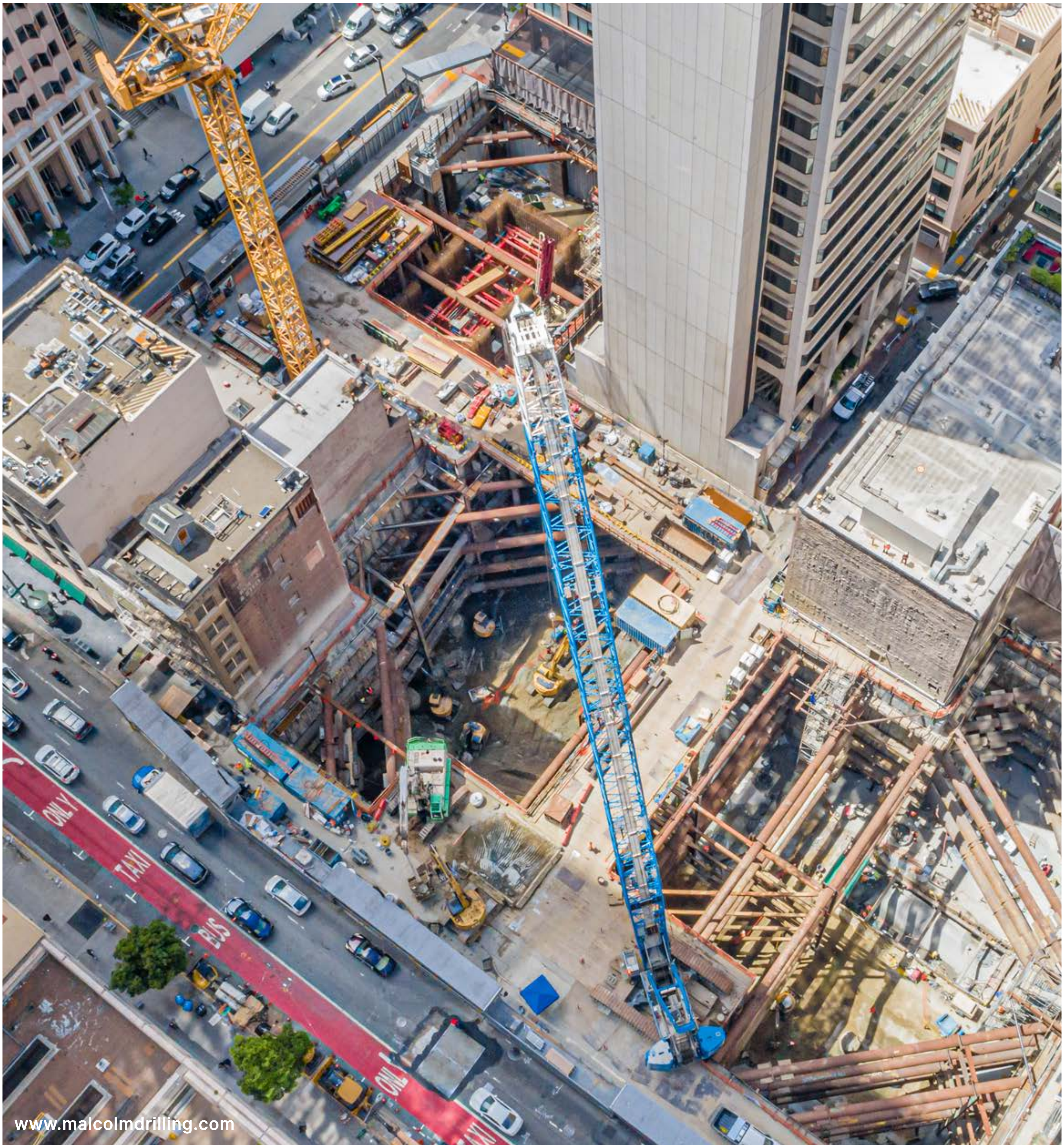
MALCOLM
Retention Systems

- Diaphragm Walls
- Secant Pile Walls
- Internal Bracing
- Soil Mix Walls
- Soldier Pile Walls
- Soil Nail Systems
- Underpinning
- Slope Stabilization



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Retention Systems

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 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.

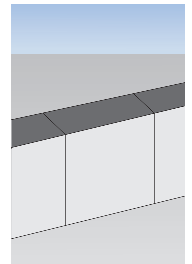
MALCOLM DRILLING COMPANY

Founded by John Malcolm in 1962 as a family business, Malcolm Drilling Company has grown into one of the preeminent Geotechnical Construction and Deep Foundation Contractors in North America, while remaining an independently owned and operated company. We are committed to teamwork, leadership, integrity, and safety at every level of the organization.

Malcolm's program of capital reinvestment positions our equipment fleet at the forefront of the industry, allowing for development and early adoption of the most advanced techniques in geotechnical construction. The synthesis of innovation, our productive, stable, and safe workforce, and unparalleled equipment resources enable Malcolm to continue to expand our core services and fulfill our clients' needs on a broad geographic basis.

