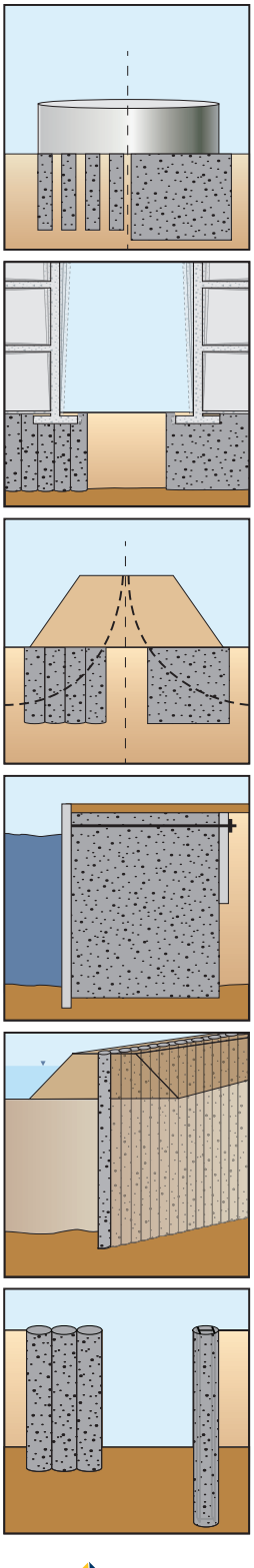
WET SOIL MIXING

Wet soil mixing offers a cost-effective and efficient means to overcome a variety of soil problems.

Above: Soil mix columns constructed along the alignment of an existing waterline provided a containment system to protect the critical utility.

Center: Soil mixing for foundation support and liquefaction mitigation at a planned hospital site.



Wet soil mixing is the controlled mechanical mixing of the in situ soil with grout slurry using a rotary mixing tool. The wet method relies on the introduction of an engineered grout slurry to create soil-cement (soilcrete) elements for soil stabilization, or to support earth or building loads. The intent of the soil mixing program is to achieve improved engineering properties of the in situ treated soil, generally a design compressive strength, shear strength and/or permeability. Soil mixing can also be used to immobilize and/or stabilize contaminants, or as a chemical treatment system.

Keller has designed and constructed soil mixing programs for over 20 years and has successfully completed over 150 projects. Experienced employees working with self-developed specialty mixing tools and proprietary data acquisition (DAQ) equipment and software enable Keller to perform the highest quality soil mixing to meet each project's requirements. For a variety of subsurface and project conditions, Keller's wet soil mixing may be the answer.

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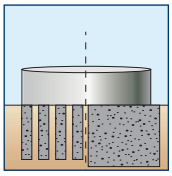
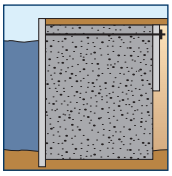
Technology & Applications . . .

Wet soil mixing is applicable to a wide range of soils. For soils with high moisture content, dry soil mixing may also be considered. Soil mixing has been performed to depths up to 30 meters. Soils vary widely in their ability to be mixed, depending on the soil type, strength, water content, plasticity, stratigraphy, and texture. Almost any soil type, including organics, can be treated, although they may require high binder contents and/or pretreatment to achieve required results. In cases when the target soil is very soft, including some very weak clays and peats, 100% of the soil may require treatment. This complete coverage of soil mixing is referred to as mass mixing, and treatment to depths of approximately 6 meters has been performed with the horizontal axis mass mixing tool. Deeper mass mixing depths can be accomplished by overlapping columns. Experienced Keller representatives are available to discuss treatment in challenging soils.



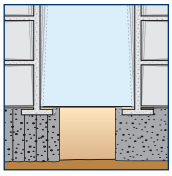
Foundation Support

Structures such as tanks, buildings, and others with heavily loaded foundations can be supported by soil mix columns or mass mixing.



