nail densities typically vary from 0.2 to 1 nail per square metre, and lengths vary from 40 to 100 per cent of the excavation depths.

The timing and methods of nail installation, facing application, and drainage introduction can drastically affect the performance of a Soil Nailed wall. While these operations are all intended to increase the soil structure's strength, their execution can result in unacceptable deformations.

Soil Nailing has proven itself as a viable alternative to soldier pile shoring systems in a variety of soil types in Europe, Asia and North America. Its main competitive advantages are cost, flexibility and performance.

1) Cost

As the main structural ingredients are usually the in-situ soil, medium grade steel reinforcing bars, and a relatively thin concrete facing reinforced with steel mesh, material costs are low. Concrete and steel quantities are usually less than those used in soldier pile and lagging shoring, and Soil Nailing does not use any timber. Only light construction equipment is necessary; as a result, mobilization, preparation and maintenance of working platforms and site access can be more timely and economical than with conventional heavy machinery.

2) Flexibility

Soil Nailed systems more readily conform to the shape of complex building perimeters, and where site conditions vary from borehole or other preconstruction information, generally offer more economical adaptation to change. Unlike conventional methods,

which require vertical pre-drilling to depth, Soil Nailed structures are created as the excavation proceeds. Hence, on a fast-tracked project where a midstream decision on basement depth is made partway through the excavation process, selection of a Soil Nailed system would likely yield considerable savings on shoring costs for the developer.

3) Performance

Research to date shows that Soil Nailed walls in competent soils generally perform as well as conventional shoring systems. Into-site deflections generally range from 0.1 to 0.3 percent of excavation depth, which translates to 10 to 30 mm for a 10-metre excavation. To date, observations of instrumented sites in southwestern Ontario have show maximum lateral movements of 0.02 to 1.0 percent. In full-scale load tests to failure, Soil Nailed wall generally have been able to undergo larger total and differential settlements than conventional systems before collapse. With so many reinforcing members, Soil Nailed structures are inherently more structurally redundant than conventional shoring.

Limitations

As with all earth retention systems, Soil Nailing has limitations. It requires a soil capable of standing unsupported while a facing is applied. Installation in free flowing sands would necessitate either short vertical lifts (less than 0.5 metres per lift), the cementation of the soil by grouting techniques, or the installation of vertical face-supporting members prior to excavation. Nailing also becomes technically and/or economically unfeasible in soft soils, particularly saturated clays or hydraulic fills, which are difficult to drain. The saturation and creep characteristics of these soils can adversely affect the nail bond strength and the structure's deformation behaviour.

Another significant roadblock to Soil Nailing in developed urban environments is the presence of man-made obstructions under street allowances; most commonly these are utility conduits and associated underground structures, but can include building mechanical rooms and basements, or subway structures. Where under-street obstructions are too numerous or of impractical geometries, installation of nails is at times too risky and/or not possible.

Whether or not a Soil Nailing (or hybrid) method is feasible for the support of existing buildings in the influence of an excavation is highly dependent on the building loads and geometry, and the strength of the supporting soils.

As with other anchored retaining systems, the use of permanent Soil Nailed structures in aggressive soils has been limited while research is conducted on the long term abilities of reinforcement protection systems. Recent use of nails using the time-proven approach of 'sacrificial' steel, has proven to be cost effective and appears to be a valuable trend particularly where on-site design flexibility is important.

Most excavations and retaining structures in Ontario are constructed in relatively competent glacial soils and weathered rock ideal for Soil Nailing and other in-situ earth reinforcing techniques. Since the 1987 entrance of a Vancouver-area contractor into the Toronto market, approximately 60 Soil Nailed/ground-improved earth retaining structures, including at least three permanent installations have been erected by a total of six Golden Horseshoe area contractors.

