DESCRIPTION This work shall consist of installing and testing of soil stabilization columns along Tonawanda Creek Road in the Town of Clarence, New York.

A. Definitions.

1. Subgrade: The surface upon which construction of the work begins.

2. Binder: Chemically reactive material (e.g., cement) that can be used for mixing with in situ soils to strengthen the soils and form soil-cement columns. Also referred to as stabilizer or reagent.

3. Binder Content: Ratio of weight of dry binder to dry weight of soil to be treated.

4. Blade Rotation Number (BRN): Total number of mixing blade rotations per meter of shaft movement.

5. Dry soil mixing: A ground treatment system used to improve the engineering properties of soft clays, peats and other weak soils, by mechanically mixing them with dry cementitious binder to create a soil-cement mix.

6. Mixing Tool: Equipment used to disaggregate the soil and distribute and mix the binder with the soil. Consists of one or several rotating units equipped with several blades, arms, and paddles with or without continuous or discontinuous flight augers, horizontal rotating cutter blades, or chainsaw-type cutters.

7. Soil-cement column: Pillar of treated soil produced in situ by a single installation process using a mixing tool, typically a rotating auger, to make a round column.

8. Quality Control (QC) Program: The materials handling and construction procedures established to produce the treated materials that meet the design requirements of the structure.

9. Quality Assurance (QA) Program: The monitoring, sampling, and testing procedures established to verify that the treated materials produced meet the design criteria.

B. References.


5. ASTM D 1586 - Test Method for Penetration Test and Split-Barrel Sampling of Soils.


7. ASTM D 5434 - Field Logging of Subsurface Explorations of Soil and Rock


C. Performance Requirements for Soil-Cement Columns.

1. The Contractor shall install soil-cement columns to improve the engineering properties of the soft clay soils at the locations and configurations shown on the design plans. As indicated on the design plan, two distinct phases of columns shall be installed, defined as primary and secondary column rows. This involves installing alternating rows of columns to allow the primary column row to cure before installing the secondary column row. The time required for curing will be identified in the pre-construction test program.

2. The Contractor shall install vibrating wire piezometers at the prescribed depths in test boring locations, as described in these specifications and as shown on the design plans. The vibrating wire piezometers will be monitored by the Engineer. The Contractor will be notified if pressures become unacceptable and modifications to the installation procedures are required.

3. The soil-cement columns will extend from the prepared subgrade surface to the top of the glacial till, as shown on the design plans. The soil-cement columns will be required to achieve the 28-day strength requirements for the Soil-Cement Mixture.

D. Contractor Qualifications.

1. The Contractor shall have previous successful experience with at least five deep mixed soil-cement column projects, excluding bucket mixing projects.

2. The Contractor shall provide at least one equipment operator with at least one year experience with the proposed equipment and three deep mixing projects.
3. The Contractor shall provide a site superintendent and/or site engineer with significant experience on at least five projects involving deep mixing.

4. The test boring contractor shall demonstrate experience on a minimum of 2 soil-cement projects. Experience shall include installation of vibrating wire piezometers and sampling of soil-cement columns. In addition, the test boring contractor shall employ an experienced geologist to supervise the explorations full time, classify the soil samples collected from the explorations, and prepare detailed logs containing the soil descriptions and showing the fill and soil stratigraphy and ground water level measurement data.

E. Submittals.

Contractor shall provide the following submittal within two weeks of Contract Award:

1. Experience Profile: Detailed experience profile showing the Contractor and the test boring contractor qualification requirements (See Section D. Contractor Qualifications) with soil-cement column installation have been met.

Contractor shall provide the following submittals at least two weeks prior to the start of construction:

1. Description of method(s) and equipment proposed to install the soil-cement columns and the proposed cement addition rate. Include details such as mixing tool, BRN, cement delivery equipment and controls, injection procedures and catalog cut sheets for all stabilization equipment.