Unreinforced Secant Pile Shaft
115ft depth, 41ft diameter
Fremont, CA

Diaphragm Walls



Continuous rigid wall formed of single panels with concrete and optional reinforcement.

Diaphragm walls, also known as D-Walls or slurry walls, are a robust retention system consisting of reinforced concrete walls that can be used for temporary or permanent shoring walls to depth of more than 300 feet. Diaphragm walls are formed by constructing a series of overlapping panels to build a continuous wall. Single panels can be aligned straight, in circles or even combined with T-shaped panels to form various layouts accommodating linear or curved structures, such as circular access shafts for tunnel projects or buttress walls for retaining structures.

These panels can be excavated in single or multiple segments (bites) of typically 9-foot length and width of 3 to 5 feet. Joints between the separate panels can be formed by using stop ends or by cutting the secondary panel into the primary panel using hydraulic cutters to form a continuous structural wall.

Prior to the excavation of the first panel, a guide wall is constructed along the alignment of the wall therefore defining the location and orientation of each individual panel. The guide wall also serves as a template for the excavation equipment to ensure proper vertical alignment of each panel down to final excavation depth. The guide wall also protects the open trench excavation in the upper 5-10 feet from unexpected caving and provides a safe working platform for equipment and personnel.

Panels are typically excavated using clamshell buckets and hydraulic cutters. Chisels can be used to remove man-made or natural obstructions. During the excavation, a bentonite or polymer support fluid is added into the trench to prevent caving of the side walls. The fluid will support the open trench until it is replaced by concrete.

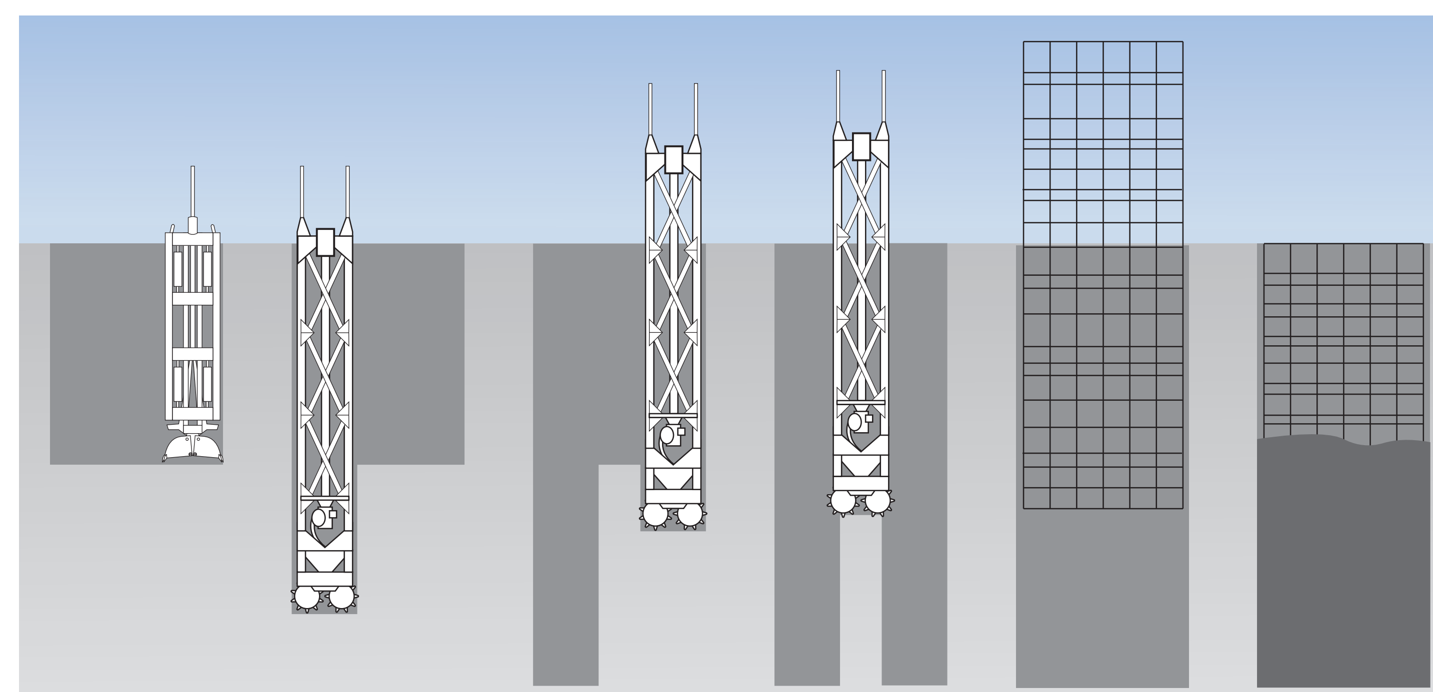
Once the final design excavation depth is reached, reinforcing steel cages are lowered into the trench and tremie concrete is placed from the bottom up, displacing the support fluid. After the tremie concrete has set, it forms a reinforced concrete wall (diaphragm wall). For trench excavations through dense soil layers or into rock, hydraulic cutters are used due to their heavy weight and ability to cut into harder materials. These cutter can excavate hard rock with strength up to 20,000 psi.