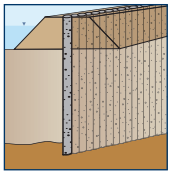
Port Development

The soft soils often found at port facilities can be treated with soil mixing. Stabilization can provide structural support, and/or it can greatly reduce lateral loads on bulkhead walls.



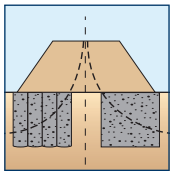
Liquefaction Mitigation

Liquefaction problems in seismic areas can be remedied by using soil mixing to support the structure and to resist lateral spreading.



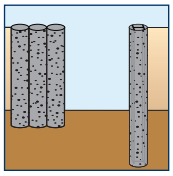
Water Cutoff

Secant soil mix columns can be constructed beneath undeveloped sites or existing levees to produce a water cutoff wall.



Slope Stabilization

Soil mixing can provide substantial shearing resistance to stabilize slopes, excavations, or embankments. Shear walls can be constructed by interlocking columns or with the mass mixing tool.



Excavation Support

Soil mix columns can be used to construct in situ retaining structures. Structural steel elements are often installed into the uncured soil mix columns to add strength and provide load distribution should anchoring be necessary.

① *Settlement control for tank foundations provided by soil mix columns.*

② *Mass soil mixing to solidify and stabilize soils underlying a planned building.*

③ *A new high-rise building requiring soil mix columns to provide earth retention and bottom seal for a dry excavation near the ocean.*

④ *Deep soil mix columns (shown) and mass soil mix cap constructed for settlement control of new tanks.*

⑤ *Mass soil mixing to create vertical panels for water cutoff in restricted access and low headroom.*

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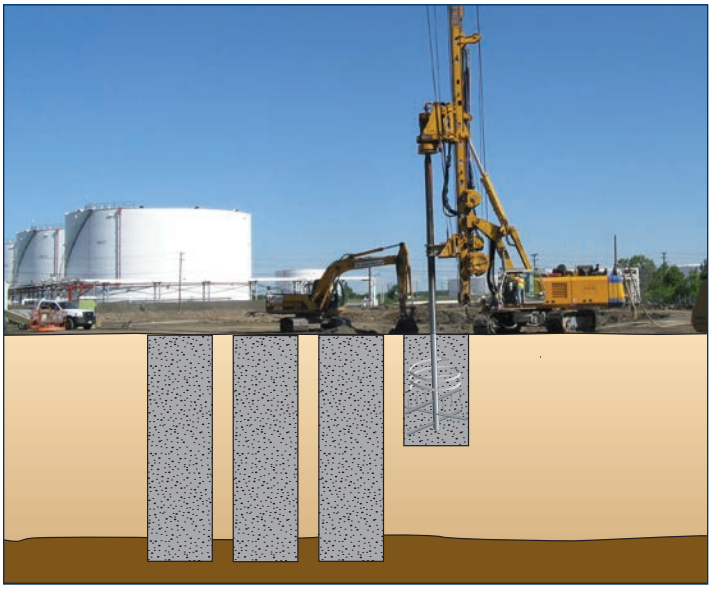
Procedures & Design Considerations . . .

Wet Mixing Procedures

A range of mixing tool configurations can be designed to construct varied geometries in diverse soils. As the soil mixing tool penetrates the ground during column construction, grout slurry is pumped through the hollow stem of the shaft and injected into the soil through nozzles located on the rotating mixing blades. The mixing blades on the tool shear and mix the soil with the grout slurry. Injection and soil mixing continue to design depth. When design depth is reached, tool rotation and grout injection continue as the tool is withdrawn, leaving behind stabilized soilcrete columns. The columns may be designed as individual foundation elements or clustered to construct larger geometries over a wider area.

When mass mixing, initial conditioning of the soil may be performed with separate equipment. The binder agents are injected as the horizontal axis mixing tool passes throughout the soil mass being treated.