2. The laboratory test program results used to determine the required cement addition rate. Including sample collection, binder content(s) tested, and 7-day and 28-day unconfined compressive strength test results. Strength testing shall be conducted by an independent testing laboratory retained by the contractor and approved by the engineer.

3. Sample Log: Sample log to be used to record column installation. The log shall contain at least the following information in English units (feet, inches.):

   a. Project name
   b. Machine type
   c. Type of mixing tool / number of blades
   d. Date and time (start and finish) of column installations
   e. Column number and reference drawing number
   f. Column diameter
   g. Elevation of top of column
   h. Column length
   i. Quantity of cement injected per foot of depth
   j. Installation air pressure reported at each 3 foot depth interval
k. Rate of penetration/withdrawal of mixing tool in feet/revolution, reported at each foot of depth
l. BRN
m. A description of obstructions or other interruptions of cement injection during installation

4. Supplier’s certifications of cement quality meeting the requirements of ASTM C150 for Portland cement.

5. The QA/QC program to be undertaken each day during production to confirm the soil-cement columns achieve the specified requirements. This includes measures that will be implemented each day during soil-cement stabilization to monitor, modify, record and control cement injection quantities, and injection pressures, auger rotational speeds, tool down pressures, auger/mixing tool penetration and withdrawal rates, and other related aspects of the soil-cement process.

6. Contractors proposed testing procedures and equipment that will be utilized to verify the strength and integrity of the soil-cement columns, including required test methods (i.e., column vane pull, SPT, and Pressuremeter). The following references shall be used to determine acceptance.

   A. Column vane pull is used to measure the shear strength of the soil-cement column. During soil-cement column installation a vane is inserted in the bottom of the column and attached to a cable that extends to the surface. At a specified curing time, the vane is withdrawn from the column and the resistance is recorded continuously. The resistance and vane cross-sectional area are then used to estimate the unconfined compressive strength.

   B. SPT testing (ASTM D 1586) involves driving a split-spoon sampler into the soil-cement column. SPT blow count values (N) will be correlated with the column vane pull data measured during test column installation.

   C. Pressuremeter testing (ASTM D 4719) is a borehole lateral load test in which a cylindrical probe is expanded radially onto the borehole walls. Strength of the soil-cement column is evaluated from the measured pressure and radial displacement.

7. Submit the instruction/operating manuals for the vibratory wire piezometers, data loggers, and pressuremeter set-up.

Contractor shall provide the following submittals during construction:

1. The Contractor shall submit to the Engineer daily production reports for each work shift. These reports shall be filled out and signed by the soil-cement mixing field superintendent at the end of every work shift. The report shall contain, but not be limited to, the following information:
a. Completed soil-cement mixing field log.

b. Computer generated report for each column installation including the cement injection quantity with depth.

c. Observations including, but not limited to: ground settlement and/or heave, collapses of soil-cement columns, and any unusual behavior of any equipment during the installation process.

d. Date, time, column location designation of any soil-cement samples collected by the Contractor and the person responsible for obtaining the samples.

e. Material delivered to the site.

f. Any sampling results obtained from previous testing.

2. Submit two copies of the test boring logs, one week following the completion of the test borings. The logs shall contain the following:

   a) Date of test boring exploration (start and completion).

   b) Depth of samples.

   c) Type of samples (Split spoon, Shelby tube, etc.).

   d) Description of soils collected in the sampler, including major and minor components.

   e) The length in inches of the sample recovered in the split spoon sampler.

   f) Classification according to ASTM D 2487 of soils removed from the split spoon sampler.

   g) Blows per 6-inch interval of split spoon penetration following ASTM D 1586.

   h) Blows required to advance the casing, if used.

   i) Standard Penetration Test N-value.

   j) Depths at which soil types change.

   k) Elevations of ground surface within 6 inches of the exploration location, the Engineer will provide a benchmark on the project site for reference.

   l) Depths to water levels in the exploration, the time that these measurements were made, the depth of the exploration when the measurements were made and the depth of the casing when the measurements were made.

   m) Vibrating wire piezometer depth and backfill types.

F. Job Conditions.

1. The Contractor shall be familiar with the project geotechnical and hydrological conditions and recognize that among others, the silts and clays have variable and often high moisture contents. Boring logs and laboratory data completed at the site are available for review. Typically the site soils consist of sandy silt/ silty sand over soft clay over glacial till, as shown on the design plans and further discussed in the references.

2. Throughout execution of the work, the Contractor shall take all precautions and measures necessary to safely move and position deep mixing stabilization equipment, support equipment and personnel around the site. Prior to the soil-cement mixing, the
Contractor’s site preparation work will have produced a suitable working surface for the soil-cement stabilization equipment. The Contractor shall provide equipment, materials, cribbing timber mats or other support structures necessary to provide a stable working surface for the soil-cement stabilization.

3. Protect nearby structures from damage. All construction-induced damage shall be repaired by the Contractor to the satisfaction of the Owner at Contractor's expense.

4. Perform all work between 0700 and 1800 hours to limit noise to nearby residences.

5. The Contractor and test boring contractor should visit the site to review all details of the work and working conditions, to verify dimensions in the field including interference from adjacent structures, utilities and overhead clearance and to advise the Engineer of any discrepancy before performing any work.

6. Consult official records of existing utilities, both surface and subsurface, and their connections, to be fully informed on all existing conditions and limitations as they apply to this work. Contact underground utilities to locate all underground utilities near the proposed exploration locations.

7. Protect existing utilities to remain in accordance with the requirements of each specific Utility Provider.

8. Vibrating wire piezometer cables and data logging devices shall be located next to the work areas and protected from the ongoing construction work. Cables shall remain operational throughout construction of the soil-cement columns. The data logging devices shall be placed in locked boxes as shown on the design plans.

9. The specified vibrating wire piezometers, associated cables and data logging devices shall be supplied by the Contractor. The Engineer will assist during the installation and monitoring.

10. The specified pressuremeter testing apparatus shall be supplied by the test boring contractor. The test boring contractor will be required to complete the test and provide the results to the Engineer. All testing shall be completed in the presence of the Engineer.

G. Equipment Requirements.

1. All equipment shall be maintained to ensure safe, continuous, and efficient production during soil-cement stabilization and other related operations. The equipment shall be capable of completing soil-cement columns with a minimum completed column diameter of 30 inches.

2. All equipment shall have computerized controls to permit accurate and continuous monitoring, recording and control of: mixing tool depth, cement volume flow rates,
cement injection pressures, rotational speed, penetration/withdrawal rates and other operations required to install the soil-cement columns.

3. The equipment shall be of sufficient size, capacity, and torque to perform the required deep mixing stabilization operations to the desired depths. The equipment shall utilize sufficient mixing and injecting equipment to adequately blend cement with the in-situ soils to produce a distribution of cement throughout the soil-cement column to provide the required strength.

H. Pre-Construction Meeting.

1. The Contractor is required to attend a pre-construction meeting at a date, time and location to be mutually agreed upon.

MATERIALS

Materials for this work shall meet the requirements of the NYSDOT Standard Specifications unless otherwise noted.

Subsurface Explorations.

1. Subsurface explorations, including furnishing equipment, drilling bore holes, split barrel sample, drill hole and bore hole grouting shall meet the requirements stated in Section 648 – Subsurface Explorations.

Vibrating Wire Piezometer Materials.

1. Vibrating wire piezometers shall meet the requirements of Item No. 203.13960017 with the following exceptions.

a) The vibrating wire piezometers shall be Geokon model 4500S (Geokon, Inc., 48 Spencer Street, Lebanon, NH, 03766, 603-448-1562 (v), 603-448-3216 (f), website: www.geokon.com, e-mail: geokon@geokon.com) or approved equivalent. The vibrating wire piezometers shall be factory constructed with sufficient cable length so that splicing is not required. The cables shall be provided with 10-pin connectors for direct connection to the data logger. Canvas-Cloth Bags shall be provided by the supplier with each vibrating wire piezometer.

b) The filter sand within the Canvas-Cloth Bags shall be Morie No. 00 quartz sand.

c) Cement/bentonite grout shall consist of:

- 94 pounds of Type I Portland cement.
- 75 gallons of water.
- 40 pounds of powdered bentonite.
**Data Logger.** The data logger shall be Geokon four Channel LC-2x4 (Geokon, Inc., 48 Spencer Street, Lebanon, NH, 03766, 603-448-1562 (v), 603-448-3216 (f), website: www.geokon.com, e-mail: geokon@geokon.com) or approved equivalent.

**Soil-Cement Columns.** Soil-cement columns shall be a stable well-mixed mixture of cement and in-situ soil meeting the following requirements:

1. Cement shall conform to the chemical and physical requirements of Type I or Type II Portland Cement per Section 701.01. Cement admixtures will not be allowed on this project. The cement addition rate shall be within the limits proposed by the Contractor in its submittal but shall not be less than 75 kilograms per cubic meter (kg/m³), which equates to approximately 4.7 pounds per cubic foot (pcf).

2. Soil-cement columns must be well mixed to avoid large and/or aggregated lumps of unimproved soil.

3. The soil-cement mix samples shall achieve a 28-day unconfined compressive strength of 10,000 pounds per square foot. In the event that a strength value fails to have the required strength, the Contractor will be required to complete additional columns or testing as described in the these specifications.

**Pressuremeter Test Materials.**

1. Pressuremeter – The pressuremeter shall be the Roctest TEXAMe Pre-Boring Pressuremeter (Roctest, 680 Avenue Birch, Saint-Lambert, QC, J4P 2N3 Canada, 978-284-0610 (v), website: www.roctest.com) or approved equivalent.

**CONSTRUCTION DETAILS**

The Contractor shall provide all labor, materials, equipment and incidentals necessary to perform all soil-cement stabilization operations, and all associated testing, monitoring, sampling, and recording required for installing and testing the soil-cement columns, as shown on the design plans and specified herein.

**Test Boring.** Test borings will be used for the following purposes:

1. To collect and test samples of soft clay from the work area to determine the appropriate quantity of cement addition required to achieve the specified soil-cement unconfined compressive strength.

2. To install vibrating wire piezometers as part of the pre-construction test program.

3. To sample the soil-cement in columns installed as part of the pre-construction test program.
4. To sample soil-cement in completed production columns as part of the Contractor’s quality control program.

**Geotechnical Instrumentation.**

1. The Contractor shall furnish and install four vibrating wire piezometers in two test borings as shown on the design plans.

2. The Contractor shall furnish one 4 channel data logger for the Engineer to use to record pore water pressures measured by the piezometers.

3. The Contractor shall furnish at least one Pressuremeter and all required accessory items to conduct the test, record measurements, and estimate the compressive strength of the soil-cement columns.

**Survey Monitoring.**

1. The Contractor shall install survey stakes/hubs at the locations shown on the design plans. Additional locations may be required during construction.

2. The Contractor shall utilize survey equipment capable of establishing the hubs (northing, easting and elevation) to the nearest 0.01 foot.

3. The Contractor shall monitor the survey hubs once a day throughout construction with the same equipment used to install and make initial measurements at the survey hub. The collected data (northing, easting and elevation) shall be tracked in tabular format and provided to the Engineer daily during construction so that variations in the location of each established survey hub may be tracked.

4. Immediately notify the Engineer if more than 1 inch of movement between readings is recorded.

**Soil-Cement Columns.**

1. Soil-cement column limits and locations shall be established by survey. Individual columns shall be marked. Sufficient vertical control shall be provided to verify that cement/soil columns reach the design depth.

2. The Contractor will be required to complete test columns as discussed below in the Quality Assurance / Quality Control of these specifications. Following completion of the test columns, the Contractor will be required to complete the column installation in an alternating pattern creating rows of primary and secondary columns, as shown on the Contract Drawings.

3. The Contractor will be required to allow for a curing time period between construction of primary and secondary column row installations. This curing time period will be determined in the pre-construction test program.
4. The Contractor shall measure, handle, transport, and store bulk cement in accordance with the manufacturer’s recommendations. Cement shall be stored to prevent damage by moisture. Material, which has become caked due to moisture absorption, shall not be used. Cement containing lumps or foreign matter of a nature and in amounts that may be deleterious to the injection operations shall not be used.

5. Prior to column installation, the Contractor shall first install piezometers. Once the piezometers are installed and operational, the Contractor shall begin installation of test columns, as described in these specifications. The data from test columns will be used to make decisions for the installation sequence of the production columns.

6. The soil-cement columns shall extend into the top of the glacial till from the subgrade surface as shown on the design plans. The Contractor will be required to add cement at the chosen rate as the mixing tool is withdrawn. The columns must be thoroughly mixed directly above the glacial till to ensure that no soft zones of soil remain. To ensure thorough mixing, the mixing tool should be lifted 5 to 10 feet above the bottom depth and brought back down to the bottom depth while continuously mixing. Required mixing effort will be verified using pre-construction test columns.

7. The Contractor will be required to install the soil-cement columns in the pattern shown on the design plans. Following installation of the primary column rows, the Contractor shall install the secondary column rows.

8. If requested by the Engineer, the Contractor will modify the installation pattern and work sequence to mitigate ground movements or excessive pore water pressures that may develop from soil-cement column installation.

9. The Contractor along with the Engineer shall monitor each column installation and if necessary make the appropriate adjustments.

10. The cement shall be injected by air pressure applied as the mixing tool is raised in each column. The Contractor shall assess if a second pass through the column is necessary for either mixing or for the addition of cement.

11. If the weight of cement injected is less than the amount required, the column must be remixed and additional cement shall be injected at the required rate to raise the deficient zone to the design injection rate.

12. Location: Horizontal alignment of the columns must be within 2 inches of the planned location. The vertical alignment must be within 1:100 (horizontal to vertical).

13. Unforeseen conditions that result in changes in the soil-cement installation procedures shall be noted on the installation log and deviations from the project specifications shall be noted and addressed with the Engineer.
14. Obstructions that prevent column installation to design depths shall be noted on the installation logs and the Engineer shall be immediately notified. The column shall be relocated as directed by the Engineer.

15. The Contractor shall prepare a log for each column installed with the information required in the Submittal.

Quality Assurance / Quality Control. The Contractor shall execute a construction quality control program to demonstrate compliance with the specifications. The program shall include the following specified activities in addition to the Contractor’s own quality control program.

1. Pre-Construction Testing
   a) Soil Sampling and laboratory testing
      i. The Contractor shall collect and prepare laboratory test samples of soft clay from the work area to determine the appropriate quantity of cement addition (minimum of 75 kg/m³) required to achieve the specified soil-cement unconfined compressive strength. The Contractor shall mix soil samples with various amounts of cement and measure the unconfined compressive strength to estimate the quantity of cement required to achieve the specified unconfined compressive strength. The laboratory test program shall also identify the time required for the soil-cement to achieve the required unconfined compressive strength.

      ii. Mix designs verified during the field validation program should be used in production. Revalidation through laboratory or field testing is necessary for changes that exceed 10 percent of approved mix design.

2. Vibrating Wire Piezometers Installation
   a) The Contractor shall drill a test boring adjacent to each pair of test columns before construction of the test columns, as shown on the design plans. These test borings shall extend to the planned depth of the test columns. The Contractor shall complete Standard Penetration Tests, ASTM D-1586, at 2-foot intervals in each piezometer test boring.

   b) Two vibrating wire piezometers shall be installed in each of these test borings to allow the Engineer to measure the pore water pressure response to the construction of the test columns. This pore water pressure response will be used to estimate the column installation sequence.

   c) The vibrating wire piezometers, connections and data loggers must be maintained for the entire project duration.
d) Place the vibrating wire piezometer and filter sand into the canvas-cloth bag and install per manufacturer’s recommendations.

e) Prepare the cement/bentonite grout (per these specifications) by first thoroughly mixing the bentonite with the water, and then slowly adding cement to the mix.

f) Fill the remaining annulus between the vibrating wire piezometer cable and the bore hole wall with cement/bentonite grout using the tremie method.

g) Upon completing the grouting, the vibrating wire cables shall be extended to the agreed upon location. The cables shall be located such that they are not damaged by future construction. This may include burying the cables or installing protective conduits.

h) Provide lockable storage boxes for installation and protection of the data loggers at the agreed upon locations. These boxes shall be properly marked and protected by suitable means such that ongoing construction or water does not damage the equipment.

3. Test Columns

a. The Contractor shall construct four pairs of test columns (total of 8 test columns) in the work area as shown on the design plans. The test columns shall extend to the design depth of the production soil-cement columns.

b. The Contractor shall continuously monitor the quantity of cement injected into each test column with depth and shall produce a graph showing the cement injection quantity with depth.

c. One column in each pair shall be equipped with a test vane (total of 4 out of the 8 test columns) that the Contractor shall pull when the Contractor has estimated that the column has sufficiently cured. The vane test (i.e., pull out resistance test) shall measure the unconfined compressive strength of the soil-cement mix.

d. For the other 4 test columns, the Contractor shall engage a test boring contractor to drill a test boring in each of these test columns. The boring Contractor shall complete Standard Penetration Tests following ASTM D-1586 at 2-foot intervals in two columns and Pressuremeter Tests following ASTM D-4719 at intervals specified and at the locations shown on the design plans in the other two locations. The test borings shall be backfilled with grout using the tremie method. The grout shall be proportioned as specified in Section 648 of the Standard Specifications. The Engineer will evaluate the results of the Standard Penetration Tests and Pressuremeter Tests and determine which test method will be employed during installation of production columns to verify the required strength is being achieved.
e. After completion of the above tests, at least one pair of test columns shall be excavated and exposed for further inspection. The Engineer will observe the test columns and determine if sufficient mixing has occurred.

f. The data from these tests shall be used to set acceptance criteria for the production columns.

4. Construction Columns

a. The Contractor shall install vanes in at least five additional test columns installed after the pre-construction testing is complete. This is in addition to the production columns. Locations of these test columns will be agreed upon with the Engineer as construction proceeds. These test columns shall be spaced as the work progresses. The Contractor shall pull the vanes following curing of the columns. The unconfined compressive strength of the soil-cement measured by the vane must meet or exceed the design strength.

b. The Contractor shall drill test borings in at least two percent (12 of the 560 total) of production columns as identified by the Engineer and shall complete Standard Penetration Tests, ASTM D-1586, at 2-foot intervals or Pressuremeter Tests following ASTM D-4719 at the intervals specified below. The number of each type of test to be conducted shall be based on the preconstruction test results, as requested by the Engineer. In the event that the SPT N-values or Pressuremeter results are less than acceptable, the Engineer will request drilling and testing of additional soil-cement columns. Additional columns may be necessary to supplement columns not meeting the project requirements. The location of supplemental columns will be determined by the Engineer.

i. Minimum vertical spacing between consecutive pressuremeter tests should not be less than 1.5 times the length of the inflatable part of the probe. A minimum of 4 tests shall be conducted within each tested soil-cement column. Initial and corrected volume and pressure data shall be provided to the Engineer in tabular form for estimation of undrained shear strength.

c. