



# Special Specification for Deep Soil Mixing

**Product 0-5179-P1**

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**THE UNIVERSITY OF TEXAS AT ARLINGTON  
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**TEXAS DEPARTMENT OF TRANSPORTATION**

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# **SPECIAL SPECIFICATION FOR DEEP SOIL MIXING**

by

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## SPECIAL SPECIFICATION

### XXXX

#### Deep Soil Mixing

- 1. Description.** Produce elements of **soil-binder mix** from the mechanical mixing of in-situ soil with **chemical binder (Table 1)** slurry to provide support for embankments and earth structures.

Table 1 Chemical Binder Types

Chemical Binders
Lime (Quick, Hydrated)
Cement (Type I, Type I/II, Type V)
Lime + Cement <sup>1</sup>
Lime + Cement + Other binders <sup>2</sup>

Note: <sup>1</sup> in various proportions between 100:0 and 0:100;

<sup>2</sup> fly ash, granulated blast furnace slag, silica fume, etc.

- 2. Definitions.** The terms used throughout the specification are defined as follows:
- **Pre-Production Program** – field test program developed and undertaken by the Contractor (or a Specialty Contractor with experience in deep soil mixing operations) and approved by the Engineer.
  - **Testing Laboratory** – independent Construction Materials Testing Firm contracted with the Owner (TxDOT) and Contractor approval and responsible for forming, curing, preserving, and transporting samples; performing laboratory testing, and reporting laboratory test results. Alternatively, separate testing laboratories can be contracted and used by Owner (TxDOT) and Contractor, respectively. In such events, Owner will have the priority to consider the laboratory results that could be used for QC/QA studies.
  - **Soil-binder** - mixture of chemical binder grout and in-situ soils.
  - **Soil-binder Element** - a soil-binder column formed by mixing soil in situ with chemical binder grout using an auger at controlled mixing rates during a single penetration and withdrawal of the auger.

- Soil-binder Structure - a number of soil-binder elements that are continuously interconnected through overlapping which may be in the form of a wall or a mass.
  - Vertical Alignment Profile - a graphical or tabular data presentation of the actual sectional view of each soil-binder element.
  - Spoil Return – all materials including, but not limited, to liquids, semi-solids, and solids, which are discharged above the ground surface or mudline, as a result of soil-cement mixing.
  - Obstructions – objects or materials at or below ground surface, which prevents the penetration of the auger to the required depth. Obstructions include, but are not limited to, concrete, brick, stone block, wood pile, metal, abandoned foundation, utilities, and other similar items. Naturally occurring materials such as cobbles, boulders, dense, well-bonded, or other competent in-situ soils will not be considered as obstructions.
- 3. Materials.** Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specification.
- A. Reagent Binder.** Furnish Type I/II cement conforming to DMS-4600, “Hydraulic Cement” and the Department’s Hydraulic Cement Quality Monitoring Program (HCQMP). Sources not on HCQMP will require testing and approval before use. Store cement to prevent moisture damage. Do not use material which has become caked due to moisture absorption. Do not stack bags of cement more than ten bags high to avoid compaction. Do not use cement containing lumps or foreign matter of a nature and in amounts that may be deleterious to the Deep Soil Mixing (DSM) operations. Secure at least two approved sources of cement supply. Tricalcium aluminate (C<sub>3</sub>A) content shall not exceed 8 percent. This requirement may be decreased by the Engineer when the in-situ soil contains sulfates in excess of 5,000 ppm per TxDOT Test Method TEX-145-E.
- B. Water.** Furnish water free of industrial wastes and other objectionable matter and meeting the requirements of Item 204, “Sprinkling.”
- 4. Equipment.** Furnish and maintain equipment to ensure safe, continuous, and efficient production during soil-cement mixing and other related operations. Provide equipment having devices to permit accurate and continuous monitoring and control of water-cement ratios, cement-grout injection pressures and quantities, mixing rotational speeds, penetration and withdrawal rates of the mixing tools, and other operations required to install and mix the soil-cement elements.
- A. Soil-binder Mixing Machines.** Furnish machines of sufficient size, capacity, and torque capable of performing deep mixing to the required depths shown on the

plans. Furnish machines capable of penetrating and withdrawing the mixing tools while simultaneously injecting cement-grout and mixing with in-situ soils.

