Soil Nailing
Earth Shoring System

Southern Ontario Experience

By Nadir Ansari, P.Eng.

In the past thirty years, the trend 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.

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 downtown Vancouver, a hybrid soil nail system called the "Ground Control Method (GCM) has captured the temporary excavation shoring market. The more conventional soldier pile shoring support methods, which dominate the Ontario industry, have become 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 has been 8 metres. Soil nailing/ground improvement methods can also be used for shored excavations with large building surcharge loadings. This is common in Vancouver, but yet to be used in Ontario.

This paper describes the fundamentals of the soil nailing method for temporary and permanent excavation support. It analyzes system strengths and limitations relative to the conventional soldier pile methods, adoption by the Ontario market, with 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 and alternative to anchored structures. This lateral retention technique, called Reinforced Earth, is a very economical as the main structural

component is 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 increases 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

Where site conditions vary from borehole or other preconstruction information, soil-nailed systems 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 shown that soil-nailed wall movements 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 0.1 to 0.2 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 very short vertical lifts (less than 0.5 metres per lift) or the cementation of the soil by some grouting techniques 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 reinforcement to soil adhesion and the structure's deformation behaviour.

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.

Most excavations and retaining structures in Ontario are constructed in relatively competent glacial soils and weathered rock ideal area for soil nailing and other in-situ earth reinforcing techniques. In 1987, the entrance of a Vancouver-area contractor into the Toronto market precipitated the erection of 25 to 30 soil-nailed/ground-improved earth retaining structures, including one permanent, instrumented structure by a total of four Golden Horseshoe are contractors.

Slow Adoption

Despite the potential cost savings and convenience offered by soil nailing methods, conventional techniques are still employed for roughly 90 percent of such earthworks in

Southwestern Ontario. There is no single explanation for the slow adoption of soil nailing methods in this large and well-suited market. However, based on experience and discussions with contractors, developers, design consultants, and local governing authorities, some credible conjectures can be made.

1) Lack of Familiarity with the Technology

This applies to all the local groups to varying degrees. The system is new in the area and people are unfamiliar with it. As with the introduction of earth anchor tie-backs to Toronto in the late '60s, designers, developers and governing authorities are reluctant to use what they consider an untried system in soil nailing. Many contractors, designers and developers, 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.

2) Financial Climate

The number of construction projects being undertaken has reduced drastically, and, in order to survive, developers, designers and contractors are competing fiercely for work. In order to maintain attractive prices, they are trying 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.

Before the construction slow-down, soil-nailed walls used to offer potential savings of approximately 30 percent over other methods. However, conventional shoring prices are now 20 to 30 percent below pre-recession levels. Thus, the saving of soil-nailing are reduced, and other related costs often tip the scales in favour of conventional methods. Soil-nailed wall construction costs roughly $125 per square metre ($11.50 psf) for a typical application. Tie-back soldier pile and lagging shoring is presently selling for approximately $140 per square metre ($13 psf), largely due to the efficiency of local lagging crews and union cooperation.

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, the close and irregular spacing of the nails usually precludes their use to support the forms. The use of 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 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.

Most parties agree that widespread acceptance of soil nailing will require proof of its performance in the form of extensive, accurate monitoring of the behaviour of many walls in different soil types. Monitoring is a cost which many developers have been

avoiding in order to keep costs down. The result is that very little local performance-related information is available to the public.

Local Review Process

Some locations, such as Toronto, have lengthy formal construction drawing reviews. While as many as 13 utility and city departments review the proposed design for interference with services and general structural competence, construction can be delayed up to six weeks after the contract has been awarded. In response, owners often retain their structural consultants to prepare temporary earthwork designs in advance of contract awards to speed up this process. However, this fast tracking procedure typically does not include design alternates in the tender package, nor does it allow for the inevitable time delay for review of materially different design alternates.

Unlike most jurisdictions, the City of Toronto's Public Works Department requires that all shoring structures be monitored. Lateral movements of 13 mm must be reported and movements of 25 mm generally require immediate remedial action. Movements of buildings adjacent to shored excavations are also commonly monitored.

Relatively extensive monitoring has long been an owner's obligation on construction sites, tions. Monitoring of soil nailing performance elsewhere in Canada has been very limited and hence Toronto authorities are wary about its performance characteristics.

Soil nailing methods are a valuable addition to the site development methods in Ontario. Extensive international and western Canadian construction and research experience have proven system viability. With suitable conditions and good control, these systems can offer cost savings for developers, easier site access, greater flexibility and performance comparable to conventional earth retention methods. However, given the present level of experience and confidence in drilled shoring methods, and present market conditions, conventional techniques are likely to retain their large share 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 100 shored excavations, including 10 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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