RETENTION WALL SYSTEM

SOIL SCREW® RETENTION WALL SYSTEM
SECTION 9

CONTENTS

SYMBOLS USED IN THIS SECTION

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

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Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

INTRODUCTION

Hubbell Power Systems, Inc. provides the SOIL SCREW® Retention Wall System as an efficient and economical system to retain soil during excavation and construction of structures below grade. The following are some of the advantages of this system over other soil retention methods:

- Fast installation without specialized equipment;
- Immediate support without curing time;
- Reduced installation time - post-tensioning not required;
- No need for H-piles, walers and heavy reinforced walls;
- Immediate on-site capacity verification; and
- Excavations adjacent to existing structures are possible when used with ATLAS RESISTANCE® Piers or CHANCE® Helical Piles;

The CHANCE® Underpinning/Shoring system provides for underpinning existing shallow footings, permitting excavation adjacent to the existing structure to a depth that would otherwise undermine the existing footing. The system allows excavation to proceed directly adjacent to an existing building without fear of vibration or structural damage to the building.

Commercial property owners often want to construct buildings with maximum possible footprints and a basement to maximize the potential of the site. If there is an existing building with a shallow footing adjacent to the proposed construction site, that building will need to be protected against damage from settlement due to removal of the soil that is laterally supporting the existing footing. Similar protection is required when a sloping excavation is cut next to an existing shallow footing in order to construct a building, parking lot, or roadway adjacent and down-slope of this footing.

The SOIL SCREW® Retention Wall System is designed to provide protection to the existing structure by using a combination of foundation support products. ATLAS RESISTANCE® Piers or CHANCE® Helical Piles are used to underpin the foundation of the existing structure. The structural load from the shallow footing is transferred down to a suitable bearing stratum below the depth of the intended excavation. The SOIL SCREW® Retention Wall System, combined with a reinforced shotcrete retaining wall is then used to maintain stability of the cut slope and the underpinning system as the excavation proceeds. For some conditions CHANCE® Helical Tieback Anchors can be used at the underpinning bracket to further ensure against lateral footing movement of existing buildings.

Other methods require the use of impact driven “soldier” piles. The major disadvantages to this system are the equipment size, noise and vibrations caused by the installation of the piles. This can be bothersome, annoying and stressful to the occupants of surrounding buildings, could damage sensitive electronics and/or could cause settlement of the building being protected. Because the CHANCE® Foundation Stabilization System and support uses hydraulic power for driving the underpinning, helical tieback anchors, and Helical SOIL SCREW® Anchors, it is extremely quiet and practically vibration free, thus allowing full use of neighboring buildings during the construction process.

PRODUCT BENEFITS

CHANCE SOIL SCREW® Retention Wall Systems offer the following benefits:

- Low installed cost
- No vibration
- Shorter installation lengths
- Ease of installation in limited access areas
- Minimum disturbance to site
- Immediate loading
- On-site load test capability
- Reusable in temporary stabilization applications

SYSTEM DESCRIPTION

The CHANCE SOIL SCREW® Retention Wall System creates an internally reinforced soil mass when closely spaced in a regular geometric pattern and protected by a reinforced facing of shotcrete. It differs from helical tieback anchors even though the appearance of the products is similar.

A tieback restrained wall is generally constructed by installing a structural wall facing system that is anchored to the earth by means of high strength helical anchors that are installed to a stratum of soil of sufficient strength to resist the forces placed upon the wall by the retained earth. The helical tieback anchor experiences a tension load equal to the retained earth forces. The structural retaining wall must be designed with sufficient strength to be able to support the soil load between tiebacks without excessive deformation.

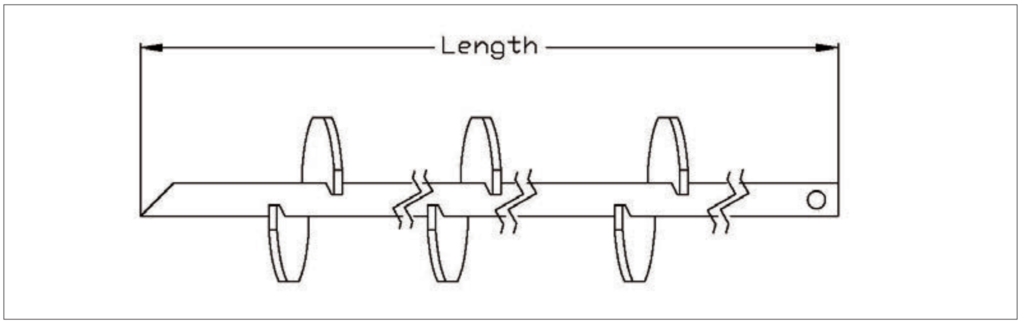
CHANCE® Helical SOIL SCREW® Anchors are designed and installed differently than helical tieback anchors. They are generally seated at a shallower depth than helical tieback anchors when installed to retain similar soil masses. Most importantly, the Helical SOIL SCREW® Anchors are not tensioned after installation; they are passive elements. When the SOIL SCREW® Retention Wall System is installed it holds the soil as a single mass of sufficient internal stability to provide a suitable Factor of Safety (FS) against failure. The load on the Helical SOIL SCREW® Anchors is created across the movement plane as the soil mass moves slightly downward due to gravity.

Many projects require that excavations be extremely close to existing structures. By combining ATLAS RESISTANCE® Modified Piers, or CHANCE® Helical Piles, CHANCE® Helical Tieback Anchors, and the CHANCE SOIL SCREW® Retention Wall System together, the designer is able to safely support an existing structure and the underlying soil mass during adjacent excavations. ATLAS RESISTANCE® Piers or CHANCE® Helical Piles support the structural load of the perimeter of the building, thus dramatically reducing the surcharge on the soil mass that must be retained. CHANCE® Helical Tieback Anchors are used for lateral support of the building's footing in projects where deep, adjacent excavations are required and/or for buildings with perimeter weights exceeding 4,000 pounds per linear foot. With the surcharge loads properly transferred away from the soil mass under the building, the design for soil retention using CHANCE® Helical SOIL SCREW® Anchors is greatly simplified and requires fewer Helical SOIL SCREW® Anchors. In many instances, this method is the only economical way to accomplish this task. This method of structure/soil mass support prevents structure distress that may manifest itself during potential settlement as the soil mass loads the CHANCE SOIL SCREW® Retention Wall System.

SOIL SCREW® RETENTION WALL SYSTEM SELECTION GUIDELINES

The CHANCE SOIL SCREW® Retention Wall System is available in two shaft sizes and two helix diameters. A variety of shaft lengths are offered to provide a designer an adequate selection for any application and load requirements. Design and installation requires input and supervision by a professional engineer and adequate site specific soil information.

CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Lead Sections



Product Designation	Product Series	Length	No. Plates	Plate Size	Weight lb.
C1100692	SS5	4'-11	2	8" Dia.	49
C1100691	SS5	7'-0	3	8" Dia.	69
C11002350301	SS175	5'-2	2	8" Dia.	62
T11006740302	SS175	6'-9	3	6" Dia.	75

RETENTION WALL SYSTEM

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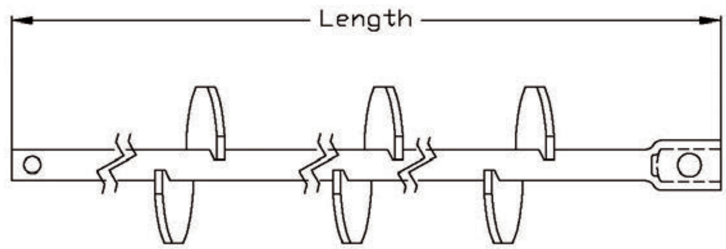
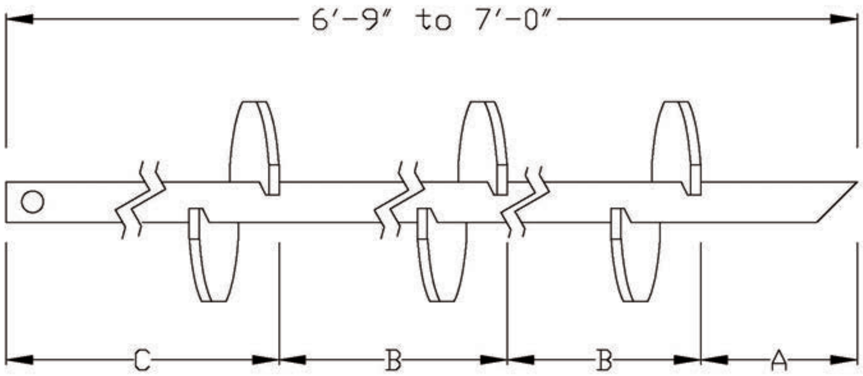
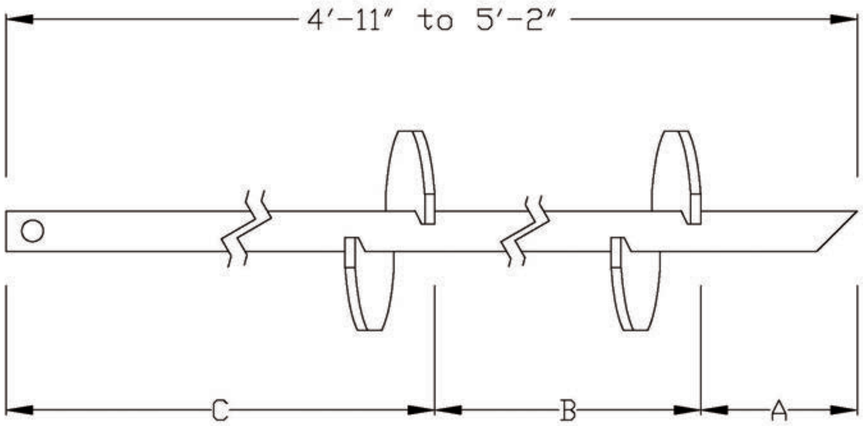
CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Extension Sections