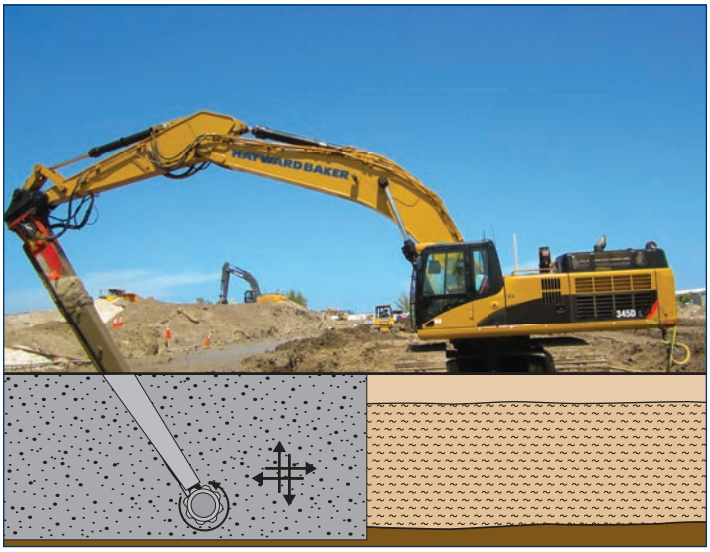


During column mixing, the mixing tool mixes the soil as it advances to the maximum treatment depth and continues mixing during withdrawal.

Depending on the soil type and required binder content, excess soilcrete generated may range from 20 to 50% of the treated volume.

Design Considerations

Soil mixing can treat a wide range of soil types. Soft cohesive soils are usually targeted as other soil types can often be treated more economically with other techniques. Variability of the product is largely a function of the variability of the soil. It is crucial to understand site geology and history, soil gradation, pH, and the in situ moisture content of each treatment stratum. The sulfate and organic content of each stratum should also be determined.



During mass mixing, the track hoe arm raises, lowers, and sweeps the horizontal axis mixing tool through the treatment zone, mixing the soil with the slurry, which is injected through a port near the mixing tool.

Soil mixing creates a soilcrete product that is stiff and strong, although final mix strength depends on many factors, some of which include soil type, water content, pH, organic content, grout quantity, and mixing energy. Therefore, it is recommended that laboratory bench scale testing using site soils and methods to simulate mixing procedures be conducted. The strength of field-mixed samples may vary from that of lab-prepared samples. Selecting a strength value for design should involve, among other things, considering the variations in strength that are inherent to this process. Additional recommendations for design can be found in the soil mixing chapter of Ground Improvement, by Dr. M. Topolnicki, Third Edition, Spon Press. ISBN 9780415599214.

It is challenging to mix low-plasticity clays with shear strength greater than 1,500 psf, high-plasticity clays with shear strength greater than 1,000 psf, and cohesive soils with moisture contents much lower than the liquid limits. However, with appropriate pretreatment even these difficult soils can be treated successfully. Obstructions need to be identified prior to implementation. Stiff soils and obstructions may require predrilling ahead of the soil mixing process.

Equipment & Materials . . .

No single tool will be the best for all soil types, and field adjustments are sometimes performed.

Wet Mixing Rig

The base mixing rig is used to provide stability, depth capability, and power to the mixing tool. Drill heads vary from conventional hydraulic drill heads to dual-motor, crane-mounted turntables. Torque units range from 40.7 kN-m to 406.7 kN-m.

The mixing tool can be a combination of partial flighting, mix blades, injection ports and nozzles, and shear blades. No single tool will be the best for all soil types, and field adjustments are sometimes performed. Column size ranges from 0.3 to 3.6 meters in diameter.

Soil mix columns constructed for foundation support and liquefaction mitigation for the expansion of a nuclear plant.

When performing mass mixing, a horizontal axis mixing tool is connected to the arm of a modified track hoe. The mixing tool is moved throughout the soil being treated as binder is injected through a port located at the rotating tool.

Grout Slurry Delivery

Depending on the in situ soil and required properties of the soilcrete, the volume of grout slurry necessary ranges from 20 to 50% by volume of soil treated, known as volume ratio.

Pre-production laboratory testing is used to prescribe the grout slurry design and volume ratio. Grout slurry is typically delivered on penetration as well as withdrawal. The grout slurry batching system can be a computer-controlled colloidal shear mixer, or a continuous jet mixing system. Grout slurry is continually agitated while it is held in storage. The grout slurry is pumped to the mixing rig from the storage unit at a delivery rate necessary to produce the designed volume ratio.

Dual axis wet soil mixing rig used to construct a perimeter retaining wall prior to excavation for a planned high-rise.

The grout slurry flow per cubic yard of soil being mixed is adjusted to the requirements of the design mix and the results of testing. Flow monitoring devices are installed in the grout slurry delivery line to monitor flow, density, total injected grout, and pressure.

Grout Slurry

The grout slurry consists of water and cementitious binders and may contain swelling clays. Cementitious binder is typically Portland cement, but fly ash, lime, and ground granulated blast furnace slag (GGBFS) may also be used.

A soil mixing grout slurry batch plant. Real-time monitoring of all mixing parameters allows for control of batching and pumping operations.

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Quality Control . . .

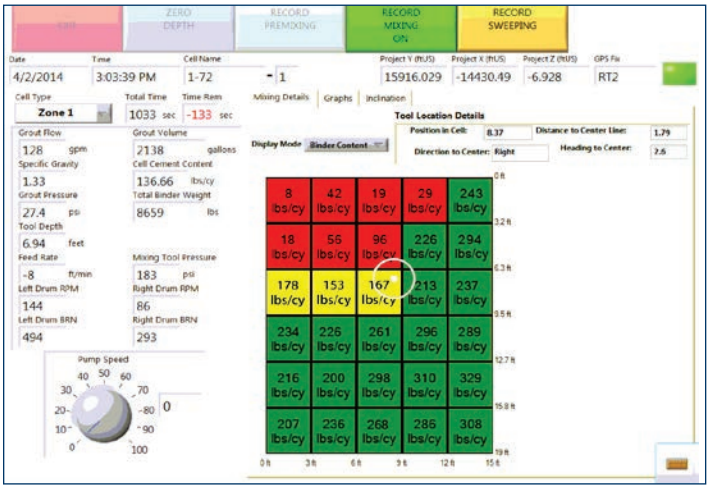
Keller has developed proprietary data acquisition (DAQ) equipment and software for real-time monitoring of all parameters during the wet soil mixing process.

Pre-Construction

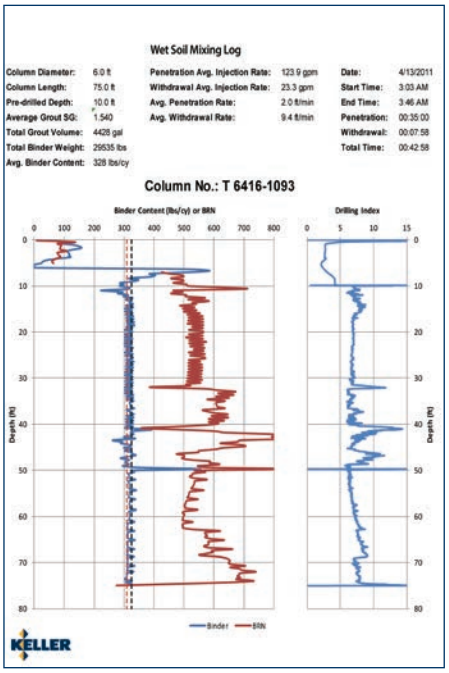
Prior to soil mixing, samples of the soil to be treated are retrieved for laboratory bench scale testing. The samples are mixed in a laboratory with varying slurry types and volume ratios to help identify the mix design that will achieve the required performance.