Panels are typically reinforced with cages or steel beams, but when arranged in a circle, may not require reinforcing since a compression ring is formed by structural concrete. The concrete can be replaced by a low-strength cement-bentonite mixture, which is flexible and provides an almost impermeable barrier in case the wall is used as a cut-off wall.

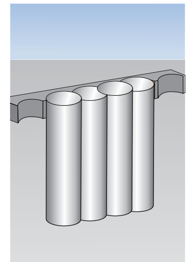
OPPOSITE: Circular wall panel installation, Vancouver, Canada

DIAPHRAGM WALL CONSTRUCTION SEQUENCE

Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Pre-Trench	First Bite	Second Bite	Intermediate Bite	Cage Installation	Concreting



Secant Pile Walls



Overlapped drilled piles create a continuous rigid support and cut-off wall before start of excavation.

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 over burden and seal into dense till or rock below excavation subgrade.

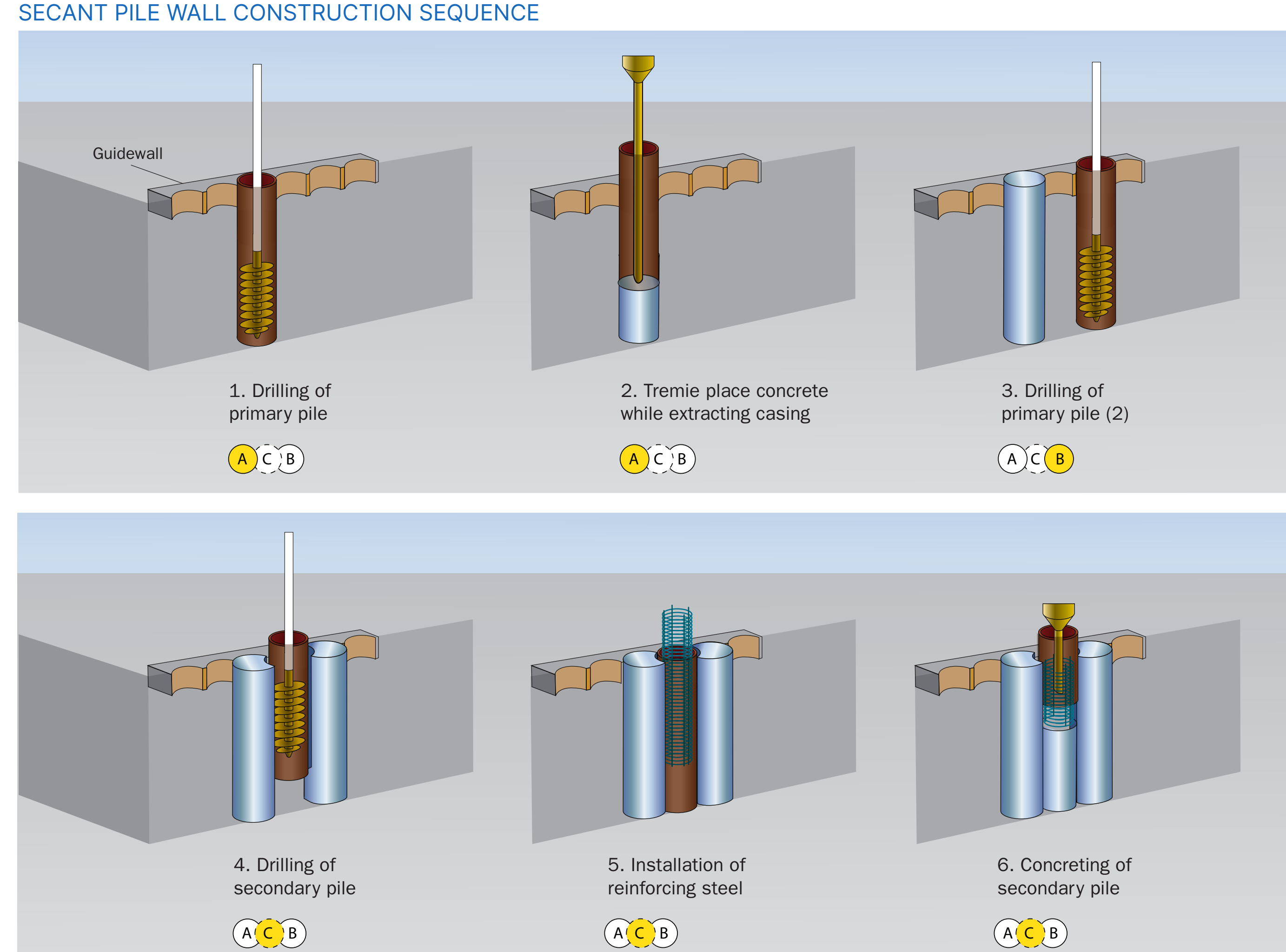
Flexible drilling methods accommodate variable ground.
Piles are drilled and concreted prior to start of excavation. The initial or "primary" piles are drilled into the ground at the selected center spacing. The wall is completed by drilling structurally reinforced "secondary" piles which cut into and overlap the primary 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 beams or rebar cage.