Product Designation	Product Series	Length	No. Plates	Plate Size	Weight lb.
C1100690	SS5	4'-9	2	8" Dia.	42
C1100689	SS5	6'-9	3	8" Dia.	50
C11004500301	SS175	6'-11	2	6" Dia.	70
C11004500302	SS175	6'-10	3	8" Dia.	75

CONFIGURATIONS - SQUARE SHAFT LEAD SECTIONS





TYPE SS5 and SS175 SERIES

RETENTION WALL SYSTEM

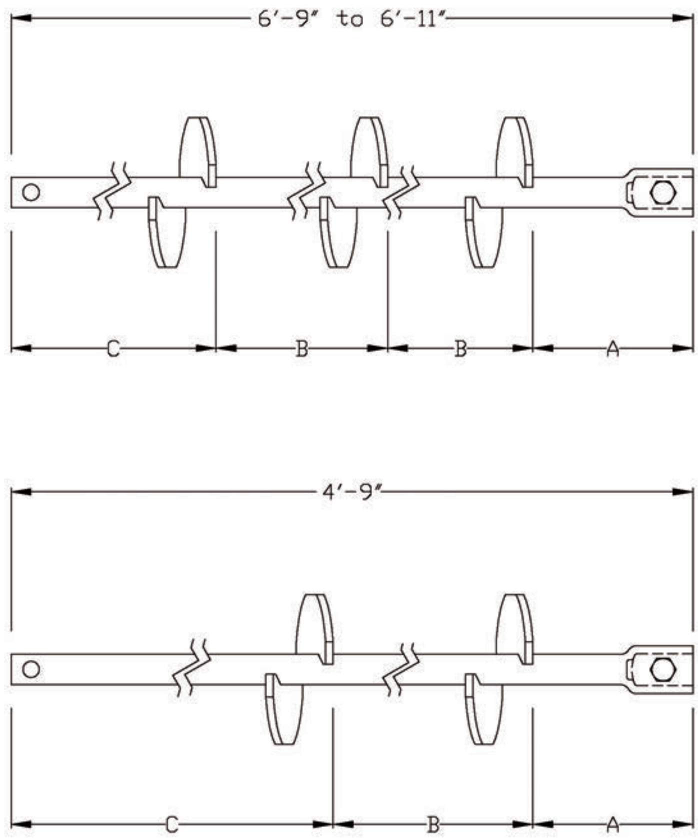
CHANCE SOIL SCREW® Retention Wall System (Type SS5 and SS175 Series) Lead Sections

CONFIGURATION TABLE (Leads and Extensions)						
Bar Size	Plate Size	Length	Dim A	Dim B	Dim C	No. Plates
1-1/2" Square Soil Screw® Lead Section	8" Dia.	4'-11	6"	29"	24"	2
		7'-0	6"	29"	20"	3
1-1/2" Square Soil Screw® Extension	8" Dia.	4'-9	5"	29"	23"	2
		6'-9	6"	29"	17"	3
1-3/4" Square Soil Screw® Lead Section	6" Dia.	5'-2	8"	30"	24"	2
	8" Dia.	6'-9	6"	30"	15"	3
1-3/4" Square Soil Screw® Extension	6" Dia.	6'-11	6"	30"	17"	3
	8" Dia.	6'-10	9"	29"	15"	3

NOTES – SOIL SCREW® ANCHOR PRODUCTS (Type SS5 and SS175 Series):

- Refer to the schematic drawings at the bottom of page 9-6 and below for Dimensions A, B and C.
- All extensions include integrally forged couplings, machine bolts and hex nuts
- All helical plates are welded to the shaft in conformance to the American Welding Society (AWS) Structural Welding Code AWS D1.1" and applicable revisions.
- Available Finish: Hot Dip Galvanized (HDG)

CONFIGURATIONS - SQUARE SHAFT EXTENSION SECTIONS



TYPE SS5 and SS175 SERIES

PRELIMINARY DESIGN CONSIDERATIONS

The following requirements must be considered:

1. An evaluation of: (a) the foundation soil strata (below the reinforced soil mass), (b) the soil stratum into which the helix plates will be located, and (c) the soil behind the reinforced soil mass to be retained by the SOIL SCREW® Retention Wall System.
2. A selection of the appropriate Helical SOIL SCREW® Anchor including shaft size, helix plate diameter and length of embedment.
3. A determination of the ultimate tension capacity of the Helical SOIL SCREW® Anchors with a suitable Factor of Safety.

The following preliminary design guide for Helical SOIL SCREW® Anchors is intended to provide a basic understanding of SOIL SCREW® Retaining Wall theory.

SOIL SCREW® Anchor wall design requires professional geotechnical and engineering input. Specific information involving the structures, soil characteristics and foundation conditions must be used for the final design.

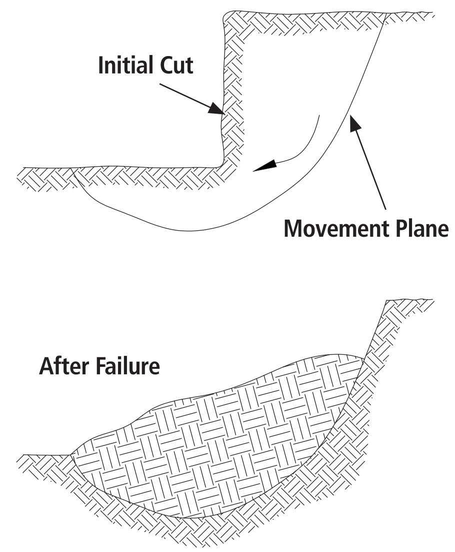
PRELIMINARY DESIGN RECOMMENDATIONS

- The top of the Helical SOIL SCREW® Anchor wall typically moves in the range of 0.1% to 0.3% of the wall height. Vertical and lateral movements are expected to be approximately 1/4" for a ten-foot cut and 1/2" for a 20-foot cut. This lateral movement is of concern when there is a structure located at the top of the proposed cut. It is therefore required that either ATLAS RESISTANCE® Piers or CHANCE® Helical Piles underpin the existing structure. It is recommended to use CHANCE® Helical Tieback Anchors at each underpinning placement location whenever the cut exceeds 12 feet and/or the existing structural line load is greater than 4,000 lb/ft.
- Surcharge loads due to slabs, column footings, overburden soils, vehicular traffic, or other structures behind the wall must be considered when calculating the soil loads to be retained by the Helical SOIL SCREW® Anchors.
- The CHANCE® SOIL SCREW® Retention Wall System is best suited to cemented or medium-dense to dense sand and to low plasticity clay soils with Standard Penetration Test (SPT) N values ≥ 8. Use caution in highly plastic clays and silts.
- The CHANCE® SOIL SCREW® Retention Wall System is poorly suited for jointed weathered rock material that dips into the excavation, loose sand with SPT N values ≤ 7 and in those cohesive soils with SPT N values of ≤ 6 (clays with cohesion < 850 psf or an allowable bearing stress < 2,000 psf) anywhere in the depth profile of soil that is to be excavated.
- Clean to relatively clean cohesionless soils with poor stand-up time typically require a 1" (±) flash shotcrete coating to be placed simultaneously with the excavation. The maximum recommended incremental face cut height is four feet or less. Use CHANCE® Helical Tieback Anchors when underpinning/shoring next to an existing structure.
- Use of the underpinning/shoring system is permissible for excavations of up to 20 feet and under extremely favorable conditions shall not exceed 25 feet.
- The underpinning/shoring system is a temporary support system. Creep is generally not a problem, however, the system is not recommended when the Liquidity Index (LI) is >0.2.
- SOIL SCREW® Anchors must have helix plates of the same diameter continuously along the installed length.
- SOIL SCREW® Anchors must be installed at a minimum downward angle of 5° from horizontal and typically do not exceed 15° downward angle.
- Engineering design shall include verification of several levels of design analysis:

  Internal stability: The soil mass acts as a coherent mass

  External stability: The ability to resist lateral sliding

  Global stability: The ability to resist massive rotational failure outside the "internally stabilized soil" mass



Typical Failure Mode of an Unstable Excavation
Figure 9-1

IMPORTANT NOTICE

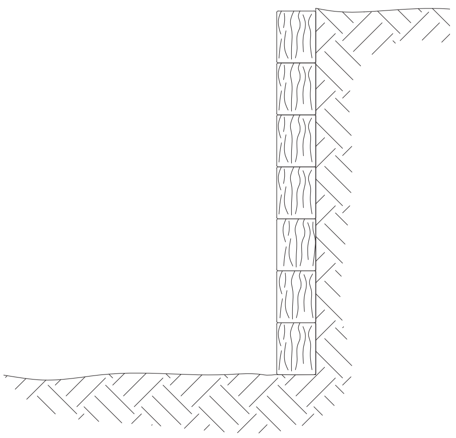
A Registered Professional Engineer shall design the CHANCE SOIL SCREW® Retention Wall System. The installation shall be performed by trained and certified installing contractors/dealers.