Continuing Slow Adoption

Despite the potential cost savings and convenience offered by Soil Nailing methods, conventional techniques are still employed for over 90 percent of such earthworks in Southwestern Ontario and it appears, at least for the short-term, that Soil Nailing/ Shotcrete methods will thrive primarily in a niche market representing less than 25% of the total. There are a few salient explanations for the slow adoption of Soil Nailing methods in this large and well-suited market. Based on experience and discussions with contractors, developers, design consultants, and local governing authorities, the following postulations are made:

1) Lack of Familiarity with the Technology

This applies to all the local groups to varying degrees. Despite a 15-year presence in the area, people are still relatively unfamiliar with the method and its appropriate applications. As with the introduction of earth anchor tie-backs to Toronto in the late '60s, designers, developers and governing authorities are still reticent to use what they consider 'new technology' in Soil Nailing. Contractors, designers, and developers, still reluctant to be the "guinea pig", are content to wait, watch and learn from others' experiences first. Most want to see concrete evidence of system performance, both physical and economical.

2) Economic Issues

Despite a number of Soil Nail project successes, the competitive market in Southwestern Ontario ensures that developers, designers and contractors compete fiercely for work. In order to maintain attractive price structures, they try to avoid risks, including growing pain risks endemic to new methods, the purchase of new plant while existing plant remains inactive, and the hiring, training or retraining of staff.

Soldier pile shoring in Ontario is commonly used as a wall backform, with the regularly-spaced soldiers used to support the forms. Though soil nailed walls are also used as backforms (at additional cost and effort), the close and irregular spacing of the nails usually precludes their use to support the forms. The need for internal forming shores can add time and expense to a project.

Smooth progress in the construction of a Soil Nailed wall demands close cooperation between excavation staging and wall installation. Construction staging is both novel and more complex in soil-Nailing than conventional shoring, as more steps are needed.

Coordination between the excavator and the shoring contractor is necessary to ensure that the work proceeds efficiently.

Though acceptance of Soil Nailing by owners, contractors and building officials is now more common, further proof of its performance and applicability in different soil types is still wanting. General knowledge as to its appropriate application remains limited.

Major Developments in the Last 10 Years

"Self-drilling" Nails

An illustrative misnomer, "Self-drilling" Nails are hollow-core drill rods, which, with the help of a sacrificial drill bit allow drilling in collapsing soils by very simple drills. The need for drills which advance casings can be almost entirely avoided by these bars which have made a real entrance into the marketplace in the last 5 years. Quite simply, these hollow-core rods serve as drill rods, the conduit for continuous hole grouting during drilling, the injection tube and the nail reinforcement. Also applicable as vertical mini- or micro-piles, these rods and their relatively straightforward use (using low-cost, flexible drills for installation) as vertical and horizontal reinforcements will have a positive impact on the feasibility of broader Soil Nailing and hybrid application.

First Permanent Soil Nail Retaining Wall

The first permanent Soil Nail wall in Toronto was installed this year. In an ideal application of the method, an undeveloped hillside plot was made viable due to the installation of a permanent Soil Nail wall. The owner said the method offered savings of roughly $200,000 over a conventional solution he had priced.

First Soil Nail Hybrid Wall support of a Major Structure

The implementation of the Vancouver-based Tied-Back Shotcrete Shoring method at the Brantford General Hospital project has established, in the eyes of some, the viability of ground improvement methods in the local market. Its performance matched that expected for the conventional continuous caisson wall (diaphragm) method which was specified as the base scheme at the time of tender.

Projections for the Next 10 Years

Soil Nailing methods have proven themselves a valuable addition to the site development tools in Ontario. Extensive international and western Canadian construction and research experience, coupled with a small number of recent local successes have proven the system's viability. With suitable conditions and good control, these systems can offer cost and time savings for developers, easier site access, greater flexibility, and performance comparable to conventional temporary and permanent earth retention

methods. However, given the present level of experience and confidence in drilled shoring methods, the large investments in plant and personnel training, and prevailing competitive market conditions, conventional techniques are likely to retain the majority of the industry market.

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Joined Isherwood Associates, foundation and geotechnical construction consultants in Mississauga, Ontario in 1987. Since then, he has been involved in the analysis, design, and monitoring of approximately 300 shored excavations, including 20 Soil Nailed/ground improved walls in southern Ontario. He has particular interest in the effect of shored excavations on adjacent earth and building movements and in-situ soil reinforcing techniques. Enquiries: Tel. (905) 820-3480.

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