Soil Nailing at the Home Depot

Construction of a new Home Depot in Gladstone, MO, near Kansas City, had an interesting foundation problem. The site was limited and highly contoured. The building required a store entrance at grade level and a rear shipping/receiving area about 30ft. below grade. A 1,000ft-truck ramp along the side of the building was needed that would drop the required 30ft and provide rear area storage. However, because the site was tightly limited, the ramp would come as close as 25ft from the property line. Generally, the most cost efficient means of excavating a foundation is cut and slope, but in this case, the surface could not be cut back enough to avoid slope failures without disturbing the neighboring property. Therefore the soil had to be reinforced to modify and control its behavior so that a vertical retaining wall could be built requiring far less land.

Traditional methods

Traditional thought in US foundation engineering has been to retain a wall either by cantilever, anchoring a reinforced concrete wall into the strata below and depending on its own mass to retain earth, or by horizontally tying back a thinner wall with pretensioned anchors. Tiebacks are steel bars equipped with an anchoring device drilled through the soil past its failure plane into unaffected soil that has the capacity, like rock, shale, etc, to withstand the desired load. The tiebacks are prestressed to prevent movement and designed to hold the load of the full height of the wall. Minimum load is considered to be the dead load of the soil weight in the slip plane of the full wall height and the bars are designed accordingly. The failure ratio for this soil was determined to be approximately 1:1. For a 30ft wall, the anchors would have to be embedded over 30ft through the failure zone plus an anchor distance into more solid soil. This meant anchoring in the neighbor's site. Easements were needed but could not be negotiated, so a tieback wall design was abandoned in favor of a cantilevered wall. The cantilevered wall was designed to be 5ft thick and keyed 25 feet deep into the underlying competent limestone.

Alternate proposal

The Judy Company, a Kansas City geotechnical specialty contractor, bid on the foundation work in conjunction with Gernot Ueblocker, a geotechnical engineer then with Golder Associates, and now with Ground Enhancement, Inc. They proposed an alternate method of securing the retaining wall by "soil nailing" , a procedure that would allow a permanent, relatively thin wall built and secured without crossing property lines and without the expense of the excavation and construction of a massive cantilever wall. The proposal saved $1,000,000 over bids using the cantilevered wall approach, and the method was sound and proven, and the Judy Company was selected as the foundation wall contractor.

Concept

Soil nailing reinforces the soil within a failure zone to make it behave as a monolith, much the same way as lumber acts after having been nailed together. The process is done from the top down, that is, soil is excavated and secured, or "nailed", in small lifts, starting at the surface. Residual stresses in the soil of the slip plane act on the grouted mass of bar in grout and "nails" itself. The great advantage of the technique is that it allows soil retention in very tight areas at any configuration and at competitive costs to other proven techniques such as tiebacks Once a lift is secured it becomes self-supporting, able to permanently hold itself in position as the excavation continues. The use of structural bars as "nails" has grown extensively in use in Europe over the past twenty years and is rapidly gaining acceptance in North America

To give the advantage of soil nailing perspective, consider the more traditional approach of tying back a wall. Long steel beams called "soldier piles" are drilled and grouted or driven vertically into soil before excavation the length of the entire wall height. As excavation proceeds, walers and wood lagging are placed between the soldier piles. The load plane is taken from the entire wall height, and the bar diameter, length, and anchor are designed accordingly. The bars are prestressed to engage the anchor and prevent lateral movement. As mentioned earlier, the anchors must reach completely through the soil failure zone until competent rock is located, because all loading is transferred through the anchor, ignoring the soil residual stresses. Only the ability of the anchor is considered for withstanding load.

Case study

On the Home Depot site, the initial wall excavation was a 6ft cut into the slope for the 1000ft length which included an inside and an outside corner. Although the wall lifts were to be 5ft, the initial 6ft included 1ft of overcut to allow a tie-in to the next, lower, lift. A mobile drill rig on tracks was brought in and drilled 8inch holes at an angle laterally into the failure zone and at the spacing specified by the designer. Eight inch holes are considered extra large but were chosen to be used with 1" diameter bars to present a very large friction surface to the soil.