- B. Deep Soil Mixing Equipment.** Use deep soil-cement mixing equipment with a single shaft or multiple shafts with multiple augers configured in one straight line. Uniformly inject cement grout through the bottom of the assembly. Advance mixing equipment through in-situ soils and/or previously installed, hardened soil-cement. Do not use continuous flight auger sections longer than 5 feet. Use auger flights and mixing paddles that extend to the full diameter of the element being formed, have discontinuous lengths, and are spaced to overlap with paddles of adjacent shafts in order to thoroughly break up the in-situ soils and blend them with injected cement grout to form a homogeneous mixture. Do not direct high pressure jets to extend beyond the perimeter of the auger flights. Do not inject air into the in-situ soils.
- C. Cement Grout Batch Plant.** Include all storage silos, weather protection, sheds, scales, pumps, mixers, valves, gauges, and regulating devices required to continuously measure and mix cement grout at the batch plant.
- 5. Construction.** Furnish all labor, equipment, and materials necessary to conduct all necessary soil-cement deep mixing operations. Perform all survey layout and utility clearances affecting the soil-cement mixing, and coordinate with all local, state, and federal agencies having jurisdiction over the project. Mobilize and maintain a sufficient number of soil-cement mixing machines, materials, cement grout batching plants, and crews to complete the work in accordance with project milestones. Coordinate soil-cement mixing operations with all other aspects of the work.
- A. Deep Soil Mixing (DSM) Plan.** Develop and follow a DSM plan. Include a detailed Quality Control/Quality Assurance (QC/QA) Program (QCP). Submit a written DSM plan, to include the QC/QA, to the Engineer a minimum of 7 days prior to the start of the DSM operation. Obtain the Engineer's approval of the DSM plan and QCP before beginning production. Obtain approval from the Engineer for changes to the DSM plan and/or QCP made during the project. Cease operations when three consecutive strength tests fail. Investigate the causes for product failure. Submit corrective measures to the Engineer and receive approval prior to commencement of operations.
- Include the following items in the DSM plan and QCP.
- 1. Project Personnel.** For project personnel, include:
    - a list of individuals responsible for QC with authority to take corrective action, and
    - contact information for each individual listed.
  - 2. Materials.** Provide a list of all materials including detailed descriptions and sources.
  - 3. Mix Design.** Provide a mix design produced from a mixture of cement and the actual in-situ soils containing the unconfined compressive strength and the total



unit weight test results. If the DSM design is intended for mitigating heave-related soil movement, the laboratory mix design should address both the free swell and linear shrinkage strain behaviors of the treated soils. Soil-cement shall be a stable, uniform mixture of cement grout and the in-situ soil. Adjust the mix design when necessary to achieve the required compressive strength and total unit weight.

**4. Production.** Include the following:

- Detailed listing of equipment proposed for the project.
- Description and plan of plant layout for the site including material storage facilities, staging areas, slurry mixing and production areas, spoil containment facilities, and spoil removal and disposal details.
- Detailed description of the QCP including methods for assuring compliance with specification requirements, sampling equipment and procedures, sampling frequency, example forms for Daily Production Reports and Alignment Profiles, and other QC forms as may be required to demonstrate and document conformance.

**B. Mix Design.** Furnish a mix design containing soil-binder to be a stable, uniform mixture of binder grout and the in-situ soils. Soil-cement obtained from wet-grab samples shall conform to the requirements shown in [Table 2](#).

**Table 2**

<u>Mix Property</u>	<u>Test Method</u>	<u>Requirement</u>	
Unconfined Compressive Strength (UCS)	ASTM D2166	> 100 psi @ 14 days	>150 psi @ 28 days.
Total Unit Weight	Core Specimens	≥ 105 pcf	≥ 105 pcf
Consolidation	ASTM D4186	Compression Index	Compression Index
Free Vertical Swell	ASTM D4546	< 1%	< 1%
Linear Shrinkage Strain	Tex-107-E	< 1%	< 1%

The minimum specified binder content shall not be reduced regardless of the unconfined compressive strength that is achieved. Conformance with the soil-binder uniformity criteria will be determined by the Engineer by evaluating the core samples immediately after field mixing operation. The soil-binder shall contain soil fragments with a maximum dimension not to exceed 1/4 of the diameter of the auger or 1 foot, whichever is smaller. In addition, seventy percent (70%) of the depth cored at a curing period of 14 days shall have a minimum core sample of unconfined compressive strength of 100 psi.

For projects where heave mitigation is the primary objective, the UCS requirement in the field will be established based on the UCS – swell strain correlations of the treated soil specimens.

**C. Soil-Binder Mixing.** Confirm satisfactory performance of this treatment by undertaking a deep mixing demonstration program prior to commencing the actual production of columns. During this demonstration program, perform the contract requirements for verifying the vertical alignment, wet-grab sampling of Deep Soil Mixing treated ground, ensuring the compressive strength of mix, and determining the total unit weight. Once the demonstration program is accepted by the Engineer, construct continuous soil-binder structures in walls and other structures to achieve the required overlap continuity as per the design plan area configurations. Use the installation sequence and schedules described in the DSM Plan and with soil-binder elements conforming to the alignment tolerances and required compressive strength, swell strains, shrinkage strains, and unit weights. Pre-drill soil with a plasticity index,  $PI > 20$  to prepare the soil for modification at no additional cost. Overlap and re-drill adjacent soil-binder elements along the line of longitudinal progression for the distances indicated on the plans. Install deep soil-binder elements with the same make and model of mixing machinery, binder grout mixing, and pumping equipment, and the same materials and procedures described in the QCP above. Adjust the mix design, as necessary, throughout the course of the work in order to achieve the requirements shown in [Table 1](#). Submit changes in the mix design to the Engineer for review and acceptance prior to implementing the changes. Ensure that soil-binder elements penetrate the full depth of the soils to be stabilized and extend to the underlying firm stratum. Upon reaching the bottom of the soil-binder element, operate the mixing equipment at sufficient speed and duration to clean and mix all loose, soft, and otherwise unmixed soil prior to final grouting and withdrawal of the mixing tools.