OPPOSITE: Braced secant wall, Mitchell Interchange, Milwaukee, WI

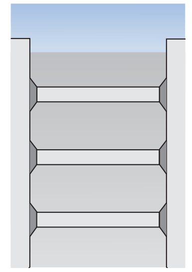
Construction maintains strict tolerances.
The key to secant pile wall construction is maintaining overlap between adjacent piles. A guide wall or template at ground surface ensures that every pile is accurately located. Drilling with heavy wall steel casing provides an extremely stiff drill string which can achieve vertical tolerance typically better than 0.5% of pile depth. Downhole surveys are performed to verify that actual drilling vertically 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.

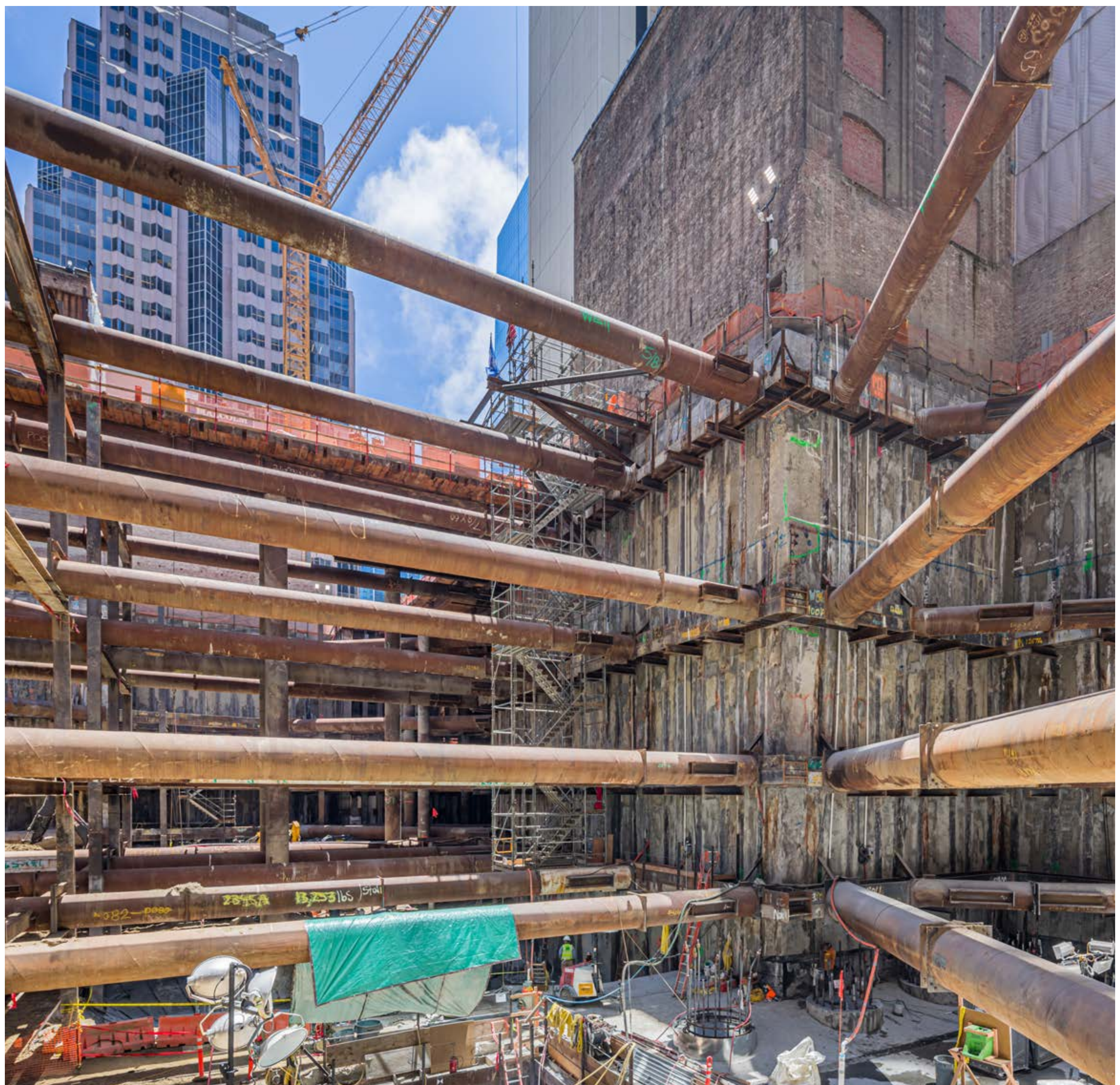
SECANT PILE WALL CONSTRUCTION SEQUENCE



Internal Bracing



Lateral support system spanning between perimeter walls and installed in lifts during excavation.