The holes were then filled with sanded cement grout delivered from a nearby batch plant, and the bars were inserted into the wet grout.

The soil nail bar type chosen was "multiple-corrosion" protected, standard for permanent soil nail applications. At the factory, bars are epoxy coated, and a corrugated, plastic sheath is placed over it and grout is inserted between the bar and sheath, constituting two measures of corrosion protection, with the third being the grout in the drilled hole. The bars were fitted with plastic centralizers to ensure even encapsulation by the grout. The bars were placed in the holes with about 6 inches protrusion, and a steel plate with headed studs and nut were installed to integrate the wall with the bar.

Next, a vertical face drainage system was installed, which prevents hydrostatic buildup Hydrostatic pressure can quickly increase wall loading beyond design parameters. The drainage system consists of manufactured panels cut into strips placed in vertical and horizontal directions along the excavation cut face, allowing water to enter from either the surface or subsurface and providing drainage to grade. The drains are held in place by small soil anchors hand pushed into the soil wall. (photo of completed drain system with mesh)

Welded wire fabric mesh was then applied along the vertical cut face. Recall that the initial cut was made at 6ft to allow for a 12in tie-in to the next lift, so the mesh extended down below this section of wall by 12 in. After the mesh was in place, the lower 12-in. was backfilled, covering the mesh.

With the mesh and drainage systems secured, "hard-facing" was applied. Facing is a surfacing coating designed to keep the soil facing in place. On most retaining walls, a hard facing is applied which is usually a sprayed concrete or "shotcrete." However, in the case of slope protection or earth retention, a vegetative cover can serve as "soft facing". For example, a geotextile fabric can be used that allows grass or vegetation to grow through it, as in the case of roadway side slopes.

In this case, a structural wall was required, so hard-facing was required. A 6 inch thickness of small aggregate, 4000psi, shotcrete was sprayed on the 5ft depth, covering the mesh and bar ends, and then troweled for a finished wall appearance. The lift was finished and considered to be self-supporting.

The next lift was then excavated 6ft, exposing the overlap mesh from the first lift and another 5ft for wall construction. New holes were drilled, bars installed, and the process was repeated for 6 lifts.

Once a new lift is cut, the retained soil from the upper lift is allowed to move, loading the nails in tension. Movement was measured at a maximum of 0.1in. / lift, and the total for the entire completed wall was 0.3 inches.

Total area for the wall was approximately 20,000 sq.ft., with a length of 1000 ft. Each lift averaged just under one week from excavation to shotcrete, and the entire project was completed in 40 days despite working during winter months.

Summary

To summarize, soil nailing was chosen as the most appropriate technique for several reasons, the most important being:

- the technique can be performed on a very tight building site
- relatively inexpensive construction costs- soil nails are relatively short because they act in friction, using the soil residual stresses in the slip zone to reinforce itself.
- soil nails use the entire length of the bar to act upon the soil.
- most cohesive soils or broken rock soils are adequate
- no prestresssing, saving labor and time
- no foundation base- retaining walls are secured laterally into the side soil, so there is no need for piles or foundation footers
- excavation and wall construction proceed together, saving schedule time
- no independent shoring system is required.
- no concrete foundation walls need to be formed and placed- walls are hard-faced by shotcreting over bar ends and reinforcing mats and trowel-finished.
- Soils nails can be inserted through different strata of soils, minimizing the impact of changing geologic strata
- The drainage system employed prevents water buildup (pressure), eliminating hydrostatic forces.

Soil nailing requires a great deal of craftsmanship and geotechnical knowledge to design and construct a system, but with the right soil and site conditions, it is a rapid and economical means of constructing earth retention support systems and retaining walls.