Malcolm Drilling Company
Soil Mixing Systems

Cutter Soil Mixing • Jet Mixing • Deep Soil Mixing
Soil Mixing is a ground modification system that blends a cementitious grout with the in situ soil to form soil cement elements, panels or columns. Soil Mixing methods utilize mechanical energy, in combination with the fluidifying action of a grout slurry, to shear the soil and create a high quality soil cement mix.

Soil Mixing has the advantage of being virtually vibrationless, applicable to a wide variety of soil conditions, highly sustainable due to its use of in situ materials, and fully instrumented for process control and quality assurance.

**Soil Mixing Applications:**
- Mitigation of liquefaction potential / seismic induced settlement / lateral spreading,
- Massive ground improvement for settlement control or increase in bearing capacity,
- Excavation support / construction of temporary or permanent retaining walls,
- Construction of cut-off walls for control of groundwater and contaminants,
- In situ encapsulation of pollutants / chemical treatment of contaminants,
- Structural support for area loads and point loads.

Malcolm Drilling Company utilizes three very different Soil Mixing techniques to provide our clients with an optimal solution to their particular problem. Our methods are: Cutter Soil Mixing (CSM), Jet Mixing and Deep Soil Mixing (DSM).

Selection of the appropriate technique depends on several factors, including the type of geotechnical constraint, the characteristics of the soil, and the desired end result. This ability to implement the best suited Soil Mixing method, in combination with our proven expertise and support, ensures that you will get the best possible solution at a competitive price.

### Soil Mixing Effectiveness by Soil Condition

<table>
<thead>
<tr>
<th>Soil Condition</th>
<th>Cutter Soil Mixing</th>
<th>Jet Mixing</th>
<th>Deep Soil Mixing</th>
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</thead>
<tbody>
<tr>
<td>Soft silts and clays</td>
<td>***</td>
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<td>***</td>
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<tr>
<td>Stiff silts and clays</td>
<td>***</td>
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<tr>
<td>Sands</td>
<td>***</td>
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<td>***</td>
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<tr>
<td>Gravels</td>
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**Benefits of Soil Mixing**
- Uses soil-cement mixed in situ, eliminating the use of concrete or aggregate.
- Economical system to construct deep foundations and retaining walls.
- Applicable to a wide range of soils.
- Excellent method for liquefaction mitigation, settlement control, excavation support, and seepage control.
- Can solidify contaminants in place.
Cutter Soil Mixing

Cutter Soil Mixing, CSM, was developed from diaphragm wall technology and utilizes two sets of counter rotating, vertically mounted, cutter wheels. The wheels cut the surrounding soil, while at the same time blending the injected slurry with the in situ soil to form soil-cement panels, 1.7 to 4 feet in width.

There are several unique aspects of CSM technology. Most importantly, the CSM system allows for control of the speed and rotational direction of the cutter wheels; each wheel is controlled independently. Instrumentation housed directly inside the cutter head relays the x, y and z coordinates of the tool in real time to a computer display inside the operator's cab. This provides assurance of complete overlap between panels to depths of up to 130 ft.

As a result of the hydraulic motor being housed inside the cutter wheels themselves, energy is applied directly at the point of attack and not at the top of the Kelly bar. The wheels can be equipped with rock teeth to allow cutting through difficult soils, including cobbles up to 8 inches in diameter or bedrock with up to 5000 psi unconfined compressive strength.

The CSM tool cuts vertical rectangular panels, resulting in fewer vertical joints when compared to multiple shaft systems, making this system ideally suited for constructing long soil mix structures such as retaining walls, permeability barriers, and liquefaction mitigation cells. This tool architecture also allows for placement of reinforcing beams at any point along the length of the panel, optimizing the structural design of the wall.

Case Study: 635 Elliot Avenue, Seattle, WA

Cutter Soil Mixing was selected as the method of choice for constructing an excavation support system to depths of 40 to 57 feet for a new office building at 635 Elliot Avenue near downtown Seattle. A cement-bentonite mix was employed, resulting in panels exceeding 200 psi unconfined compressive strength, with permeabilities at or below $5 \times 10^{-6}$ cm/sec. The Cutter Soil Mixing system successfully keyed into the underlying glacial till and effectively limited infiltration of contaminated groundwater, offering cost and schedule advantages over secant piles and other composite cut-off/earth retention systems.

Benefits of Cutter Soil Mixing

- Two, vertically mounted, counter rotating heads cut and mix through difficult soils, including stiff plastic clays, gravels and cobbles.
- Builds rectangular panels, not columns, making it ideally suited for constructing walls.
- Instrumentation inside the cutting head monitors x, y and z coordinates of the tool in real time.
- Cutting and mixing energy generated at the point of attack.
- Has the ability to key into the underlying bedrock.
Jet Mixing is a unique soil mixing system developed by Malcolm Drilling Company that combines mechanical paddle mixing with high pressure hydraulic energy to shear and blend the soil in situ, creating a soil cement mix of the highest quality. Our high energy jet mixing system has allowed us to extend soil mixing to stiff, highly plastic clays and weathered rock, soils not normally treated by soil mixing methods.