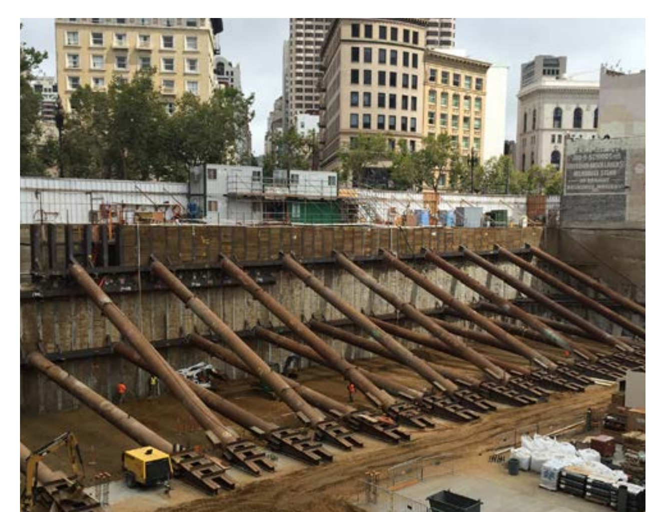
Internal bracing is a temporary lateral support system that is used to facilitate deep excavations that cannot be cantilevered or supported by ground anchors or soil nails. It can be used in conjunction with all retention wall systems including soldier beam and lagging walls, soil mixed walls, secant pile walls, and diaphragm walls. Internal bracing is often used in metropolitan areas where post-tensioned anchors cannot extend beyond the property line due to adjacent structures, utilities, or right of way restrictions. It is also an efficient solution when poor soil conditions and high groundwater would make post-tensioned anchors difficult to install or prohibitively long to achieve the required load capacity.

The internal bracing typically consists of wide flange steel beam 'walers' that run parallel to the perimeter wall and steel pipe 'struts' that span across the excavation between the walers. The steel pipes can also be angled down to the bottom of the excavation and connected to concrete blocks, piles, or the mat slabs to act as 'rakers'.

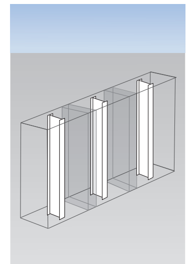
Like post-tensioned anchors, the internal bracing system is installed in lifts as the excavation proceeds downward, typically every 10 to 15 feet. Bracing lifts are located to avoid the permanent basement floor slabs and can be sequentially removed once the preceding floor slab has reached design strength.

Internal bracing can also be pre-loaded to provide an extremely rigid lateral support system that minimizes deflections. For deep excavations adjacent to sensitive structures, such as tall buildings, existing basements, rail lines, or tunnels, internal bracing is often the best solution. Internal bracing can be equipped with various instrumentation to monitor stress and deflection throughout the various excavation stages.

OPPOSITE: 70ft deep excavation, Oceanwide Center, San Francisco, CA
TOP LEFT : Secant pile wall bracing, Folsom, CA
BOTTOM LEFT: Double level raker system, San Francisco, CA
RIGHT: Braced shoring for shear key construction, Los Angeles, CA



Soil Mixed Walls



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

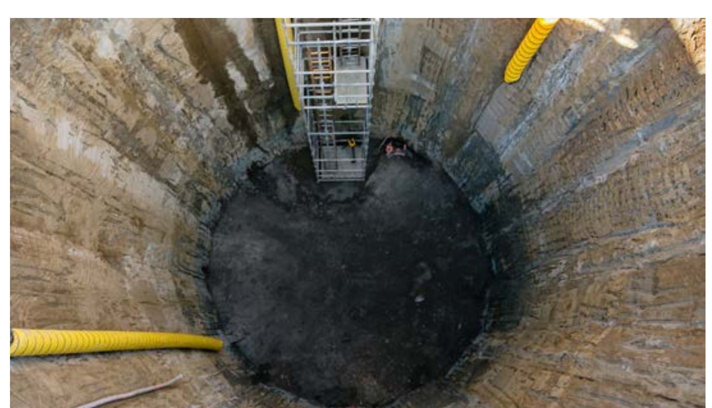
Soil mixing improves the engineering properties of soil by injecting cementitious grout and blending the materials in-situ. Soil mixed walls are constructed by overlapping elements of soil mixed ground and inserting structural beams for reinforcing. Soil mixed walls offer a relatively low-cost option 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.

