

**TECHNICAL SPECIFICATIONS
DEEP SOIL MIXING
(CUTOFF WALL, RETAINING WALL,
IN-SITU TREATMENT, IN-SITU FIXATION)**

(This technical specification is to be used to guide the writer in the contract requirements for Deep Soil Mixing (DSM) construction for a specific site. Included are _____ to be filled in with project specific data. Also included are [] which denote options to be considered for specific design requirements. Optional subsections are denoted by *. Parenthetic remarks () are included when appropriate to provide the writer with additional, nonessential information. Most [] and * are used to include DSM designs which go beyond the standard design and may include addition of proprietary additives, injection of air for vapor phase extraction of organics. All [], (), and * should be filled in or omitted from the writer's specification.)

DEFINITIONS

DEEP SOIL MIXING is a soil improvement technique used to construct cutoff or retaining walls and treat soils in-situ. This is accomplished with a series of overlapping stabilized soil columns (typically 36-inch diameter). The stabilized soil columns are formed by a series of mixing shafts (2 to 4) guided by a crane supported set of leads. As the mixing shafts are advanced into the soil, (grout/slurry) is pumped through the hollow stem of the shaft and injected into the soil at the tip. The auger flights and mixing blades on the shafts blend the soil with grout or slurry in pugmill fashion. The mixing shafts are positioned to overlap one another and form a continuously mixed overlapping column. When the design depth is reached, the augers are withdrawn and the mixing process is repeated on the way to the surface. Left behind are stabilized DSM columns having the following (property/properties): (low permeability, improved bearing capacity, or shear strength, immobilized contaminants, and when reinforced, able to withstand differential soil and hydrostatic loading).

SLURRY is a stable colloidal mixture of water and bentonite clay and/or attapulgite clay. Other additives may be used as approved by the Engineer to enhance the behavior of the slurry.

GROUT is a stable colloidal mixture of water and Portland cement. Additional materials such as bentonite clay, attapulgite clay or fly ash may be added.

SCOPE OF WORK

This section of the specifications include requirements for the Deep Soil Mixing (DSM) (cutoff wall, retaining wall, in-situ treatment, in-situ fixation) and related work as indicated on the drawings and as hereinafter specified. The work consists of furnishing all plant, labor, equipment and materials and performing all operations as required to construct the DSM (cutoff wall, retaining wall, in-situ treatment, in-situ fixation).

QUALIFICATIONS OF CONTRACTOR

The Contractor shall submit evidence that he is experienced and competent to construct (a) DSM (cutoff wall, retaining wall, - treatment, in-situ fixation). This evidence will include the successful completion of at level three similar projects. This evidence will insure that the Contractor will have sufficient competent experienced personnel to carry out the operations specified.

DSM (CUTOFFWALL, RETAINING WALL, IN-SITU TREATMENT, IN-SITU FIXATION)

(A) DSM (cutoff wall, retaining wall, in-situ treatment, in-situ fixation) shall be constructed to the lines, grades and cross sections as indicated on the drawings. The DSM shall have essentially vertical columns, a minimum width of 24 inches, and shall extend through the overburden and key a minimum specified depth (of ___ ft into the aquiclude). The completed DSM (cutoff wall, retaining wall, in-situ treatment, in-situ fixation) shall be a homogeneous mixture of (grout, slurry) and the in-situ soils. Mixing is to be controlled by mixing shaft speed, penetration rate, and (grout, slurry) take. A generalized description of the overburden through which the DSM (cutoff wall, retaining wall, in-situ treatment, in-situ fixation) is to be excavated is indicated by boring logs included in the drawings.

MATERIALS

(Grout, Slurry)

The material added to the soil will be water based (grout, slurry). The purpose of the (grout, slurry) is to: 1) assist in loosening the soil for penetration and mixing, 2) (lower permeability, aid in structural support, treat in-situ soils, fixate in-situ contaminants). The (grout, slurry) will be premixed in batch plants which combine materials in predetermined proportions.

Bentonite

Bentonite used in preparing slurry shall be pulverized (powder or granular) premium grade sodium cation montmorillonite and shall meet the most current API Standard 13A

"API Specifications for Oil-Well Drilling Fluid Materials".

Water

Fresh water, free of excessive amounts of deleterious substances that adversely affect the properties of the (grout, slurry) shall be used to manufacturer (grout, slurry). It is the responsibility of the Contractor that the (grout, slurry) resulting from the water shall always meet the standard of this Specification.

Additives

Admixtures of softening agents, dispersions, retarders or plugging or bridging agents maybe added to the water or the (grout, slurry) to permit efficient use of materials and proper workability of the (grout, slurry). However, no additives shall be used except as approved by the Engineer.

Cement

Cement used in preparing a (grout, slurry) shall conform to ASTM Designation C-150 "Requirements for Portland Type I-II Cement." The cement shall be adequately protected from moisture and contamination while in transit to and in storage at the job site. Reclaimed cement or cement containing lumps or deleterious matter shall not be used.

Reinforcing Steel

Shall meet ASTM A36 and free from any defects affecting its usefulness.

Proprietary Chemicals

Shall be approved by the Engineer based on initial bench scale testing.

EQUIPMENT

Batching Equipment

The batch plant shall consist of colloidal mixers, volumetric screw feeders and flow controllers. Dry materials shall be stored in silos and fed by screw feeders to the colloidal mixers for agitation and circulation. The resulting (grout, slurry) will be transferred to a surge tank for additional mixing and to supply the deep soil-mixing rig.

The precise arrangement and sequence of mixing shall be based on the results of the design mix program. Commercial grade clays (i.e., bentonite and/or attapulgate) maybe premixed with water (hydrated) in a separate mixer and the slurry stored in a holding tank. The clay-water slurry shall be transferred to a second mixer (only if premixing is

necessary) where cement and/or other materials will be added and mixed into the grout.

Slurry (grout) proportions shall be monitored and controlled to ensure proper proportioning. Density measurements shall be made to verify (grout, slurry) proportions. Dry ingredient proportions shall be batch mixed by weight to a predetermined final density. A minimum mixing time of five minutes and a maximum holding time of three hours will be enforced for the grout.

Calibration of mixing components shall be done at the beginning of the project and monthly thereafter. The screw feeders shall be calibrated against time to deliver a predetermined weight. Water shall be controlled by flow meter and/or by volume level indicators in the colloidal mixer.

Deep Soil Mixing Equipment

The DSM rig shall consist of a series of overlapping mixing shafts capable of creating a wall with a minimum thickness of 24 inches. The shafts will have a bottom discharge capability for (grout, slurry). The mixing shafts and mixing blades shall be configured in such a manner to be capable of blending the insitu soils and (grout, slurry) into a homogeneous mixture.

The power source for driving the mixing shafts shall be sufficient to maintain required RPM and penetration rate from a stopped position at the depth specified.

CONSTRUCTION

Horizontal Alignment

The DSM wall shall be accurately staked prior to construction. A shallow pretrench shall be excavated on the centerline of the wall to define the location of the installation. Continuity between stabilized soil column shall be accomplished by overlapping the auger flights and mixing blades between the shafts of the DSM rig. (The wall is advanced by overlapping primary and secondary strokes. The last column and the first column of the primary strokes shall be overlapped by the first and last column respectively of a secondary stroke.) (The soil treatment shall be a sequence of overlapping and alternating primary and secondary strokes, so that no areas are left untreated.) The placement of strokes shall be controlled by the use of a template or other approved means to gauge the distance between strokes. The template will be set according to surveyed reference points.

Vertical Alignment

Vertical alignment of the auger stroke will be controlled by the DSM equipment operator. Two measurements of verticality will be monitored. These are the fore-aft and left-right vertical mast positions.

These measurements will be accomplished by two servo accelerometers mounted at right angles to each other with both their sensitive axes in the horizontal plane. When mounted to the lead structure, one unit will be sensitive only to fore-aft (pitch) of the lead, and the other to the left-right (roll) axis of the lead. The output of these units will be routed back to the DSM console for scaling and display. Resolution and accuracy of this method will be within one tenth of a degree. The outputs will be compared to preset levels of $\pm 0.1^\circ$ and when exceeded will trigger display lights in a panel visible by the operator. The operator will monitor the verticality of the leads and adjust the position of the equipment as necessary.

Mixing Shaft Speed

The mixing shaft speed (RPMs) shall be adjusted to accommodate a constant rate of mixing shaft penetration based on the degree of drilling difficulty. The mixing shaft speed can be adjusted according to drilling difficulty. The mixing shaft speed can be adjusted to aid mixing of the soil column when needed. Mixing shaft speed may be adjusted to assist penetration in hard drilling.

Penetration Rate

In order to ensure adequate mixing, the penetration rate of the mixing shafts shall be maintained such that the proper amount of slurry is added and the proper amount of mixing time is allowed. The bottom of the columns shall be double mixed by raising the mixing shafts 10 ft off the bottom and then reinserting them for remixing. The penetration rate and maximum depth of each stroke shall be recorded on the Daily QC form.

Grout Take

The (grout, slurry) take (or injection rate) per vertical foot of column will be adjusted to the requirements of the design mix. Positive displacement pumps will be used to transfer the grout from the mix plant to the DSM rig. The grout will be delivered separately to each auger. Flow monitoring devices will be installed in each grout line to detect any line blockage.

The rate of application may be controlled and monitored by any of the following three methods. First, the positive displacement grout pumps will be calibrated according to real site conditions to produce a time vs. flow correlation. By adjusting the pump output to the penetration rate, a preset grout take can be achieved.

Second, the transfer pumps will deliver grout to the DSM rig where a return line can be adjusted to bleed off any overflow back to the surge tank. The surge tank will be a cylindrical vessel with a constant depth-volume relationship that can be monitored while the return line is adjusted to ensure a constant injection rate. Third, a programmable electronic controller, flow metering, pressure regulating robot may be employed.

Generally, the injection rate will be approximately eighty percent while the augers are moving downward and twenty percent while moving upward. These rates may be adjusted for variable soil condition. The overall application rate to each stroke can be monitored, calculated and controlled. Additional mixing will be used when necessary to evenly distribute the grout through the entire column. The injection of grout to each stroke will be monitored, checked by calculation and recorded.

Key

Unless otherwise directed, the bottom of the DSM (wall, treatment) will be keyed the minimum specified penetration into the underlying aquiclude beneath the site as indicated by soil borings. If drilling resistance at the key slows penetration to a rate of less than one ft per minute for five minutes, the final depth of the shaft shall be acceptable at refusal. The final depth and penetration of the (wall, treatment) shall be measured from shaft penetration and checked by the Contractor and approved by the Engineer immediately following penetration.

Obstructions/Mixing Shaft Refusal

If obstructions including, but not limited to, boulder or timber are encountered which reduce the rate of penetration to one ft per minute for five minutes, the stroke shall be completed in accordance with the specifications and remedial measures/investigation taken.

QUALITY CONTROL AND QUALITY ASSURANCE

Prior to construction, a mix design program shall be conducted to determine the design mix ingredients, sequence of mixing, grout and/or slurry properties and soil mix properties. The basic guiding principal for the laboratory mix program is to strive to accurately model expected field conditions.

Sampling

Samples will be retrieved from the wall for testing (every 100 lineal ft of the DSM wall, from each days work). These samples shall be taken by a special sampling tool at mid-depth of the DSM column immediately following installation. The soil mix shall be placed in suitable molds, rodded to remove trapped air pockets and then sealed. The samples will be stored in a damp environment for curing until initial set has been achieved. After initial set, a dead weight load may be imposed on the sample to model the stress from earth pressures.

Testing

The samples will be transported to an independent geotechnical laboratory for testing once they have sufficient strength gain so that the transporting will not adversely affect the properties.

(Cured samples will be tested in a triaxial permeability apparatus similar to that used by Daniel, Trautwein, Boynton and Foreman (ASTM Geotechnical Journal, September 1984, Page 113.) (Compressive strength tests will be performed in accordance with ASTM C39.)

(Grout, Slurry)

Based on the mix design program field testing of the (grout, slurry) properties shall be submitted for approval. (Grout, Slurry) control may be performed by one or a combination of the following tests:

- Unit weight by Mud Balance method
- Viscosity by Marsh Funnel method
- pH by pH meter or paper
- Filtrate by filter press

Frequency and standards for field tests will be determined by the mix design program. Calculations of mix proportions will be by the absolute volume method. Proportions calculations will be based on the weight of the water proportion of the (grout, slurry) i.e., cement/water, bentonite/water, etc.

Documentation

All quality control and measurement for payment data shall be recorded on specially prepared forms. The forms will contain space for the following information:

- Data
- Quality control test results
- Location of test samples
- Measurement of pay quantity
- Pay quantity
- Other comments as necessary
- Signatures