GEOTECHNICAL and STRUCTURAL ENGINEERING

For an introduction and guidance on how to design retention walls using the CHANCE SOIL SCREW® Retention Wall System, refer to the SOIL SCREW® Retention Wall System Design Manual. For a copy of this manual, please contact your area CHANCE® Distributor or visit the Hubbell Power Systems, Inc. website at www.abchance.com.

Design Example 10 in Section 8 provides a detailed wall design using the CHANCE SOIL SCREW® Retention Wall System.

CHANCE Helical SOIL SCREW® Anchors look similar to helical tieback anchors, but they are different and they act differently to stabilize a slope. To understand how Helical SOIL SCREW® Anchors act and the differences between the two products, we must examine a cut slope that is unable to stand for an extended time on its own (see Figure 9-1).

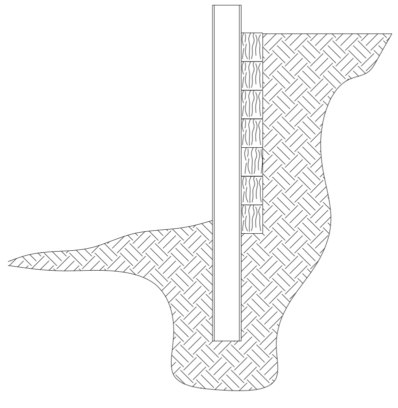

Cut Slope with Timber Wall
Figure 9-2

A simple method to improve stability of the slope would be to stack railroad ties against the cut face so that the soil would have to push the ties over in the process of failing (see Figure 9-2). If this proves insufficient, driving "soldier" piles in front of the railroad ties (now termed "lagging") enhances the stability. Now the soil must push the lagging and the soldier piles over before failure can occur (see Figure 9-3).

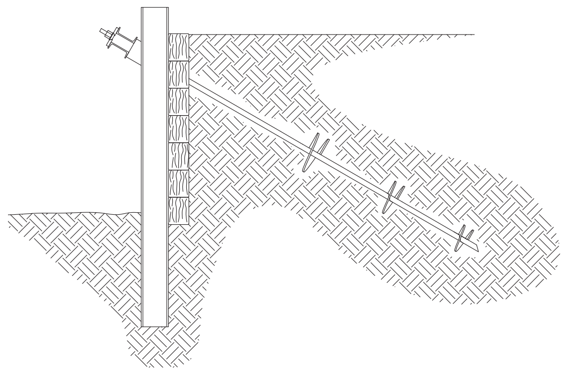
If this is still insufficient to stabilize the soil, a beam can be installed along the wall connecting the soldier piles. This beam is called a "waler" and it is anchored by helical tieback anchors to a stable portion of the soil mass behind the failure plane (see Figure 9-4). Now as the slope attempts to fail, the sliding soil pushes against the lagging, the lagging pushes against the soldier piles, the soldier piles push against the waler, and the waler pulls on the tiebacks. If the helical tieback anchors provide enough resistance, the whole system is stable. The design of the wall system (the lagging, soldier piles and the waler) brings the distributed soil force against the lagging toward, and concentrates the load at, the helical tieback anchors. After the tiebacks are installed, they are usually post-tensioned. When helical tiebacks are used for this type of application, they are typically concentrated in a few tiers, and are designed so that all tension resistance is attained within the stable soil mass behind the potential movement plane.

Helical SOIL SCREW® Anchors differ from helical tieback anchors because they are designed to attain pullout resistance within the sliding soil mass as well as the stable mass behind the movement plane. For Helical SOIL SCREW® Anchors to be effective, they must have helices along the whole length of the shaft. When the unstable soil mass begins to slide, it moves against the helices buried within this unstable mass (see Figure 9-5). The resistance generated on the helices within the unstable mass secures the soil directly and reduces the resulting soil pressure against the wall. The net effect is that Helical SOIL SCREW® Anchors reduce the structural requirements for the wall system. In most cases the Helical SOIL SCREW® Anchors are connected directly to the wall without the use of soldier piles or walers. The retaining wall is therefore thinner than a wall required when using tieback anchors.

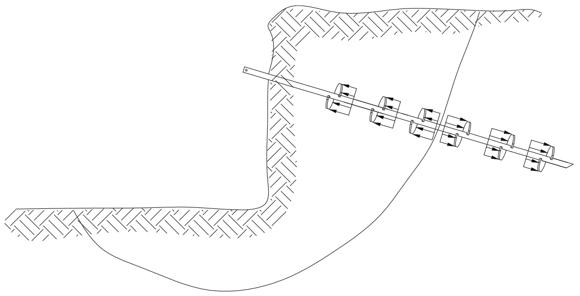
Helical SOIL SCREW® Anchors are more evenly distributed on the wall and therefore carry lighter loads than helical tieback anchors. Helical SOIL SCREW® Anchors should not be post-tensioned as post-tensioning puts bearing stresses on the wrong side of the helices that are embedded in the unstable soil mass. Some engineers require that a small load (1000 pounds or less) be applied to newly installed Helical SOIL SCREW® Anchors to remove any slack in the connections.



Cut Slope with Solder Pile and Lagging
Figure 9-3



Cut Slope with Tieback Wall
Figure 9-4



Cut Slope Stabilized with
Helical SOIL SCREW® Anchors
Figure 9-5

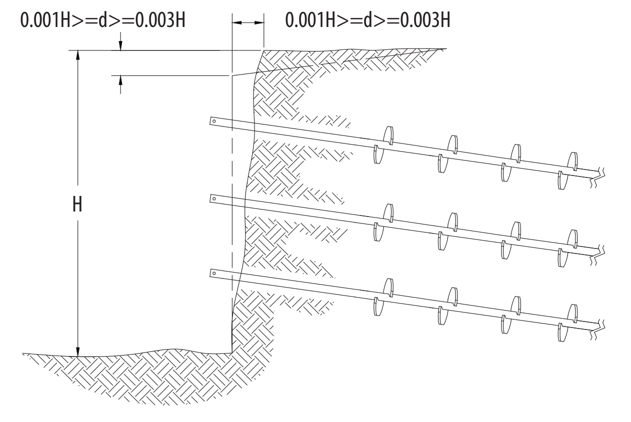
Because Helical SOIL SCREW® Anchors are not post-tensioned, the unstable soil mass has to slump slightly before the SOIL SCREW® System can develop resistance. SOIL SCREW® Retaining Walls deflect both vertically downward and laterally outward during this slumping process. The magnitudes of both deflections typically vary from 0.1% to 0.3% of the wall height (see Figure 9-6). For example, the top of a 12-foot high wall will typically deflect from 1/8" to 3/8" downward and outward. Because 3/8" settlement approaches the level that can cause damage in some structures, the Hubbell Power Systems, Inc. Underpinning/Shoring System includes helical tieback anchors at the underpinning bracket whenever excavation depths exceed 12 feet or structural footing loads exceed 4,000 lb/ft. Post-tensioning these tieback anchors prior to excavation allows the deflections at the footing to be controlled to an acceptable level.

Because of the potential severity of a structural failure involving one of these systems, Hubbell Power Systems, Inc. recommends that a staff application engineer, or an engineer from an authorized CHANCE® Distributor perform a preliminary design and make a final wall design review. The preliminary design will give recommendations for the Helical SOIL SCREW® Anchors and, if the project requires, specific underpinning piers/piles and/or helical tieback anchors to be used on the specific project. Details for the placement of the products, the required embedment depths and minimum installation resistances and torques will be recommended. These preliminary recommendations, estimates of installation depths and wall thickness will aid in preparing cost estimates. Both the installing contractor/dealer and the Engineer of Record shall review these recommendations. The CHANCE® Distributor or Hubbell Power Systems, Inc. Engineer will work with the Engineer of Record as required to resolve any issues regarding the preliminary design. The Engineer of Record must accept and approve the final design before construction can begin.

Shotcrete

Shotcrete is portland cement concrete or mortar propelled at high velocity (typically by air pressure) onto a surface. With wet process shotcrete, the dry materials are mixed with water and pumped to a nozzle, where air is added to project the material onto the surface. Dry process shotcrete, also known as "gunite", delivers the dry material to the nozzle by air pressure where water is added at the point of discharge. The water and dry materials mix during deposition. Each process has its own advantages and disadvantages, but either, or both, may be used to construct the wall facing for the CHANCE SOIL SCREW® Retention Wall System.

The wet process allows for high deposition rates up to three times the rate attainable with gunite with less rebound (5% vs. 15% for gunite). In addition, the nozzleman need not be as highly skilled for this process. The major disadvantages to the shotcrete wet process are the extensive cleanup required and the difficulty scheduling ready-mix deliveries. The gunite (dry) process has the advantage of easy clean up and the ability to mix materials on site. Gunite has more disadvantages than shotcrete. Gunite has a relatively low deposition rate (slower application), has more rebound and requires highly skilled operators.



Typical Horizontal and Vertical Deflections
of a SOIL SCREW® Wall
Figure 9-6

The functions of shotcrete in the CHANCE SOIL SCREW® Retention Wall System are:

- To prevent sloughing and spalling of the excavated soil face.
- To prevent buckling of the underpinning pier/pile, if required on the project.
- To transfer the earth pressures to the Helical SOIL SCREW® Anchors instead of the inner wall face.

In some instances, the system is exposed only temporarily. The excavation is usually filled in after the basement wall is constructed or permanent facing is built in front of the system's wall. In some cases, however, the system wall will be permanently exposed and must also perform cosmetic functions.

