Malcolm provides a comprehensive range of shoring, underpinning and slope stabilization solutions. Our retention systems address diverse project challenges including high groundwater, sensitive structures and facilities, as well as noise and vibration constraints. Malcolm’s experience and specialized resources will provide design and construction services tailored to your needs.

SELECTION OF SHORING SYSTEMS
Every construction project has unique requirements. Site, geotechnical and groundwater conditions must be evaluated with consideration for schedule, environmental and physical constraints in order to select the optimal construction approach for each case.

Malcolm’s extensive experience, personnel and equipment resources facilitate a Design-Build approach, allowing timely collaboration with owners and contractors to optimize safe and cost-effective retention solutions for every project. The following pages present an overview of technologies offered and illustrate our expertise.
Soldier pile walls provide a core system for earth retention in both temporary and permanent applications. Structural “soldier” piles are installed from original grade. Then, as the site excavation proceeds in lifts, lagging is placed between the piles to retain soil. Soldier pile walls, supplemented with post-tensioned anchors or internal bracing form a very stiff shoring system, well suited for deep excavations adjacent to sensitive structures or facilities. Malcolm has constructed anchored soldier pile walls to depths exceeding 100 feet, and cantilever systems to over 25 feet.

**Optimal installation method selected for each site.**
A range of construction techniques are used for soldier pile installation, including conventional cased or uncased pile drilling, wet setting reinforcing into soil mix or augercast piles, or vibro-placement of beams. Site-specific conditions and constraints are evaluated in order to select the most appropriate and cost-effective system for each project. Piles are typically installed at 4 to 8 feet centers and extend at least 8 to 10 feet below final excavation grade to provide passive toe resistance. As site excavation proceeds in lifts, typically 5 feet in depth, lagging comprised of either wood or shotcrete is placed between the piles. Each lagging and excavation cycle is repeated to the full depth of excavation. The soldier piles provide arching resistance which helps support the exposed soil face until lagging for each lift is completed. Although soldier pile walls can be constructed in most ground conditions, short lift heights or additional ground treatment may be required for pre-stabilization of exceptionally soft or loose soils. Dewatering systems can be combined with pile and lagging walls to allow excavation support in otherwise flowing granular soils below the groundwater table.

**Temporary and Permanent Earth Retention Systems.**
Most temporary walls use wood lagging. Soil is trimmed behind the front flange of soldier pile, then lagging boards are placed to bear against the exposed steel. For permanent walls, either pressure treated wood or structural shotcrete can be installed, anchorage systems are corrosion protect- ed and any exposed steel is shop coated. When shotcrete is used, it is attached to piles using headed studs and fully encases the steel for corrosion protection. Malcolm offers a range of aesthetic solutions for the shotcrete wall finish including rod, float or “natural rock” sculpting and coloring.
Soil Nail Systems

Retain soil mass with passive soil anchors and shotcrete facing installed during excavation in lifts.

Soil nail systems stabilize a section or block of retained ground by installing closely spaced grouted steel rods into the exposed face as the excavation proceeds downwards. This approach provides a flexible, cost-effective and efficient earth retention solution. The rows of soil nails are connected to structural shotcrete at the exposed face of excavation. As the excavation proceeds top-down in lifts, the soil will incrementally deform towards the excavation, mobilizing tensile strength of the nails to internally stabilize the retained soil. The nail layout and facing system are selected to create a stable retained soil mass, which is also designed as a gravity block to resist global rotation, sliding or bearing capacity failure.

Efficient and cost effective earth retention.
Soil nail walls typically offer reduced cost and construction time compared to soldier pile walls. Temporary or permanent walls can be constructed, and nails can enhance stability of existing or re-graded slopes. The small, agile construction equipment can accommodate sloping ground profiles and complex geometries with interior and exterior corners. Selection of soil nail systems should recognize that some limited ground deformation is necessary to mobilize the passive resistance and that the high density of nails requires consideration of any adjacent subsurface utilities and facilities.

