DRY SOIL MIXING

Dry soil mixing is a low vibration, quiet form of ground treatment that is often used in very soft and wet soil conditions and has the advantage of producing minimal spoil.

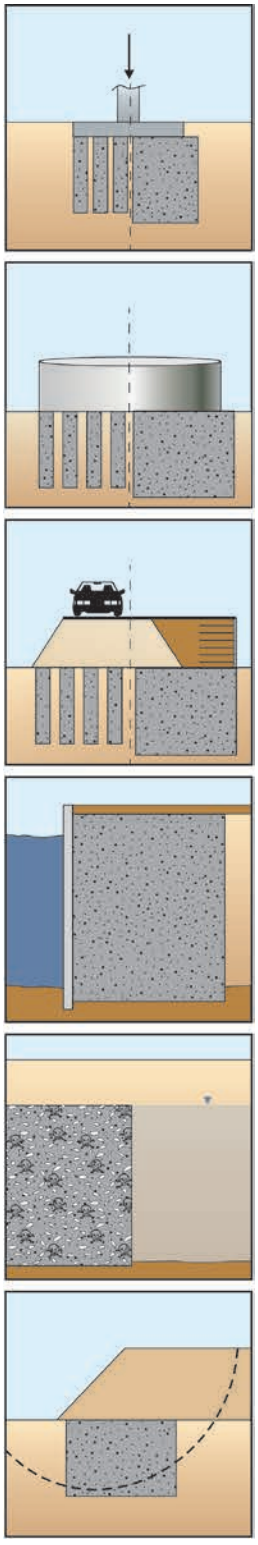
Above: Dry soil mix columns in shear panel arrangement being constructed from on top of a levee for ground improvement.

Center: Dry soil mix columns for foundation support of a new trucking terminal.

Dry soil mixing is a highly effective ground treatment system used to improve the engineering properties of soft clays, peats and other weak soils. The process uses cementitious binders to bond soil particles, thereby increasing the shear strength and reducing the compressibility of the soil. Dry soil mixing is a low vibration process, and uses readily available materials. The process is often used in high ground water conditions and has the advantage of producing minimal spoil.

Dry soil mixing was initially developed in Scandinavia and Japan and used extensively throughout Northern Europe. The dry soil mixing system has provided cost-effective support for embankments, roads, railways, tanks, buildings, and marine land reclamation. Dry soil mixing has been successful in treating such soils as peat, glacial clay, and very soft silty marine clays at sites worldwide.

Keller is committed to providing the most economical solution that satisfies the technical requirements of each project. Whether a situation is typical or unique, we have the experience and innovation to assist engineers, contractors and owners with identifying and implementing the best solution. For a variety of subsurface and access conditions, the dry soil mixing method may be the answer.



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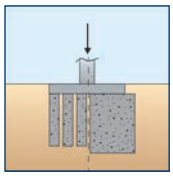
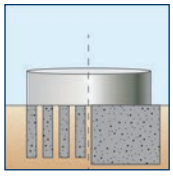
Technology & Applications . . .

Dry soil mixing is used to stabilize wet, soft soils in situ to strengthen the ground. Specialized mixing tools are used to treat the complete mass of soft soil or construct individual column or panel geometries. Soil mix columns with diameters of 0.6 to 0.9 meters and depths of over 23 meters can be constructed. In cases when the target soil is very soft, including some very weak clays and peats, the complete mass may require treatment. This complete coverage of soil mixing is referred to as mass mixing, and treatment to depths of ~6 meters can be performed with the horizontal axis mass mixing tool. Deeper mass mixing depths can be treated by overlapping columns.



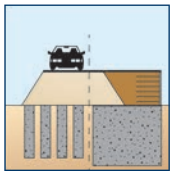
Foundation Support

Structures such as embankments, tanks, earth retaining systems, and buildings can be supported using soil mix columns or mass mixing.



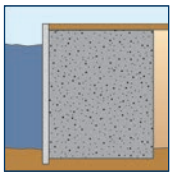
Tank Support

Soil mixing creates reinforced platforms for more uniform settlements and to resist seismic loading, and allows for greater tank capacities.



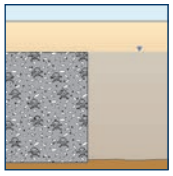
Embankment Support

Embankment loads are transferred through soft compressible soils to a competent stratum.



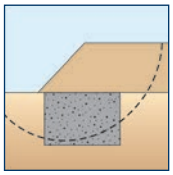
Port Development

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



Pollution Control

Mass mixing has been used to remediate contaminated sites by mixing the soils in situ with binder agents.



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.