Flexural strength, shear strength and ductility are the important characteristics of the wall in this application. The wall must resist the movement of the retained soil and restrain the underpinning pier/pile (if used on the project) from buckling, both of which require flexural strength. The wall must also transfer load to the SOIL SCREW® Anchor head, which requires both shear and flexural strength. Because deformation is necessary to generate the resistance that makes the system stable, the wall must tolerate some deformation without losing its strength. The properties of the shotcrete that contribute to these wall characteristics are compressive strength and bond strength.

A structural engineer employed by the owner will typically prepare the final shotcrete wall design. Hubbell Power Systems, Inc. suggests that the wall design be reviewed by one of their staff application engineers or authorized Distributors.

LIMITING LOAD CAPACITIES

Ultimate Tension Strength

The ultimate tension strengths indicated in Table 9-1 represent the net tension strengths of the Helical SOIL SCREW® Anchor shaft/coupling systems. The designer must use an adequate Factor of Safety in the design to preclude Helical SOIL SCREW® Anchor failure in tension. A Factor of Safety of 2:1 is often used.

Torque Strength Rating

The torque ratings indicated in Table 9-1 represent the maximum torque that should be applied to the Helical SOIL SCREW® Anchor during installation in homogeneous soils. The risk of torsional fracture increases significantly as the applied torque increases beyond these limits. In obstruction-laden soils, the maximum torques that should be applied during installation are 80% of the table limits due to the increased risk of torsional fracture posed by impact loading. The designer must consider these torque ratings in evaluating whether the Helical SOIL SCREW® Anchors can be installed to the required depths. In addition, these torque ratings pose practical limits to the ultimate tension capacities that can be developed by limiting the strengths of soils into which the Helical SOIL SCREW® Anchors can be installed. The practical limit to the ultimate tension capacities that can be achieved (in lbs) is about ten times the installation torques (in ft-lbs) that may be applied during installation using a torque factor (K_t) of 10. See Section 6 for a detailed discussion of the correlation of installation torque of a helical anchor to its ultimate tension capacity.

Ultimate Tension Strengths and Torque Ratings for CHANCE® Helical SOIL SCREW® Anchors, Table 9-1

CHANCE® SOIL SCREW® PRODUCT	ULTIMATE TENSION STRENGTH	TORQUE RATING
SS5 Series 1-1/2" (38 mm) Round Corner Sq	70,000 lbs	5,700 ft-lbs*
SS175 Series 1-3/4" (45 mm) Round Corner Sq	100,000 lbs	10,500 ft-lbs*
*Refer to Ultimate Tension Strength and Torque Rating in the text. Practical load limits in the field may be limited due to the factors discussed in the above paragraph.		

GENERAL CONSTRUCTION CONSIDERATIONS of UNDERPINNING/SHORING SYSTEMS

The CHANCE SOIL SCREW® Retention Wall System for underpinning/shoring next to an existing structure is a specialized construction process and must be installed by Certified CHANCE® Installer. Listed below are some general items regarding the construction procedures:

WARNING! DURING THE COURSE OF CONSTRUCTION, THE FOOTING AND FACE OF THE SHORING SHOULD BE CONTINUOUSLY MONITORED FOR ANY MOVEMENTS. IF MOVEMENTS ARE NOTED, THE CONSTRUCTION PROCESS SHOULD BE STOPPED, TEMPORARY BRACING INSTALLED AND THE ENGINEER AND/OR GEOTECHNICAL ENGINEER SHOULD BE IMMEDIATELY NOTIFIED FOR FURTHER DIRECTION.

1. As is the case in conventional underpinning of buildings using ATLAS RESISTANCE® Modified Piers or CHANCE® Helical Piles, the footing must be properly prepared so that the pier/pile bracket can be positioned under the footing with a minimum of eccentricity with the wall load. This process may involve chipping the concrete to provide a proper bearing surface and creating a notch in the spread footing to reduce pier/pile eccentricity.
2. For those projects requiring underpinning and CHANCE® Helical Tieback Anchors at the pier/pile bracket, the tieback must be installed to the required length and torque prior to installing the underpinning system.
3. If ATLAS RESISTANCE® Modified Piers are used as the underpinning system, the process requires the use of pier sleeving to prevent buckling at the joints of the pier pipe. Every sleeve joint must be at least 18" away from a pier pipe joint. In some cases grouting of the pier pipe along with the insertion of a steel reinforcement bar may be specified.
4. The pier sleeving must be installed to a minimum of 2 feet below the deepest excavation (cut).
5. If using ATLAS RESISTANCE® Modified Piers, the piers shall be driven to the required depth and load tested to 150% of the design load. Then each pier shall be preloaded to at least 95% of the design load and locked off. If using CHANCE® Helical Piles as the underpinning system, the helical piles shall be installed to the required minimum depths and minimum average installation torques.
6. When the ATLAS RESISTANCE® Pier or CHANCE® Helical Pile underpinning system installation is complete, the helical tieback anchor shall be attached to the pier/pile bracket and preloaded. Normally the tieback is preloaded to the design load.
7. Upon completion of all of the underpinning and tieback operations, the wall face excavation can commence. If the soils are generally cohesionless (sands, etc.) or there is any danger of the soil face sloughing off, a 1" thick flash coat of shotcrete shall be immediately placed against the face of the cut as the excavation proceeds. If the cut soil is capable of standing by itself, then the first layer of shotcrete can be applied after the initial cut is complete. The same procedure shall be followed for subsequent incremental excavations. Under no circumstances should a cut of any height be left open at the face for more than two hours.
8. The depth of cut on the first excavation, as well as on subsequent incremental excavations shall be at least one foot deeper than the depth of the row of Helical SOIL SCREW® Anchors. See Figure 9-13, which shows a 6-foot cut and 5-foot deep row of Helical SOIL SCREW® Anchors.
9. When the first excavation is complete (with or without shotcrete flash coating), the first row of CHANCE® Helical SOIL SCREW® Anchors is installed to the requirements indicated in the design specifications (length of installation, minimum torque, installation angle, etc.). A Helical SOIL SCREW® Anchor shall be positioned immediately adjacent to each underpinning pier/pile. Shotcrete is placed onto the cut face to 1/2 of the total specified shotcrete thickness.
10. The welded wire mesh reinforcement is set against the face of the wet shotcrete along the cut face of the wall with excess reinforcement turned outward at the bottom of the cut to allow for overlap of reinforcement on successive stages.
11. Welded rebar assemblies with bearing plates are positioned over each Helical SOIL SCREW® Anchor and secured against the welded wire mesh reinforcement and (still) wet shotcrete face.
12. The remaining shotcrete is installed to provide the total thickness specified.
13. Steps 7 through 12 above are repeated after each incremental excavation. Stabilization continues until all of the Helical SOIL SCREW® Anchors are installed and the reinforced shotcrete wall is completed to the design depth.

CONCEPTS and APPLICATIONS of UNDERPINNING/SHORING SYSTEMS

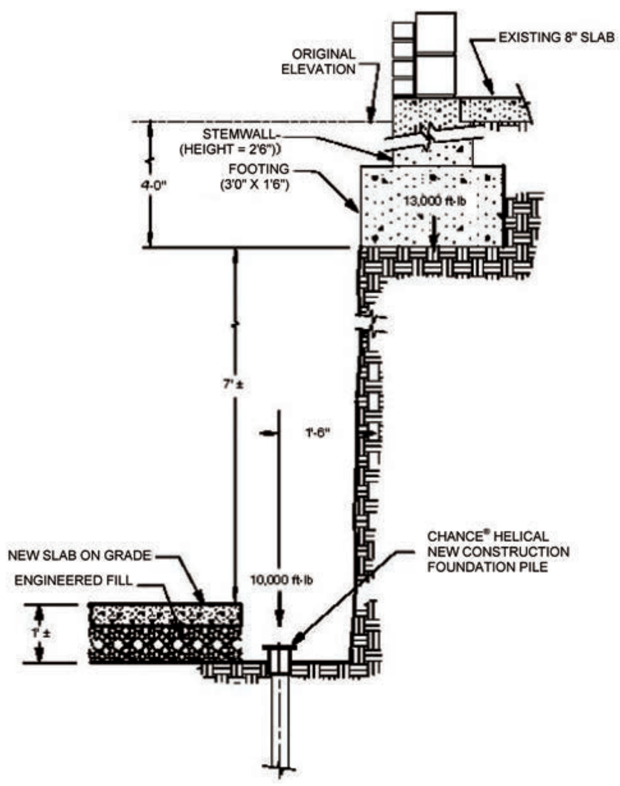
BACKGROUND

The construction of additions to office and commercial buildings or new construction adjacent to existing buildings requires earth excavation much deeper than the footing elevation of the immediately adjacent building(s). The use of sheet pile and/or H-piles with wood lagging to prevent adjacent footing subsidence requires the use of dynamic pile driving equipment with the attendant vibrations and noise levels. There are decided disadvantages to these traditional approaches since the vibrations may cause movement of the existing building foundation and subsequent structural damage. Additionally, the vibration levels can often lead to a shutdown of business operations if conducted during normal working hours.

Hubbell Power Systems, Inc. offers an underpinning/shoring system that not only avoids the vibrations and noise level issues, but also permits the shoring and excavation to proceed at a more rapid pace. In many cases this results in an overall cost savings to the prime contractor and owner. The examples covered below are intended to illustrate some of the design concepts and applications of this system.