Soil nail walls are constructed from the top down in lifts of approximately 5 feet. Nails are drilled at each lift, with steel bars grouted into 4 to 6 inch diameter holes.

SOIL NAIL WALL CONSTRUCTION SEQUENCE
1. Mass excavation lift
2. Drill, install and grout soil nail
3. Trim face of excavated ground
4. Install geocomposite and mesh reinforcement
5. Shotcrete placement
6. Screed and finish face of wall

The wall facing is constructed by embedding steel nail head plates into lightly reinforced shotcrete. Vertical drainage strips placed on the excavated soil face ensure drainage and prevent build-up of hydrostatic pressures on the wall. Shotcrete is placed directly against excavated soil face (covering drain strips and encasing steel mesh or bar reinforcing), and then rod-finished to complete the structural facing. For permanent walls, nails are corrosion protected and a second layer of shotcrete or cast-in-place concrete may be installed. Exposed permanent walls are often sculpted and colored to represent local rock formations. Nail pull-out tests verify design parameters at the start of construction. Shotcrete test panels and nail pull-out tests are performed throughout the production work to ensure compliance with quality control procedures.

Suitable for variable ground types.
This top-down construction process requires relatively stable ground which can stand after excavation long enough to allow for nail drilling, facing placement and initial cure. Stiff cohesive soils, soft rocks and granular materials with some cohesion or cementation are ideal for soil nailing. Dewatering systems can be combined with soil nails walls to stabilize strong, but potentially flowing ground. In marginal ground, the excavation face can be pre-stabilized by pre-installation of vertical nails, or use of berms to limit area and duration of exposed soil prior to shotcrete placement. Soil nail systems are not suited to weak cohesionless soil, soft clays, organics, or highly corrosive ground.
Secant piling is a robust, rigid system which can be used to construct combined earth retention and groundwater cut-off walls. The continuous wall is constructed by drilling overlapped concrete piles with diameter typically between 2 and 4 feet. A wide range of drilling techniques can be employed allowing secant pile walls to be constructed in variable ground conditions. In many cases a wall is constructed to penetrate through water bearing overburden and seal into dense till or rock below excavation subgrade.

Flexible drilling methods accommodate variable ground.

Piles are drilled and concreted prior to start of excavation. The initial or “primary” piles are drilled into existing ground at the selected center spacing. The wall is completed by drilling structurally reinforced “secondary” piles which cut into and overlap with the adjacent primaries. Secant walls overlap individual piles which allows for flexible layouts accommodating linear or curved alignments with multiple corners. Vertical reinforcement is typically installed only in secondary piles and may be either a steel pile or rebar cage.

OPPOSITE: Braced Secant Wall, Mitchell Interchange, Milwaukee, WI

Construction maintains strict tolerances.
The key to secant pile wall construction is maintaining overlap between adjacent piles. A guide wall or template at ground surface ensures that every pile is accurately located. Drilling with heavy wall steel casing provides an extremely stiff drill string which can achieve vertical tolerance typically better than 0.5% of pile depth. Downhole surveys are performed to verify that actual drilling verticality meets the design requirements. Under certain soil conditions and for moderate excavation depths, alternative installation methods, such as auger-cast or soil mixed piling, can be highly productive and may be employed in lieu of cased drilling to construct secant walls at a lower unit cost.

Amongst other considerations, lateral support systems are selected to minimize risk of water infiltration. Options include tieback anchors and internal bracing, with tiebacks usually located above groundwater table. For circular excavations, self-supporting systems rely on internal hoop stresses and may not require steel reinforcing. The exposed face of secant pile can be mechanically ground and leveled to improve the substrate for waterproofing purposes.
Soil Mixed Walls

Continuous stiff walls constructed by mixing soil in-situ with cementitious grout and installing steel reinforcement elements.

Soil mixing improves the engineering properties of soil by injecting cementitious grout and blending the materials in-situ. Soil mixed walls are constructed by overlapping elements of soil mixed ground, and inserting structural piles for reinforcing. Soil mixed walls offer a relatively low cost option to construct continuous, deep, low-permeability walls, and recent developments in construction technology have allowed even more widespread and cost effective applications. Lateral support options for soil mixed walls include reinforced cantilever systems, tieback anchors or internal bracing. In circular or elliptical layouts, unreinforced hoop action can provide shaft support. Malcolm offers three soil mixing technologies applicable to retention systems:

Soil mixing provides lower cost and highly productive solutions for shoring and cut-off walls.

CUTTER SOIL MIXING (CSM) employs two sets of counter rotating vertically mounted cutter wheels to form rectangular panels of soil mixed ground, 21 to 60 inches wide. The cutter head is advanced into soil or soft rock as grout or similar fluid agent is injected, cutting and blending the ground with the injected cementitious slurry. Panels are overlapped end to end and reinforced with steel piles to create a continuous wall. CSM systems can install walls in diverse ground conditions including cohesive and non-cohesive soils as well as soft rock. The system offers a high level of quality control with the capability of down-hole steering which allows CSM support walls to be used for access shaft and wall construction to depths exceeding 100 feet.

JET MIXING is unique to Malcolm Drilling and combines mechanical paddle mixing with high pressure hydraulic energy to shear and blend soil in-situ. This system offers high-speed installation while forming soil mixed columns of 30 to 42 inches in diameter. Continuous walls are constructed by overlapping adjacent soil cement elements, and installing steel pile reinforcement. Jet mixing is ideally suited for wall installation to depths of 40 to 65 feet in weak to moderately strong ground which can be efficiently cut and mixed by the jetting action of high pressure grout injection.

MULTI-AXIS MIXING simultaneously advances three vertical overlapped mixing shafts to create a soil cement panel. The system, routinely referred to as Cement Deep Soil Mixing (CDSM), mechanically cuts and blends the soil with injected grout using interlocked cutting heads and mixing paddles on the shafts. Continuous walls are constructed by overlapping panels end to end, and frequently the construction sequence will completely re-mix the end column of adjacent panels to ensure wall continuity. Multi-axis soil mix walls are installed at depths up to 120 feet.

Soil mixing provides lower cost and highly productive solutions for shoring and cut-off walls.
Underpinning systems allow excavation adjacent to and directly below sensitive structures and facilities. Low vibration and sequenced construction techniques are employed to provide vertical load capacity while maintaining ground support. After new support systems are installed, load is transferred either at the base of existing foundations, or directly applied to columns or walls higher in the structure through “column picks.” Underpinning is highly specialized and requires case by case design and implementation to minimize risk during each step of the construction process. Systems are designed with consideration for vertical loads imposed from the supported structure, lateral loads from retained ground and any temporary induced loads. Malcolm draws from a toolbox of techniques to safely and securely perform underpinning, with careful consideration for the existing structure, ground conditions and the proposed site improvements to optimize solutions for each case. Some key techniques are described below:

**HAND-DUG PIERS** mine a small vertical pit below the existing foundation. Reinforcing steel is placed within the pit, and then excavation is backfilled with concrete. A hydraulic jack pre-loads the underpinning pier, then stiff cement mortar is packed to complete the connection. Hand-dug piers are installed in a phased sequence. They are suitable for relatively stable soils above groundwater, or when water can be readily drawn down by wells without risk of subsidence to existing structures.

**SLANT DRILLED SOLDIER PILES** are placed directly below the existing structure by drilling an inclined oversized hole, and then pushing the steel pile into a vertical position below the foundation. A shallow hand-dug pier is used to create clearance for the pile head directly below the existing structure. As excavation proceeds, lagging is placed between slant drilled piles. Alternately jet grouting can construct a continuous soil cement wall spanning between the soldier piles before the start of adjacent excavation.

**JET GROUTING** injects grout slurry through horizontal nozzles at high pressure and flow rate, hydraulically eroding and mixing soil in-situ. Small diameter tooling (2 to 4 inches) is advanced, then slowly rotated and withdrawn while jetting to form columns of cemented ground, with diameter typically from 2 and 4 feet. Underpinning jet grout columns are installed on an incline below adjacent structures. The system is applied in erodible soils, such as sands, silts and clays and is particularly useful below the water table. Jet grouting creates an improved soil block which acts as a gravity mass providing direct vertical support as well as lateral earth retention. Jetting can be combined with other structural underpinning solutions such as micropiles or slant drilled piles.

**MICROPILES** are small diameter steel reinforced drilled and grouted piles. They are constructed using specialized drilling equipment which can fit through conventional doorways and can operate with headroom clearance of less than 9 feet. Micropiles are installed in almost all ground conditions, including caving soils below water, and into rock. For underpinning applications, load can be transferred by drilling through and bonding into existing footings, or via transfer frames.

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Malcolm’s drilling and grouting expertise is applied to safely and securely reinforce existing unstable slopes and to allow re-grading for development of new facilities. Our slope stabilization projects employ post-tensioned anchors, stitch piers and dewatering in addition to more conventional retention systems in order to directly resist the slide forces and to increase shear resistance along existing or potential failure surfaces. Detailed geotechnical evaluations identify critical stability conditions and potential sliding mechanisms. Case-specific analysis, design and implementation are required to minimize risk at each stage in the process of enhancing the slope factor of safety for both emergency repairs and long term solutions. Malcolm’s cased drilling methods are ideally suited to the variable ground profiles encountered within slide areas and minimize the hazards associated with the introduction of drilling fluids into marginal ground.

**POST-TENSIONED ANCHORS** efficiently increase both lateral and shear resistance. Anchors can be drilled over 200 feet fully cased to penetrate and transfer load beyond potential slip planes. Small crawler mounted drills can work from temporary construction benches on marginal slopes. Load resistance is transferred into the slope through reinforced concrete pads bearing directly onto the exposed face, or using a pile and water system.

**STITCH PIERS** penetrate through the potential slide plane functioning as dowels between the sliding mass and underlying stable ground. These systems rely on arching to transfer slide loading to points of support, both embedment below the slip plane and lateral anchorage close to grade. Malcolm has installed stitch piers ranging from micropiles (less than 12 inches diameter) up to reinforced drilled shafts with 8 feet in diameter. Soil cement columns (SCC) can act to both improve shear capacity of insitu soils and key into firm underlying substrates. Micropiles constructed with “A-frame” configurations create structural efficient systems which develop shear, tension and compression capacity of these elements to resist slide pressures.

**RETENTION WALLS**, particularly secant pile or soldier pile and lagging walls, are frequently used for slope stabilization. Permanent retention systems are constructed to resist the full slide pressure. Temporary shoring is also employed to allow slope re-grading or construction of shear keys by removal and replacement of weak soil zones within the ground profile.

**DEWATERING SYSTEMS** enhance slope stability by lowering groundwater levels, increasing effective stress along potential slide planes. Malcolm offers extensive dewatering expertise including horizontal drains, deep wells, eductor wells and well-point systems which can control groundwater and enhance slope safety. In most cases, dewatering is used in combination with other structural systems.

OPPOSITE: Anchored Stitch Piers, Big Sky, MT.
LEFT: Braced shoring for Shear Key Construction, Los Angeles, CA.
BELOW: Slope Anchorage, Orange County, CA.
Malcolm Drilling Company was founded in 1962 in San Francisco, California, which remains our headquarters today. Malcolm operates throughout United States, maintaining a network of regional offices to serve our clients across the country. To learn more about our expertise and for a complete list of locations, visit:

www.malcolmdrilling.com