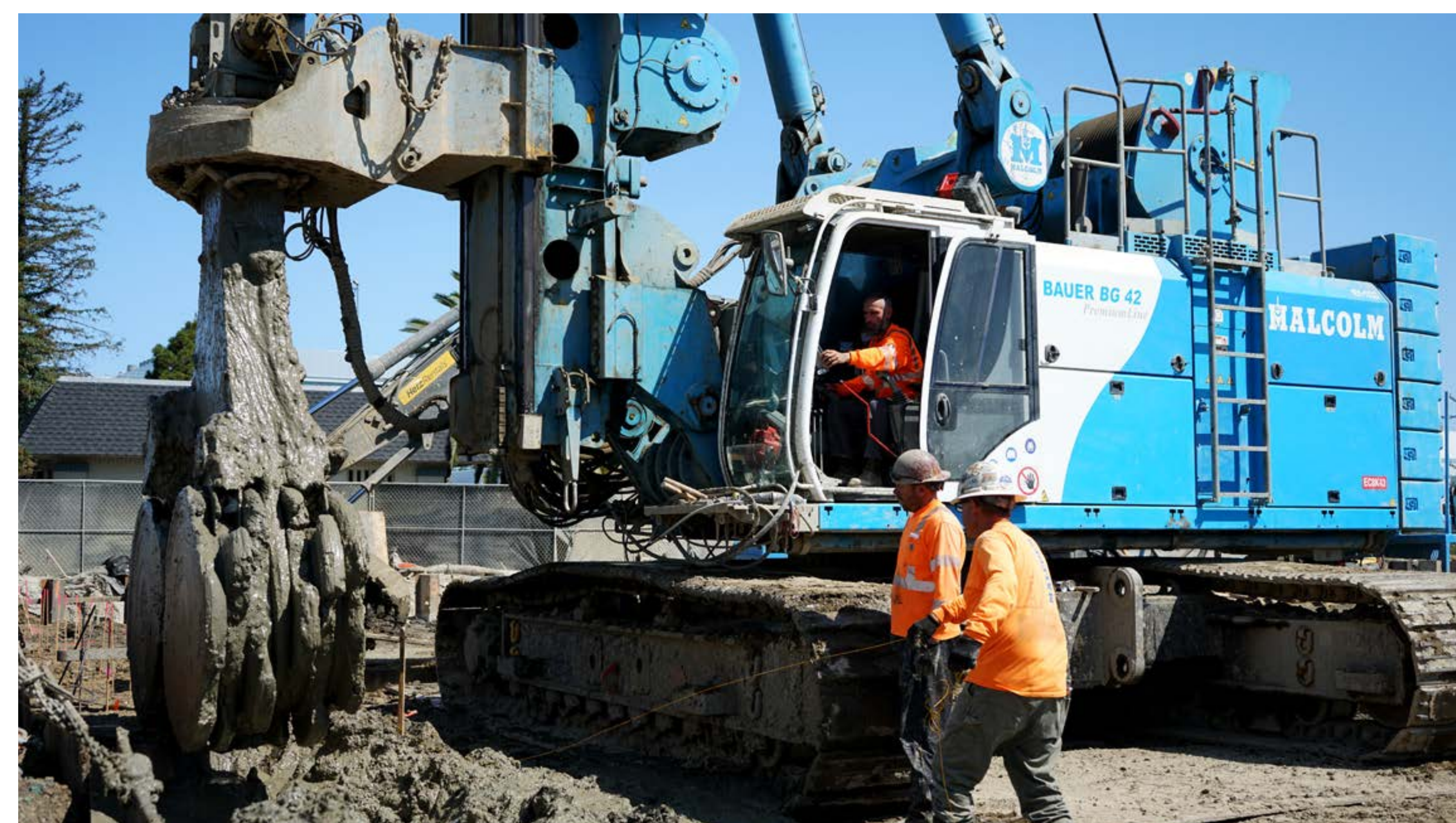
CUTTER SOIL MIXING (CSM) employs two sets of counter-rotating vertically mounted cutter wheels to form rectangular panels of soil mixed ground, 21 to 60 inches wide. The cutter head is advanced into soil or soft rock as grout or similar fluid agent is injected, cutting and blending the ground with the injected cementitious slurry. Panels are overlapped end to end and reinforced with steel beams 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.

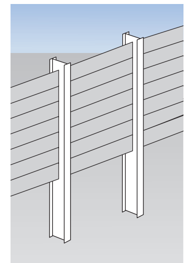
MULTI-AXIS MIXING simultaneously advances three vertical overlapped mixing shafts to create a soil cement panel. The system, routinely referred to as Cement Deep Soil Mixing (CDSM), mechanically cuts and blends the soil with injected grout using interlocked cutting heads and mixing paddles on the shafts. 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.