In conducting preliminary designs for projects using the underpinning/shoring system and in the development of the case studies that follow, Hubbell Power Systems, Inc. uses certain guidelines. These guidelines are briefly summarized below:

1. Hubbell Power Systems, Inc. does not currently recommend using the underpinning/shoring system for excavations exceeding 25 feet.
2. Although ATLAS RESISTANCE® Piers or CHANCE® Helical Foundation Piles can be used for the underpinning stage; it is preferred to use the ATLAS RESISTANCE® Pier if "hard stratum" is within a reasonable depth at the proposed construction site.
3. The ATLAS RESISTANCE® Piers used for underpinning the existing building foundation must be sleeved with the joints of the sleeves offset from the joints of the underpinning pier pipe.
4. It is recommended in cases where the line load equals or exceeds 4,000 pounds per lineal foot and/or the depth of cut exceeds 12 feet to use a CHANCE® Helical Tieback integrated at the pier bracket level. This requirement uses the pier and tieback combination as illustrated in Figure 9-11. This helical product is used as a tieback anchor and not a SOIL SCREW® Anchor.
5. Helical SOIL SCREW® Anchors must be installed at a minimum downward angle of 5° and generally not to exceed 15°.
6. All Helical SOIL SCREW® Anchors have the same size helix plates continuously along the installed length of the shaft.
7. The bottom cantilever of shotcrete wall should be limited to 2/3 of the typical spacing for the Helical SOIL SCREW® Anchor row, but should not exceed 3 feet.
8. If the foundation soils to be excavated contain cohesionless soils (sands, sands and gravels and gravel and silty sands) a "flash coat" of shotcrete should be applied immediately as the cut is made.
9. CHANCE® Installers must receive formal training in the "concept" and "field installation technique" prior to using the underpinning/shoring system on an actual project.



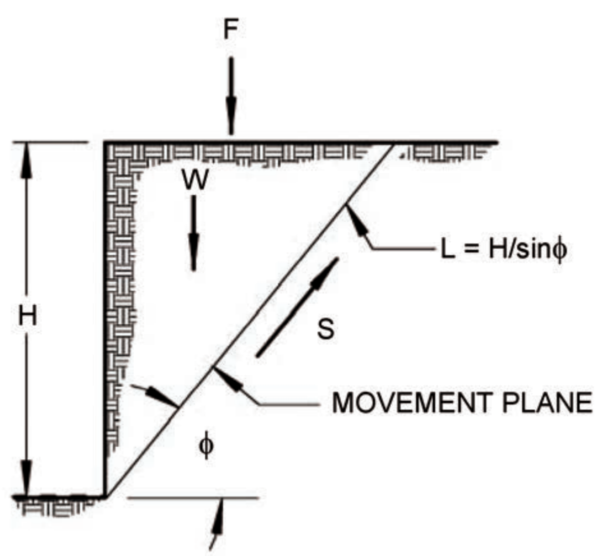
Cross Section of Existing Footing and Planned Excavation
Figure 9-7

NOTE: The designs and data shown in the following examples are not intended for use in actual design situations. Each project and application is different as to soils, structure and related factors.

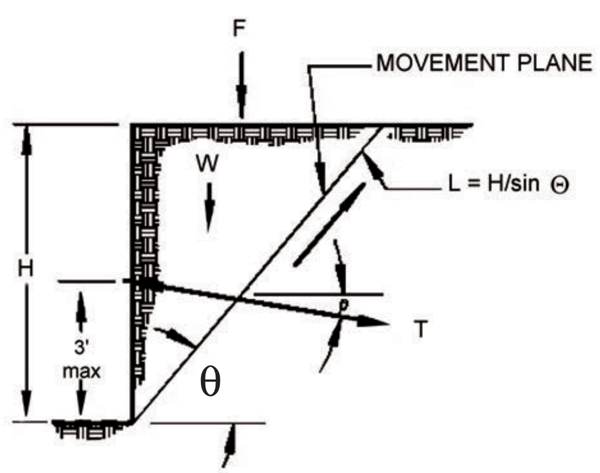
CASE STUDY 1 - HIGH FOUNDATION LINE LOAD with SHALLOW CUT

Northern Excellence University is planning to construct an addition to the existing Book Science Building. The existing building has a continuous perimeter footing as shown in Figure 9-7. The building is a 3-story structure and has a foundation line load of 13,000 pounds per lineal foot. This reinforced concrete footing is seated about 4 feet below the existing ground line as noted in Figure 9-7. There are no column footings at the exterior wall of the existing building immediately adjacent to the proposed addition.

The proposed building addition will be placed immediately adjacent to a 100-foot section of one wall of the existing building as shown in Figure 9-10. The foundation for the new building will also be a reinforced concrete continuous footing, but it will be set eight feet below the bottom of the existing building footing as shown in Figure 9-7. The estimated footing load for the new addition is 10,000 pounds per lineal foot. As noted in Figure 9-7, a surcharge load will exist arising from the Live Load on the floor slab (100 lb/ft^2), the weight of the concrete slab and the overburden pressure from approximately 3-1/2 feet of soil cover over the top of the existing footing.



Analysis of Soil Mass Forces
Figure 9-8



Analysis of Stabilized Mass Forces
Figure 9-9

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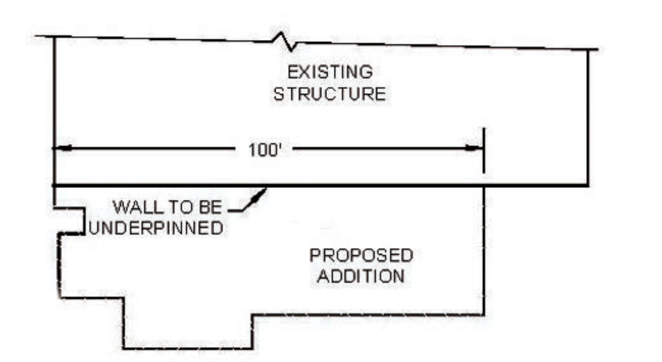
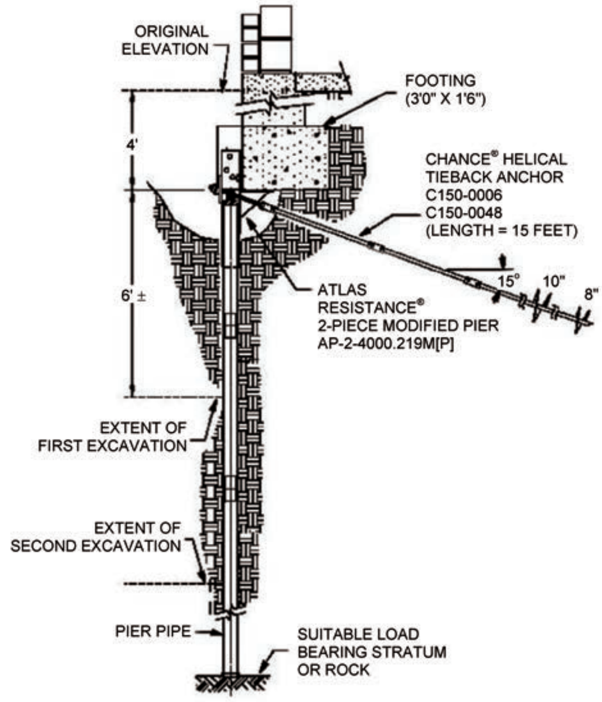


Plan View of Job Site
Figure 9-10



Existing Structure Underpinning with Integral Tieback Anchor
Figure 9-11

A geotechnical investigation was conducted at the site and the results showed that below the first foot of top-soil, a stratum of silty to sandy clay existed to a depth of 18 feet. The Standard Penetration Test (SPT) blow count, "N" for this soil was consistently in the 9 to 10 range through the 18 feet. Both by correlation with the "N" values and from the results of hand held penetrometer tests on the soil, this silty to sandy clay was determined to have a cohesion, "c" of 1,000 pounds per square foot and a friction angle, "φ" of 10°. Below the 18 feet of silty to sandy clay a stratum of weathered sandstone was encountered to the bottom of the borings at 20 feet at which the driller experienced auger refusal. No ground water was encountered during the soil borings.

Underpinning System - ATLAS RESISTANCE® Modified Piers

As noted above, a stratum of sandstone exists at the site beginning at a depth of 18 feet. Auger refusal was experienced at a depth of 20 feet. Allowing for four feet from the ground elevation of the boring log to the bottom of the footing to be underpinned indicates that the length of the underpinning pier pipe will be 16 feet. The existing footing line load is:

$p = 13{,}000 \text{ lb/ft}$ **Equation 9-1**

If we assume a pier spacing of 4 ft, center to center, the load per pier becomes:

$p_{des} = 13{,}000 \text{ lb } (4 \text{ ft})$ **Equation 9-2**

$= 52{,}000 \text{ lbs}$

Based on a requirement of installing an ATLAS RESISTANCE® Pier to a tested load resistance of at least 50% higher than the design load leads to:

$DS = 52{,}000\,(1.5)$ **Equation 9-3**

$= 78{,}000 \text{ lbs}$

An ATLAS RESISTANCE® 2-Piece Modified Pier part number AP-2-4000.219[M] is selected. This pier is designed with a 4" diameter pier pipe and has an ultimate capacity of 98,000 lbs. The "M" indicates the use of 4-1/2" diameter sleeving over the pier pipe. The sleeved portion of the pier shall extend down to a depth of 10'-6" (three lengths of sleeve pipe). Since this is temporary construction, corrosion protection is unnecessary. Details of the underpinning and tieback anchorage are shown in Figure 9-11.