During Construction

To assist in monitoring and controlling the construction process, HBI has developed proprietary data acquisition (DAQ) equipment and software for real-time monitoring of all parameters. Soil mixing rigs are fully instrumented with an on-board computer system to monitor the slurry dosage and mixing energy. During column mixing, the system also regulates the penetration and lift rates to keep the dosage within the specified range. Data are recorded and displayed on an in-cab monitor.



Mass soil mixing DAQ system rig operator interface.



Example of DAQ system full data report for wet soil mixing.

It is also possible to remotely monitor the feedback. All data are transmitted in near real-time to an online central database via cell modem.

The following information is documented prior to and during construction:

- *Column or cell identification*
- *Working grade*
- *Column diameter or cell volume*
- *Slurry type*
- *Mixing time*
- *Slurry dosage rate and pressure*
- *Tool rpm*
- *Total quantity of slurry added during mixing*
- *Mixing depth*
- *Lab tests on soilcrete samples*

Fresh soilcrete is sampled immediately after mixing for casting into cylinder molds for later laboratory strength and permeability testing.

Post-Construction

Core sampling is common but challenging in the relatively low-strength soilcrete. Coring crews experienced with coring lower strength materials with appropriate equipment are required to retrieve quality samples. Soil inclusions are common, but should not exceed a size that will adversely affect the required performance of the soilcrete system. Rock fragments in soilcrete may break free during coring and grind up the core sample, resulting in low recovery from high-quality soilcrete.

Soilcrete core sample ready for curing and subsequent strength testing.

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Advantages of Keller Wet Soil Mixing

Wet soil mixing offers a cost-effective and efficient means to overcome soft soil problems for a variety of soil types, loadings, and project requirements. Possible benefits include:

- *Development of otherwise unusable (cost/time-prohibitive) sites*
- *Accelerate construction schedule*
- *Possible elimination of site dewatering*
- *Often economical compared to remove-and-replace options*
- *Low vibration and noise*
- *Rapid mobilization*
- *Excess soilcrete can often be used as a fill material*
- *Often combined with other ground improvement systems to increase savings*
- *Contaminant solidification/stabilization*

Soil mixing performed to increase bearing capacity and reduce settlement for planned tanks.

You have a strong partner with Keller

As a leading specialty geotechnical construction firm, Keller provides a full range of ground engineering techniques and solutions, related to earth retention, foundation support, ground improvement, and ground treatment.

Built on a reputation of safety and quality, Keller sets the standard for performance and innovation through our commitment to the integration, implementation, and further development of advanced technologies for specialized geotechnical construction. With technical excellence, and teamwork at our core, we deliver projects safely, on budget and on schedule.

Offering a wide range of services, including design-build packages, Keller meets the needs of our clients by providing comprehensive cost effective solutions to the most complex problems.

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Design-Build Services for the Complete Range of Geotechnical Technologies

Grouting
Fracture grouting/compensation grouting
High mobility (rock/fissure) grouting
Injection systems
Jet grouting
Low mobility (compaction) grouting
Permeation (chemical) grouting
Polyurethane grouting

Ground Improvement
Cutter soil mixing
Dry soil mixing
Dynamic compaction
Earthquake drains
Rapid impact compaction
Rigid inclusions
TRD - soil mix walls
Vibro compaction
Vibro concrete columns
Vibro (Aggregate) Piers®
Vibro stone columns
Wet soil mixing
Wick drains

Deep Foundations
CFA piles (auger cast)
Displacement CFA piles
Drilled shafts
Driven piles
Franki piles (PIFs)
Helical piles
Jacked piers
Macropiles®
Micropiles

Earth Retention
Anchors
Anchor block slope stabilization
Gabions
Micropile slide stabilization system (MS³)
Sculpted shotcrete
Secant or tangent piles
Sheet piles
Slurry wall - structural or cutoff
Soil nailing
Soldier piles & lagging

Additional Services
Dewatering
Ground freezing
Pit underpinning
Slab jacking

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