ABOVE: Anchored CSM wall, Miami, FL
BELOW: CSM shaft, Fremont, CA
OPPOSITE: CSM equipment, San Carlos, CA



Soldier Pile Walls



Shoring system constructed by excavation in lifts, installing lagging between pre-placed steel soldier piles.

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.

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 ground water table.

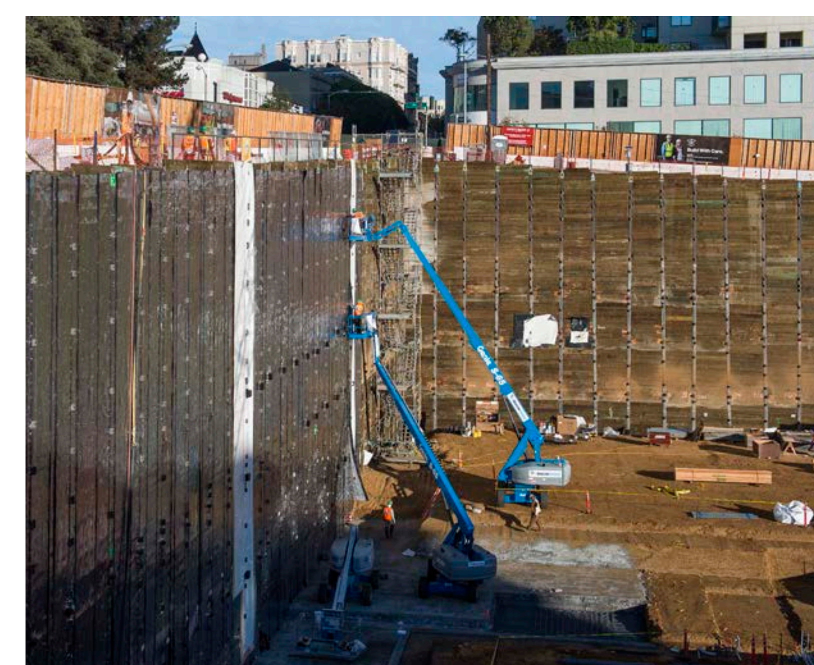
Optimal installation method selected for each site.

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 spacing and extend at least 8 to 10 feet below final excavation grade to provide passive toe resistance.

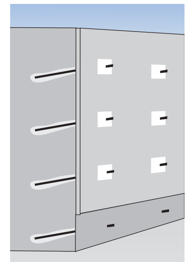
Temporary and Permanent Earth Retention Systems

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 protected and any exposed steel is shop coated. When shotcrete is used, it is attached to piles using headed studs and full encases the steel for corrosion protection. Malcolm offers a range of aesthetic solutions for shotcrete wall finish including rod, float, or "natural rock" sculpting and coloring.

OPPOSITE: Tieback testing, anchored pile and timber lagging wall, Palo Alto, CA
TOP LEFT: Anchored pile and timber lagging wall, Los Angeles, CA
BOTTOM LEFT: Interally braced pile and timber lagging, Palo Alto, CA
RIGHT: Anchored pile and timber lagging wall, San Francisco, CA



Soil Nail Systems



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

Soil Nail Wall
Salt Lake City, UT

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.

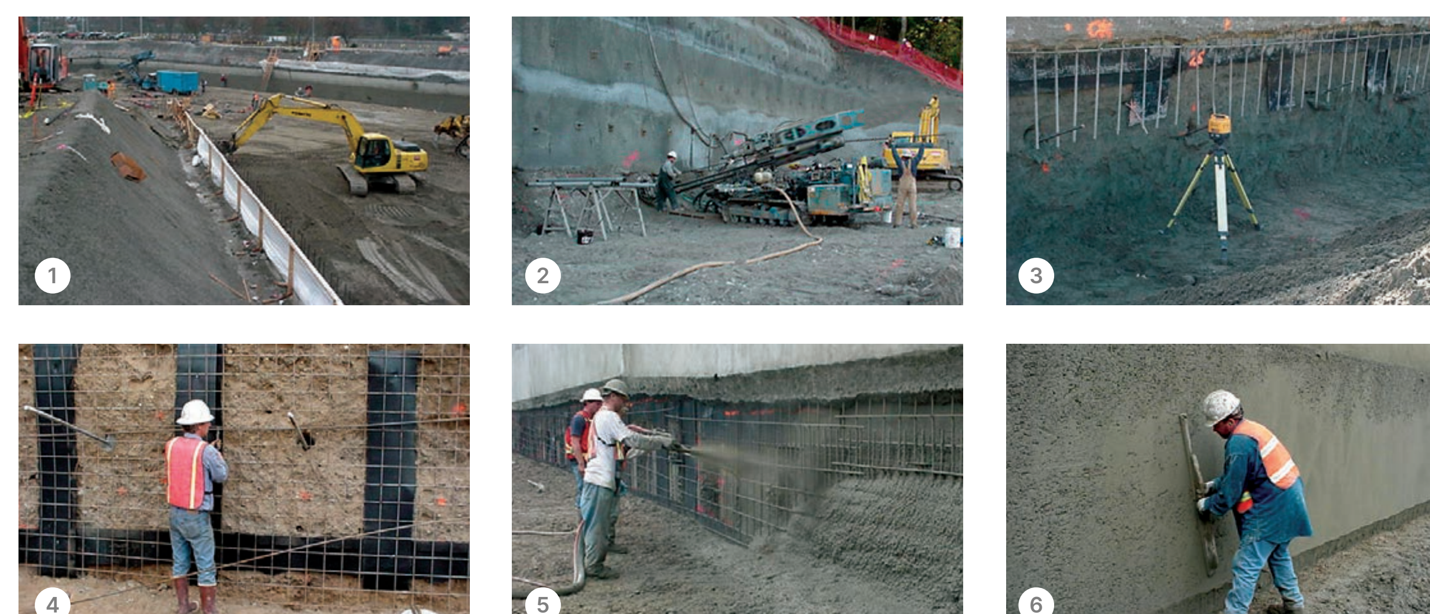
Soil nail walls are constructed from the top down in lifts of approximately 5 feet. Nails are drilled at each lift, with steel bars grouted into 4 to 6 inch diameter holes.
The wall facing is constructed by embedding steel nail head plates into lightly reinforced shotcrete. Vertical drainage strips placed 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-put out tests are performed throughout the production work to ensure compliance with quality control procedures.