During soil-binder mixing, introduce grout into the soil only by injecting binder grout through the bottom of the operating mixing equipment. Introduce grout during the initial penetration of the augers, or during subsequent down strokes of the augers, for the entire depth of the elements. Continue grout injection while removing the mixing equipment from the bottom of the holes to the top. After final grouting of the soil-binder element, obtain samples of in-situ soil-binder in accordance with the locations and frequencies required in the QC/QA. During the course of all soil-binder mixing, do not allow water, debris, or spoil material to enter the soil-binder element. Backfill any soil-binder element which exhibits partial or total instability (e.g., excess flow of grout from the column location, settlement of ground, and/or squeezing of soil on the drill rods) with weak binder grout and remix the full depth at no additional cost.

**D. Horizontal and Vertical Alignment Tolerances.** Mix each soil-binder element to within the following tolerances:

- Vertical plumbness - no more than two (2) percent.
- Vertical length - no more than two (2) percent of plan element length.
- Horizontal length - no more than two (2) inches from horizontal plan position element center coordinate.

Remix or supplement with one or more adjacent or overlapping elements when the alignment exceeds the allowable tolerance shown above unless approved by the Engineer. Provide repair at no additional cost.

**E. Spoil Collection and Containment.** Maintain the site clear of all debris and excessive free water at all times. Pipe or channel spoil return and other spoil material to holding ponds, tanks, or other retention structures or facilities as shown on the plans or as specified by the Engineer. Remove and dispose of all waste materials daily in accordance with the QCP. Take all necessary precautions and implement measures to prevent any spoil return, other spoil material, or stockpiled materials from entering storm drain structures, drainage courses, and other utility lines or from leaving the site via surface runoff. Prevent the migration of spoil return, spoil material, or stockpiled materials into any surface water body beyond the immediate limits of the soil-binder mixing operations or designated spoil disposal areas. This shall be in conformance with the SW3P plan.

**F. Quality Control / DSM Testing Frequency.** Take wet-grab samples of the soil-binder mixture at the rate of at least one sample for each 750 cubic-yards of soil-binder elements with a minimum of one sample per day. Each sample shall be of sufficient size to produce four (4) specimens for testing. The specimens shall be cylindrical with a nominal diameter of 3 inches and length of 6 inches. Test one cylinder for unconfined compressive strength at 7 days, one at 14 days, and one at 28 days. Reserve the fourth cylinder and test at 56 days if the 28 day result does not meet the required strength. Determine unit weight on each 3 inch cylinder as part of the unconfined compressive strength testing process. Other specimens for free swell (three specimens) and linear shrinkage bar tests (three) shall be prepared from the same wet grab samples. One specimen shall be tested at 7 days curing and two other specimens shall be tested at 14 days curing.

Take a minimum of 15 random, continuous core samples along the full element depth for uniformity determination as selected by the Engineer. The core samples shall be a minimum of 2 inches in diameter. The core samples shall be examined by the Engineer for uniformity determination. Test a minimum of nine randomly selected specimens from the core samples for unconfined compressive strength and unit weight determinations. All specimens shall exhibit UCS values exceeding those mentioned in [Table 1](#) and the coefficient of variation of all nine tests shall not be less than 25 percent.

The testing frequencies listed above may be increased if determined necessary by the Engineer based on the evaluation of test results.

**G. Contractor Assistance.** Stop drilling and mixing operations when material samples are being taken in the vicinity of an element.

- 6. Measurement.** Soil-binder elements will be measured by the cubic yard in place, to the nearest cubic yard, only within the area of the proposed soil-binder areas shown on the plans or approved by the Engineer. The volume shall be determined by multiplying the plan area times the actual length of the soil-binder elements which achieve the required depth. Areas of overlapping and over-drilling will not be measured more than once. Quantities of soil-binder installed during remixing to achieve the specification requirements due to augmentation required to supplement non-conforming elements, or that are outside the limits of soil-binder mixing shown on the plans without the acceptance of the Engineer, will not be measured for payment.
- 7. Payment.** The unit prices for this Item will be full compensation for furnishing all equipment, materials, testing, and labor required to install soil-binder in accordance with the specified strength requirements in accordance with the plan area configurations and coverage over the depths and limits shown on the plans. No separate measurement will be made for additional quantities of soil-binder installed to overcome obstructions. Transportation and disposal of soil mix spoil will be subsidiary to the DSM operation and will not be a separate pay item.



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