INTEGRATED TIEBACK SYSTEM - CHANCE® Helical Tieback Anchors

Following the recommendation of using an integrated tieback whenever the line load exceeds 4,000 lbs/ft, a CHANCE® Helical Tieback Anchor must be selected for used with each ATLAS RESISTANCE® 2-Piece Modified Pier placement. For this situation, the C1500006 Tieback Anchor Lead Section and C1500048 Tieback Extension with coupling and hardware is recommended.

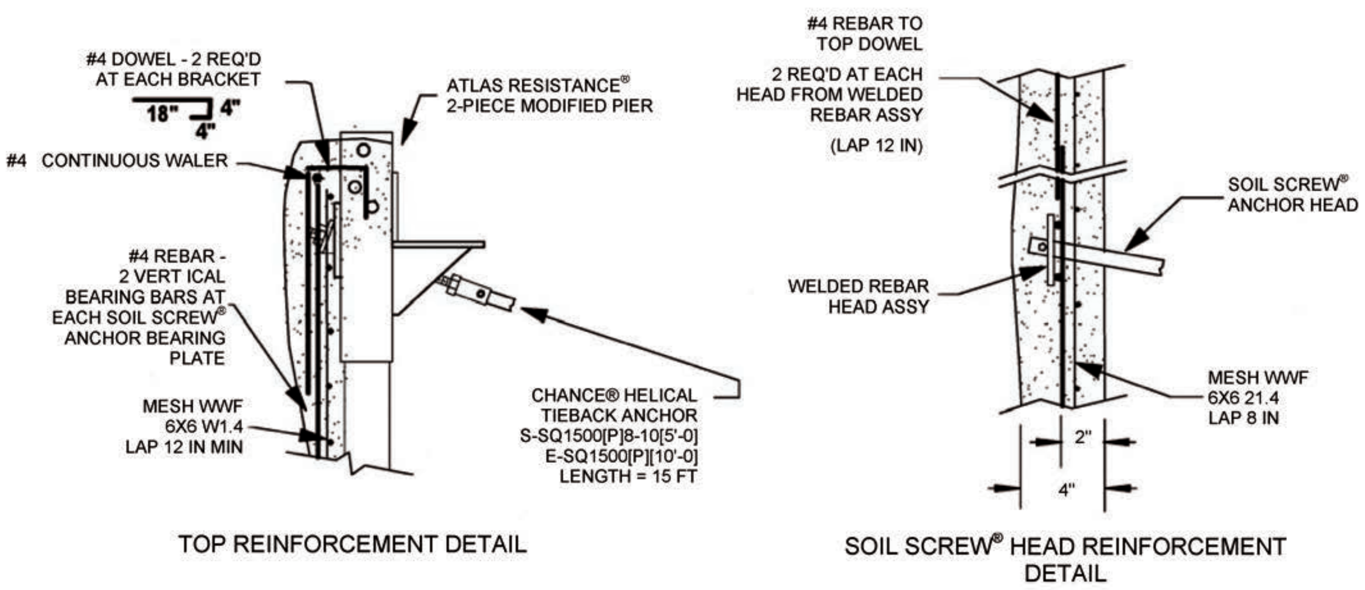
The installed length is estimated to be 15 feet. The installed angle is 15° down from horizontal. The lead section consists of one 8-inch and one 10-inch diameter plate welded to a 1-1/2" square solid steel shaft. Installed torque is estimated to be 2,000 ft-lbs, minimum. No corrosion protection is required because the construction is temporary.

SOIL SCREW® RETENTION WALL SYSTEM

The body mass of soil that would slide along the movement plane if failure were to occur as excavation takes place is illustrated in Figure 9-8. If one uses the soil properties previously listed with an assumed failure plane angle (θ) of 51°, the driving force and resisting force may be calculated. In order to provide a Factor of Safety against failure of the body mass, a single line of CHANCE® Helical SOIL SCREW® Anchors will be used. A minimum Factor of Safety of 2.0 is required against such a failure. (Note that the typical design Factor of Safety for Helical SOIL SCREW® Anchors ranges from 1.3 to 2.0.) A Factor of Safety of 2.0 was selected because of the very high foundation line load of the existing footing above the excavation. In conducting the SOIL SCREW® Anchor analysis, it assumed that the CHANCE® Helical tieback anchors did not contribute to the holding capacity of the body mass of soil even though the tieback prevents cantilever at the top of the wall.

Also shown in Figure 9-8 is the resistance to movements that occur along the movement plane arising from the shear strength of the soil. This shear strength is made up of both the cohesion and friction acting along that plane.

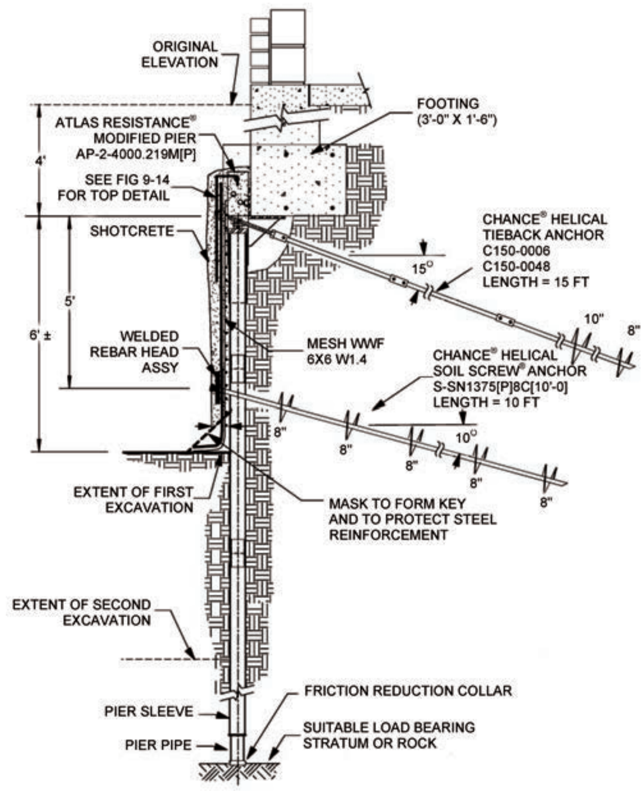
In Figure 9-9 the same body mass of soil is shown, but now the single Helical SOIL SCREW® Anchor shown provides additional resistance to sliding that develops along the movement plane. If the installation angle of the Helical SOIL SCREW® Anchor is 10°, the new driving force and new resisting force may be calculated.



Reinforcement Details for Case Study #1
Figure 9-12

Generally, the Factor of Safety is illustrated by the following equation:

	FS	=	RF / (DF - SSCF)	**Equation 9-4**
where	FS	=	Factor of Safety	
	RF	=	Resisting force	
	DF	=	Driving force	
	SSCF	=	SOIL SCREW® Anchor component force	



SOIL SCREW® Anchor Configuration for Case Study #1
Figure 9-13

Resisting Force (RF) arises from the shear strength of the soil (c and φ) along the movement plane and the Helical SOIL SCREW® Anchor component parallel to the movement plane. Driving Force (DF) is the component of the soil body mass (weight) in the direction of the movement plane. Helical SOIL SCREW® Anchor Component Force (SSCF) is the component of the total Helical SOIL SCREW® Anchor holding capacity (ultimate capacity) in the direction of the movement plane. Internal stability analysis as described herein is typically done with commercially available software such as SNAILZ (Caltrans) or Gold Nail (Golder Associates); see the CHANCE® Soil Screw® Retention Wall System Design Manual for an example. Helical SOIL SCREW® Anchor tension capacity is calculated with HeliCAP® Helical Capacity Design Software and input into the stability analysis software.

For the specific conditions defined above, the CHANCE® Helical SOIL SCREW® Anchor Lead Section C1100692 and C1100690 Extension is selected. The Helical SOIL SCREW® Anchor lead section consists of 8" diameter plates welded along the entire length of a 1-1/2" square shaft. Minimum installed length is 10 feet. Installed angle is 10° down from horizontal. Installed torque is estimated to be 1,500 ft-lb minimum. The single row of Helical SOIL SCREW® Anchors is set immediately adjacent to each underpinning pier pipe at a depth of 5 feet below the integrated tieback anchor (this will maintain the 3 foot maximum allowable bottom cantilever). No corrosion protection is required.

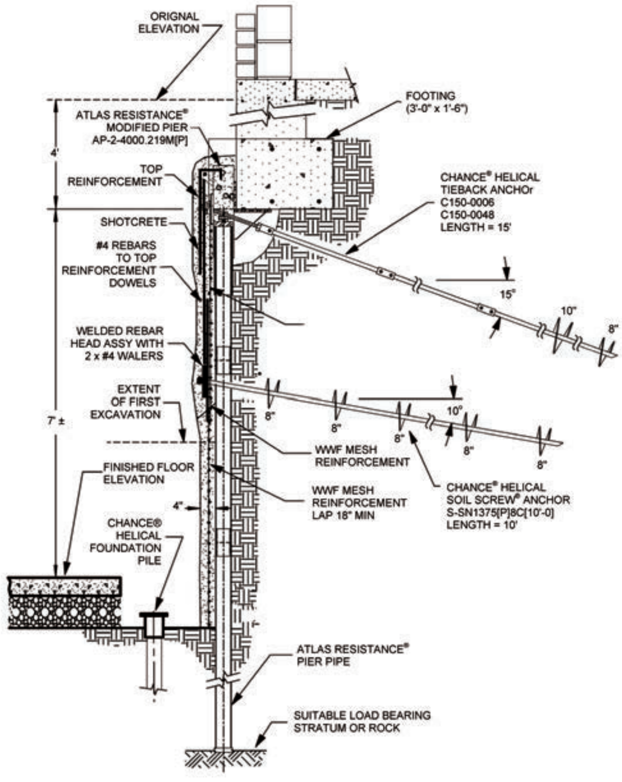
RETENTION WALL SYSTEM

SHOTCRETE WALL

The shotcrete wall is a temporary facing for the excavation. Since there is a CHANCE® Helical Tieback Anchor at the top, the wall will be laterally anchored at the pier brackets to allow longer spacing for the single row of Helical SOIL SCREW® Anchors. The bottom cantilever should be 3 feet.

The vertical bearing bars are extended from the welded rebar head assembly to the dowels and waler at the top of the wall in order to augment the welded wire fabric reinforcing (see Figures 9-13 and 9-14).

The top wall segment is checked for flexure and shear using the distributed SOIL SCREW® Anchor head forces and one-way beam action. Two #4 reinforcing bar walers shall be placed continuously along the SOIL SCREW® Anchor row. The selected wall thickness is 4". Reinforcing is a welded wire fabric (WWF 6x6 W.14 or equivalent) spaced midway in the shotcrete wall at a 2" nominal depth.



Excavation to the Final Elevation
Figure 9-14

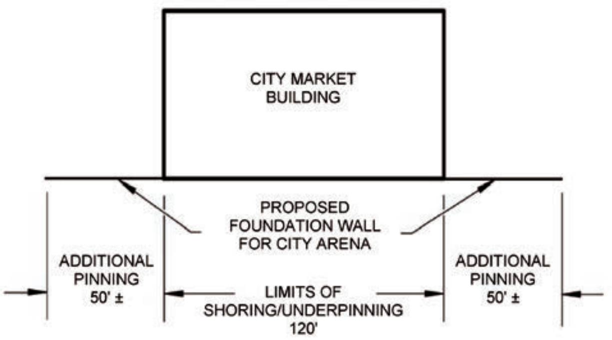
SOIL SCREW® ANCHOR HEAD DESIGN

The shotcrete wall design is critical to the punching shear of the SOIL SCREW® Anchor heads and flexural strength of the all face between the SOIL SCREW® Anchor heads. The SOIL SCREW® Anchor head forces are expected to be approximately 1/2 of the total SOIL SCREW® Anchor tension load. The shotcrete facing is checked for flexure and punching shear using two-way slab action. This information is used in the internal stability analysis. A welded rebar head assembly can be used at each placement to provide local reinforcement. It is spliced to the horizontal walers and the vertical bearing bars previously described. To accomplish the proper positioning of the welded rebar head assembly and rebar, the welded wire fabric must be pushed into the initial 2" face coat of shotcrete approximately 1/2" at each SOIL SCREW® Anchor head. The 4" wall thickness and reinforcement selected above are adequate.

The first 6 feet of soil is excavated and the soil body mass is stabilized. Figure 9-13 shows the installation of a CHANCE® Helical SOIL SCREW® Anchor, welded wire reinforcement, welded rebar head assembly and shotcrete. Note that the shotcrete stops short of the bottom of the excavation to allow for splicing the welded wire mesh reinforcement and a suitable shotcrete joint. Figure 9-14 show excavation to the final elevation along with continued stabilization of the soil mass. Construction of the new foundation begins with the installation of CHANCE® New Construction Helical Piles.

CASE STUDY 2 - LOW FOUNDATION LINE WITH DEEP CUT

The City of High Hope is planning to build a new multi-purpose arena that will seat 8,000 people. The arena will be located within the downtown district. A 20-foot deep cut will be required for the new construction to provide sufficient elevation for the arena seating yet maintain a low ground level building profile. A portion of the arena wall will be immediately adjacent to the existing historic city market building (see Figure 9-15). The city market building is a single story warehouse that measures 60 by 120 feet. The back wall of the market building will abut the new arena wall. The market building was constructed in the early 1900s and has an unreinforced concrete grade beam foundation that measures three feet wide by two feet deep. The grade beam, seated three feet below the existing grade, has a line load of 3,000 lbs per lineal foot. The general configuration of the footing along with installed underpinning and tieback is shown in Figure 9-16.



Plan View of Job Site
Figure 9-15

A geotechnical investigation conducted at the site found a 30-foot thick stratum of silty sand below approximately two feet of topsoil and fill material that consisted of silt, sand and cinders. The Standard Penetration Test (SPT) blow count "N" in this silty sand increased with depth from N=13 to N=18. Sufficient silt is present in the sand to hold a shallow vertical cut for a short period of time. Below the silty sand stratum at a depth of 32 feet the borings encountered a hard glacial till of clayey sand and gravel. The SPT value recorded were N=50+. By correlating the N values, the friction angle of the silty sand (ϕ) was estimated to be 30°. The ground water table (GWT) was located at 15 feet which means dewatering will be required prior to excavation.

Based on discussion with the designer and contractor, a decision was made to use the CHANCE® Helical underpinning/shoring technique in the immediate vicinity of the city market building. The Helical SOIL SCREW® Anchors will continue for an additional 50 feet on each side of the market building as the slope is cut in a benched pattern. Beyond this zone, adequate clear distance exists to back-slope the cut side without providing any wall retaining system.

Underpinning System - ATLAS RESISTANCE® Modified Piers

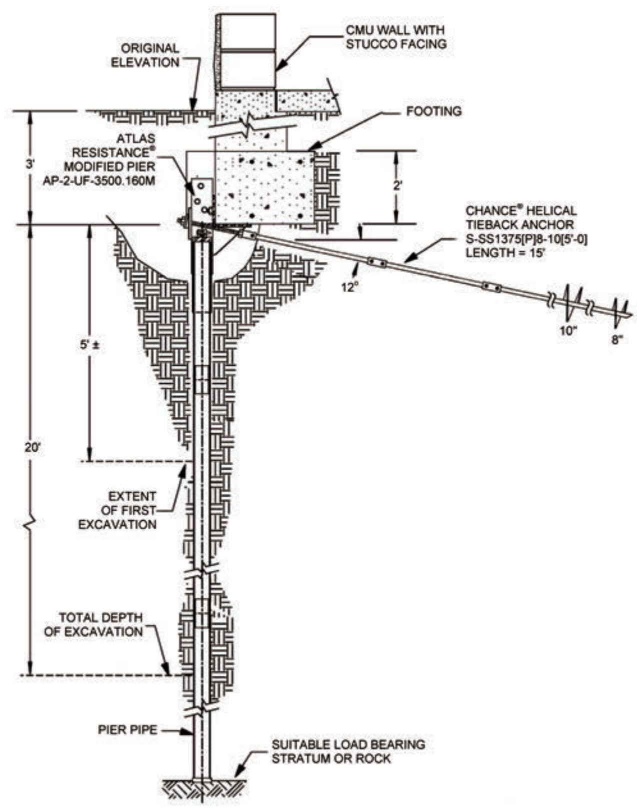
As noted above, a hard glacial till exists at a depth of 29 feet below the bottom of the market building footing. The estimated length of the underpinning pier pipe is 32 feet. The existing line load is 3,000 lb/ft. Although the footing line load is relatively light, the fact that the 24" thick footing is not reinforced will limit the spacing of the piers to five feet on center. Based on this spacing, the design load per pier becomes:

$$P_{des} = 3{,}000 \text{ lb } (5 \text{ ft}) \qquad \textbf{Equation 9-5}$$
$$= 15{,}000 \text{ lbs}$$

Based on the requirement of installing ATLAS RESISTANCE® Modified Piers to a tested load resistance of at least 50% higher than the design load leads to:

$$DS = 15{,}000 \ (1.5) \qquad \textbf{Equation 9-6}$$
$$= 22{,}500 \text{ lbs}$$

For this requirement, the ATLAS RESISTANCE® AP-2-3500.165[PA] M 2-Piece Modified Pier is selected. The modified pier has a 3-1/2" diameter pier pipe and has an ultimate capacity of 91,000 lbs. "M" indicates the use of 4" diameter sleeving over the pier pipe. The sleeved portion of the pier shall extend down to a depth of 21 feet (six lengths of sleeve pipe). "PA" indicates the product is manufactured of mill finish steel (plain) with flow coated corrosion protection of the pier pipe. Since this is temporary construction, the corrosion protection is unnecessary; however this product is supplied with corrosion protected pipe as standard. Details of the underpinning and tieback anchorage are shown in Figure 9-16.



SOIL SCREW Configuration for Case Study #2
Figure 9-16

Integrated Tieback System - CHANCE® Helical Tieback Anchors

Although the footing line load is less than the 4,000 lb/ft criteria, the depth of the cut to be shored is 20 feet. This exceeds the recommended 12 foot limitation and as such a CHANCE® Helical Tieback Anchor must be selected for use with each modified pier placement. For this situation Type SS5 1-1/2" square shaft Lead Section and Extension are the recommended components.

The lead section consists of one 8" and one 10" diameter plate welded to a 1-1/2" square shaft. Minimum installed length is estimated to be 15 feet. Installed angle is 12° down from horizontal. Installed torque is estimated to be 1,800 ft-lb minimum. No corrosion protection is required since the construction is temporary.

SOIL SCREW® Shoring System - CHANCE® Helical SOIL SCREW® Anchors

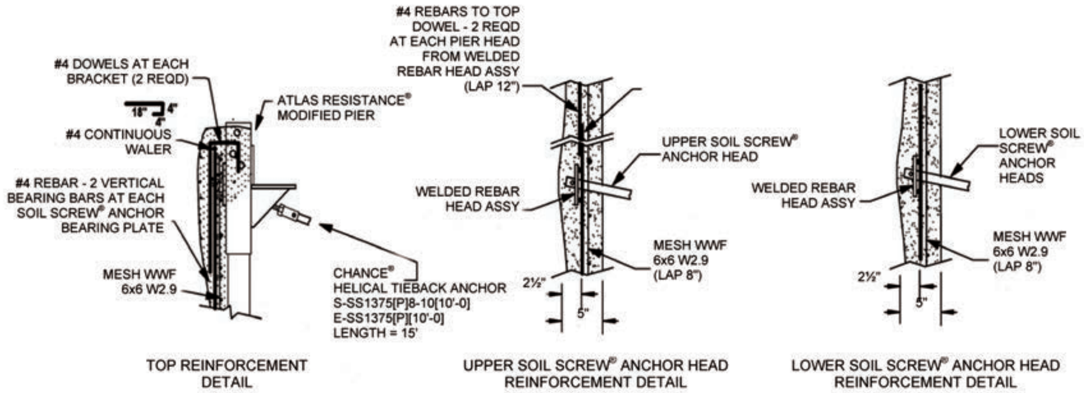
Because the depth of cut is 20 feet from grade (17 feet below the bottom of the footing of the market building), three Helical SOIL SCREW® Anchors are required. In this case a Factor of Safety of 1.5 was used because the existing market building is relatively light. In conducting the soil analysis, it was assumed that the CHANCE® Helical Tieback Anchor does not contribute to the holding capacity of the body mass of soil. As in Case Study 1, internal stability analysis is typically done with commercially available software such as SNAILZ (Caltrans) or GoldNail (Golder Associates), and SOIL SCREW® Anchor tension capacity is calculated with HeliCAP® Helical Capacity Design Software and input into the stability analysis software. In this project, the shear strength is from the frictional nature of the cohesionless soil (silty sand) and its magnitude is related to the friction angle ($\varphi = 30°$ in this case).

As described in the CHANCE® SOIL SCREW® Retention Wall System Design Manual, SOIL SCREW® Anchors add to the resisting force along the movement plane. In this case, however, the indicated force (T) is the resultant of all three rows of Helical SOIL SCREW® Anchors. Placement of the three rows of Helical SOIL SCREW® Anchors is shown in Figure 9-18. The value for the ultimate holding capacity required (including the Factor of Safety) is:

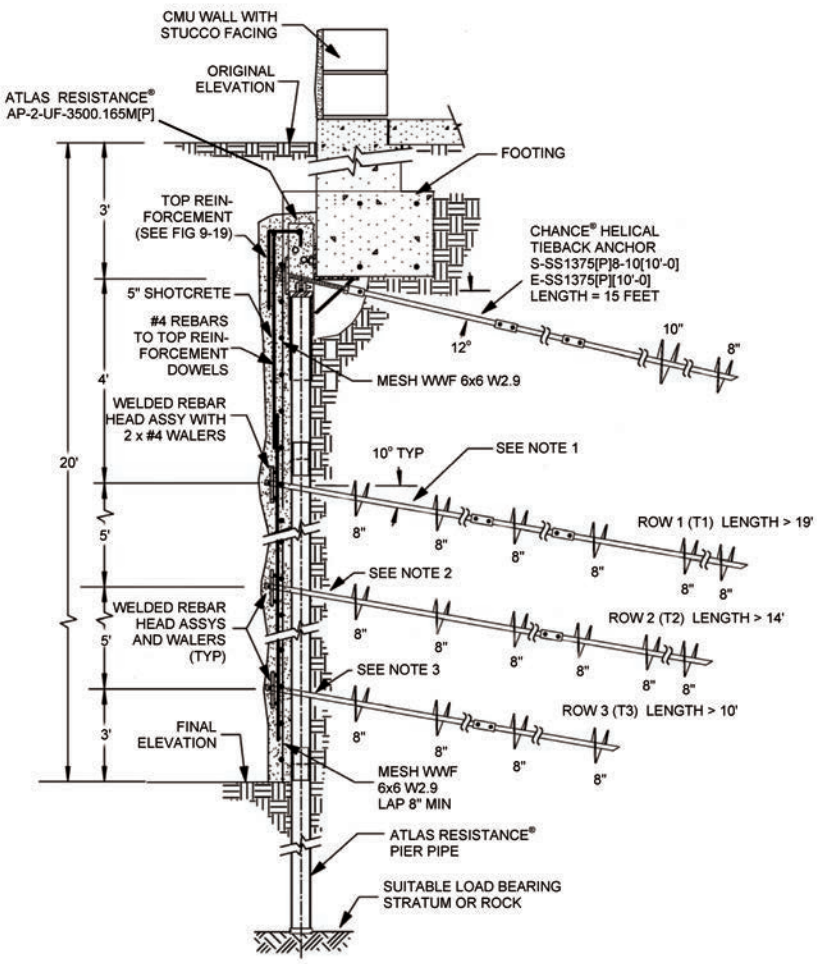
$$T = T_1 + T_2 + T_3 \qquad \textbf{Equation 9-7}$$

The results of extensive testing of soil nail walls indicate that the top row of soil nails or screws is most heavily loaded with the successively lower rows having lesser holding capacity requirements. The following are the recommended CHANCE® Helical SOIL SCREW® Systems for this project:

- SOIL SCREW® Anchor Row #1 (T_1): C2200691 Lead and two C1100689 Extensions. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 19 feet, 10° down from horizontal and to an estimated torque of 2,500 ft-lbs.
- SOIL SCREW® Anchor Row #2 (T_2): C2200691 Lead and one C1100689 Extension. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 14 feet, 10° down from horizontal and to an estimated torque of 1,800 ft-lbs.
- SOIL SCREW® Anchor Row #3 (T_3): C1100692 Lead and C1100690 Extension. The SOIL SCREW® Anchor has continuously spaced 8" diameter plates along the entire length of a 1-1/2" solid square steel shaft. The SOIL SCREW® Anchor will be installed to a minimum length of 10 feet, 10° down from horizontal and to an estimated torque of 1,000 ft-lbs.



Reinforcement Details for Case Study #2
Figure 9-17



NOTE 1: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P][10'-0] - LENGTH = 20'
NOTE 2: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P][6'-8] - LENGTH = 16'-8"
NOTE 3: CHANCE® HELICAL SOIL SCREW® - S-SN1375[P]8C[10'-0] - E-SN1375[P][6'-8] - LENGTH = 13'-4"

Excavation and Stabilization
Figure 9-18

Shotcrete Wall

The shotcrete wall is a temporary facing for the excavation. Since the soil analysis assumed that the CHANCE® Helical Tieback Anchors do not contribute to the holding capacity of the body mass of soil (see Figure 9-8), the CHANCE® Helical SOIL SCREW® Anchors were designed to hold the total body mass. The bottom cantilever should be limited to 2/3 of the typical spacing for the SOIL SCREW® Anchor row, but should not exceed 3 feet. In this case the cantilever is 3 feet.

Vertical bearing bars are extended from the welded rebar head assemblies at the upper row of SOIL SCREW® Anchors to the dowels and waler at the top of the wall in order to augment the selected shotcrete wall thickness (5”). Welded wire fabric reinforcing (WWF 6x6 W2.9 or equivalent) is spaced midway within the shotcrete wall at a 2-1/2” nominal depth. The top wall segment is checked for flexure and shear using the distributed SOIL SCREW® Anchor head forces and one-way beam action. Two #4 reinforcing bar walers are placed continuously along each SOIL SCREW® Anchor row (see Figures 9-17 and 9-18).

SOIL SCREW® Anchor Head Design

The SOIL SCREW® Anchor head forces are expected to be approximately 1/2 of the SOIL SCREW® Anchor tension load. The shotcrete facing is checked for flexure and punching shear using two-way slab action. This information is used in the internal stability analysis. A wall plate could have been placed at the wall face to maximize punching shear resistance, but in this example a welded rebar head assembly that includes a wall plate is placed on each Helical SOIL SCREW® Anchor at the middle of the shotcrete wall as shown in Figure 9-18 (refer to SOIL SCREW® Anchor Wall Accessories for details of the welded rebar head assembly). The welded rebar head assembly shall be spliced to the horizontal walers at each row of Helical SOIL SCREW® Anchors and to the vertical bearing bars between the upper row of Helical SOIL SCREW® Anchors and the dowels at the pier brackets. To properly position and embed the welded rebar head assembly and rebar, the welded wire fabric must be pushed into the initial 2-1/2” face coat of shotcrete approximately 1/2” at each SOIL SCREW® Anchor head. The 5” wall thickness and reinforcement described above are adequate.

References:

1. AASHTO Highway Subcommittee on Bridges and Structures, Manual on Foundation Investigations, American Association of State Highway and Transportation Officials, 1978.
2. Federal Highway Administration Publication No. FHWA-SA93-026, Recommendations Clouterre, English Translation, 1993.
3. Federal Highway Administration Publication No. FHWA-SA-96-069, Manual for Design and Construction Monitoring of Soil Nail Walls, 1996.
4. Federal Highway Administration Publication No. FHWA-SA-96-071, Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines, 1996.
5. Federal Highway Administration Publication No. FHWA-SA-96-072, Corrosion/Degradation of Soil Reinforcement for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, 1996.