Suitable for variable ground types.

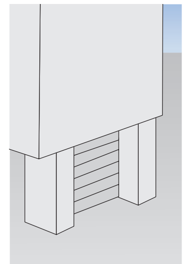
This top-down construction process requires relatively stable ground which can stand after excavation long enough to allow for nail drilling, facing placement and initial cure. Stiff cohesive soils, soft rocks and granular materials with some cohesion or cementation are ideal for soil nailing. Dewatering systems can be combined with soil nail 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.

SOIL NAIL WALL CONSTUCTION 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



Underpinning



Directly supports vertical loads from adjacent structures and provides earth retention during excavation.

Malcolm's 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 exiting 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 perform underpinning safely and securely, with careful consideration for the exiting 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 in 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.

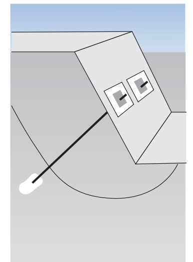
OPPOSITE: Micropiles with load transfer frames, San Francisco, CA
LEFT: Jet grouting installation, San Francisco, CA
RIGHT: Slant drilled piles with jet grout lagging, San Francisco, CA

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.

Slope Stablization



Geotechnical and structural systems constructed to enhance slope stability.

Malcolm's drilling and grouting expertise is applied to reinforce existing unstable slopes safely and securely 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 waler system.

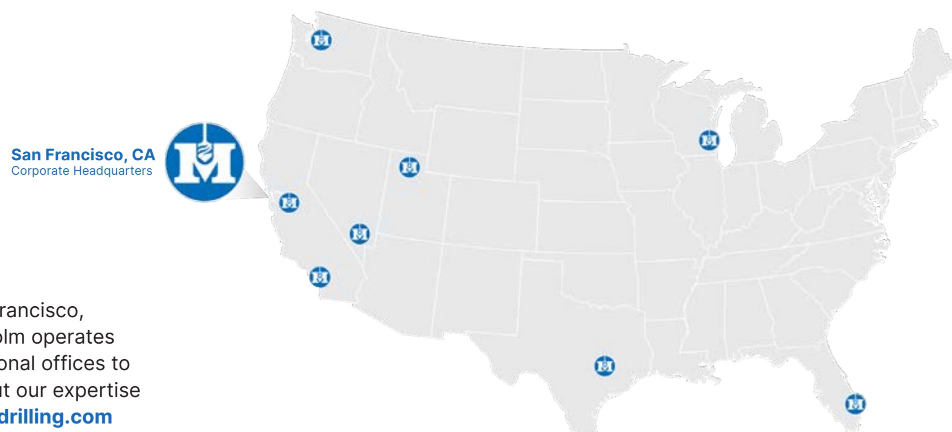
STITCH PIERS penetrate through the potential slide plane functioning as dowels between the sliding mass and underlying stable ground. These systems rely on arching to transfer slide loading to points of support both embedment below the slip plane and lateral anchorage close to grade. Malcolm has installed 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 in-situ 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.

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, educator 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 stitched piers, Big Sky, MT
LEFT: Suspended drilling platform, Santa Monica, CA
RIGHT: Slope anchorage, Orange County, CA

MALCOLM
Look to the Blue

FRONT COVER: Internal bracing, Oceanwide Center, San Francisco, CA
BACK COVER: Tieback anchor drilling, Miami, FL



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**