① *Construction of a retaining wall for slope stabilization using dry soil mix columns.*

② *Dry mass mixing for road support.*

③ *Support of a three-story replacement building by dry mass mixing.*

④ *Dry mass mixing of dredged material to solidify industrial contaminants and enable transportation to a landfill disposal site.*

⑤ *Ground improvement with dry soil mix columns at a canal. GPS instrumentation allowed precise mixing of column locations from the barge.*

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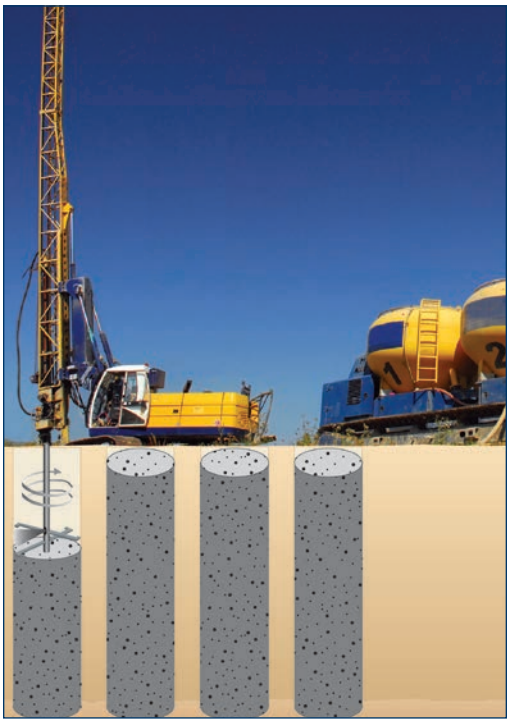
Procedures & Design Considerations . . .

Dry Mixing Procedures

Locations to be mixed are marked on site prior to starting work, with each column or cell given its own designation. Boulders, foundation remnants, and utilities must be removed or marked before treatment can begin. The mixing tool is positioned at the marked location. When column mixing, the rotating mixing tool is advanced with compressed air to the design depth to precondition the soil. At the column base, the binder agent, which has been pressurized and blended in the machine's storage tank, is then pneumatically conveyed to the tool. Binder agent output is flow-controlled and synchronized with the upward movement of the mixing tool.

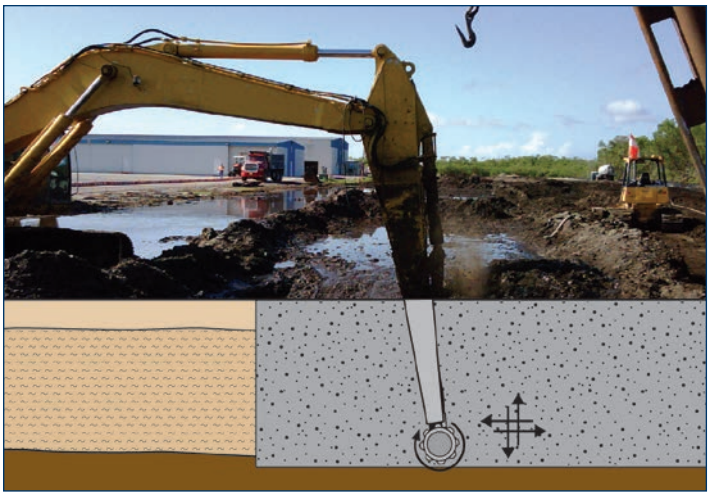


During column mixing, the mixing tool preconditions the soil as it advances to the maximum treatment depth. During extraction, the tool mixes the soil with the binder agent which is injected through a port near the mixing tool.

When mass mixing, initial conditioning of the soil may be performed with separate equipment. The binder agents are injected throughout the soil mass being treated. Shortly after mixing, a soil surcharge preload may be used to provide confinement and precompression during curing, especially when mass mixing.

Design Considerations

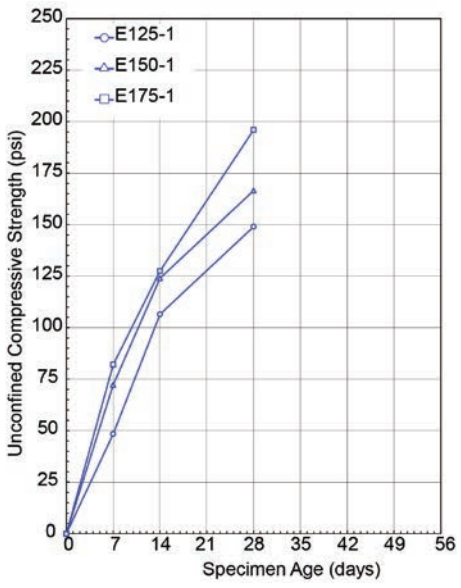
Dry soil mixing is typically best suited for high moisture content (greater than 25%) soils, which are near the liquid limit. The strength starts to increase a few hours after mixing and then rapidly increases during the first week. About 90% of the final strength is usually achieved after three weeks. Organic soil and peats are generally good candidates for dry mixing.



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

An assessment to determine whether or not the project is suitable for stabilization with the dry soil mixing method is made based on an examination of the properties of the soft soil, in combination with knowledge about existing and planned loading, and allowable deformations. Prior to production in the field, laboratory testing is performed on samples of the untreated soil and treated soil samples using a range of binder proportions to determine the strength that can be achieved and the binder quantity and type required to achieve the design requirements.

The performance of the improvement is related to the strength and deformation properties of the improved ground. In determining column spacing, the load is distributed between the untreated soil and the soil mix column in proportion to the stiffness, and the treatment area ratio.



Unconfined compressive strength results from laboratory bench scale test program.

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Equipment & Materials . . .

Dry soil mixing permits construction on sites previously considered unsuitable. Soft coastal soils can be rendered buildable land.

Dry Mixing Rig

The dry soil mixing base rig is a tracked drill or crawler crane, providing stability on what are typically soft sites. When constructing columns, a mast is connected to the base rig. The mast height depends on the required treatment depth. A high speed motor connected to drill rod and a mixing tool is raised and lowered on the mast during treatment. The mixing tool, located at the lower end of the drill rod, consists of a series of paddles that mixes the soil and binder as the drill rod is rotated by the high speed motor. The binder is pneumatically pumped through the drill rod and exits from a port located near the mixing tool.

Dry soil mixing column rig and mast.

The dry soil mixing column rigs have a horizontal reach of 0.9 to 4.8 meters from the front edge of their tracks and a rotation speed of 100 to 200 rpm.

Mass mixing rig.

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.

Binder Shuttle

The dry binder powder is stored in pressure vessels located on a base crawler shuttle, which moves to remain in close proximity to the mixing rig. Once a vessel has been loaded with binder, it is sealed and pressurized. The binder is pneumatically transported to the mixing tool at a rate corresponding to that of the volume of soil being treated.

The accompanying shuttle supplies the binder, which is pneumatically conveyed to the binder outlet through the mixing tool system.

Binder Agents

The time rate of strength gain of the treated soil depends on the type of soil and the amount and type of binder being used. Binder agents may include cement, lime, gypsum, or slag. Strength and stiffness of the treated soil generally increase with increasing binder dosage.

By varying the amount of binder and using mixtures of different binders, a range of strength gains can be achieved. Strengths are highest for inorganic soil with moderate water content.

The binder agents are transported to the work site in bulk trucks and unloaded into storage tanks. The amount of binder added to the soil during the mixing is typically determined through pre-construction laboratory bench scale testing.

Quality Control . . .

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

Pre-Construction

Prior to dry 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 binder contents and types to determine the mix design that will achieve the required performance.

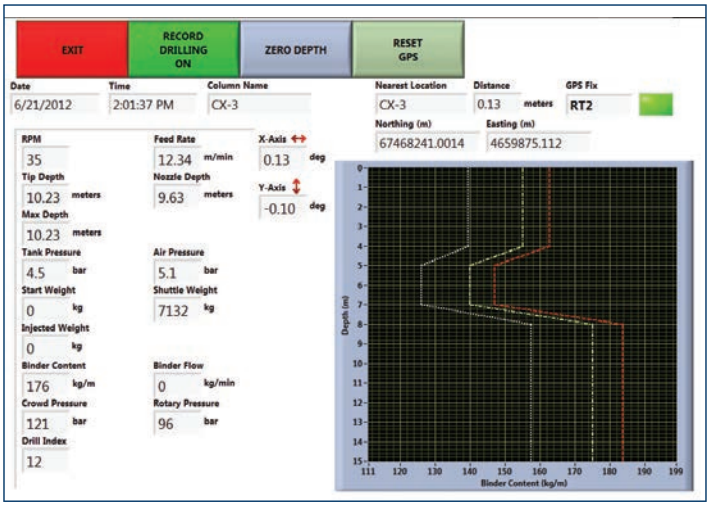
During Construction

To assist in monitoring and controlling the construction process, Keller has developed proprietary data acquisition (DAQ) equipment and software for real-time monitoring of all parameters. Dry soil mixing rigs are fully instrumented with an on-board computer system to monitor the binder dosage. During column mixing, the system also regulates the lift rate to keep the dosage within the specified range. Data are recorded and displayed on an in-cab monitor. 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 in-cab monitor displays data such as binder and tool depth, alongside specified target values.

The following information is documented prior to and during construction:

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



The monitoring page shows the operator all the pertinent information of building the dry soil mix column. This information is displayed in real-time. This example shows two binder dosage zones.

Post-Construction

Core sampling has been the standard for much of the product produced in North America. Coring crews experienced with coring weak materials and using appropriate equipment are required to retrieve quality samples.

Fresh core sample ready for curing and subsequent strength testing.

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Advantages of Keller Dry Soil Mixing

Dry soil mixing offers a cost-effective and efficient means to overcome soft soil problems for a variety of soil types and is effective for a variety of structures. Advantages of dry soil mixing include:

- *Allows development of otherwise unusable (cost/time-prohibitive) sites*
- *Can be combined with other ground improvement systems to increase improvement*
- *Generally more economical than remove-and-replace options*
- *Accelerates construction schedule over preload options*
- *Low vibration and noise*
- *Dewatering not required*
- *Rapid mobilization*
- *Minimal spoil compared to other methods*

Dry soil mix columns to repair a levee failure on a dredge disposal island.

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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