Jet mixing is fast and the system of choice to construct cylindrical soil cement elements, 30 to 42 inches in diameter, to depths of up to 65 feet. It is ideally suited to construct soil cement piers for settlement control and increase of bearing capacity. It is highly efficient for constructing tangent and secant pile walls, which can be reinforced with wide flange beams (soldier piles) and tiebacks, as required. Because it produces a soil cement material of the utmost quality, Jet Mixing can routinely provide permeabilities of $1 \times 10^{-6}$ cm/sec or less for cutoff walls and groundwater barriers.

**Case Study: 1 Hawthorne St, San Francisco, CA**

1 Hawthorne Street, San Francisco is the site of a new high rise condominium project. The construction plans called for a 40 ft deep excavation through sand and sandy clay with a water table at approximately 30 ft below grade. Adjacent to the excavation was a circa 1910 unreinforced masonry building and a multi-story reinforced concrete high rise. To save dewatering costs and construction time, a composite cutoff/earth retention system was determined to be the most economical solution. Malcolm Drilling constructed a design-build shoring system utilizing jet mixed columns along the two open sides of the project. There were 110 jet mixed elements with a design unconfined compressive strength of 200 psi and permeability of less than $1 \times 10^{-6}$ cm/sec. 48 ft long wide flange beams were inserted in selected jet mix columns. Post tensioned tiebacks were utilized to support the lateral loads. The two adjacent buildings were supported on battered jet grout piles.

**Benefits of Jet Mixing**

- Combination of mechanical and hydraulic energy enables efficient installation, even in stiff, highly plastic clays.
- High energy system results in uniform, high strength soil cement blend.
- Economical system to construct walls, permeability barriers, and soil cement columns.
- Has the ability to key into the underlying bedrock.
Deep Soil Mixing

Malcolm Drilling’s Deep Soil Mixing (DSM) system utilizes mechanical mixing tools to shear the soil in situ and mix it with a cementitious slurry pumped at low pressure. This method has the ability to create large soil mix columns, typically 5 to 8 feet in diameter, to depths of up to 80 feet.

Deep Soil Mixing is a very economical system for mass ground improvement projects. It is ideally suited to provide settlement control and increased bearing capacity in soft soils. Its ability to create large diameter soil mix columns also make it well suited to mitigate the effects of liquefaction induced settlements and lateral spreading. DSM is also the soil mixing method of choice for in situ remediation and encapsulation of contaminated soils and for the construction of Permeable Reactive Barrier (PRB) walls.

Case Study: Market St Bridge, Santa Cruz, CA

Market Street Bridge in Santa Cruz, California required liquefaction and lateral spreading mitigation under both bridge abutments. The system design required 80 soil mixed columns, three to six feet in diameter and up to 60 feet in depth, with H 10 x 42 steel beams inserted in the center of each column to impart lateral ductility. The construction was performed within the confines of a residential neighborhood. The soils at the site were primarily silty sands and silty clays with gravel lenses. Soil mix columns were required to attain a minimum 400 psi unconfined compressive strength. The flexible tooling allowed by this system was ideally suited to create large and variable diameter columns, and the low pressure grout injection was compatible with the site environmental constraints.

Benefits of Deep Soil Mixing

- Ability to construct large diameter columns.
- Very efficient and cost effective method to mix large volumes of soil.
- Effective method for settlement control, liquefaction mitigation, and remediation of contaminated soils.
All of Malcolm Drilling’s soil mixing systems utilize batch weight mixing grout plants with fully automated controls. The batch plants record all grout batch component weights, duration of mix, specific gravity of the batch, and date and time of the batch. The advantage of this type of grout plant is the ability to add both solid and liquid admixtures to the grout batches. As many as 3 different solids and 4 different liquids can be used in a grout mix, giving us the flexibility to design grout mixes for the specific ground conditions and engineering application.

After constructing one or more test columns and conducting wet sampling in fresh columns and coring in cured columns, the critical mixing parameters of penetration rate, mixing speed, grout batch components, and pumping rates are adjusted and established for the project. Once these critical parameters are validated, Malcolm Drilling utilizes the same QA/QC control hardware and software for all three soil mixing systems.

The system monitors grout volume, grout pressure, tool verticality, RPM, torque, crowd forces, and machine parameters such as hydraulic energy employed. The information is presented graphically to the operator in real time for operational control and is recorded for QA analysis. The stored data can be downloaded as a function of depth or time and is separated by downstroke and upstroke. Included in the hard copy report are element identification number, date, start and finish time, and operator/rig identification.

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**Typical production log and grout mix report.**

Every Malcolm soil mixing system is fully instrumented, monitoring grout flow rates, injection volumes, injection pressures, and penetration rate. This information is portrayed on a computer screen mounted inside the operator’s cab.
Only Malcolm Drilling can provide you with a wide array of soil mixing techniques to suit your site. We can combine soil mixing with a variety of deep foundation and geotechnical construction methods to handle even the most challenging ground conditions. Our customer base is efficiently serviced through our network of regional offices, allowing Malcolm Drilling to deliver the highest quality product consistent with our position as an industry leader in soil mixing technology.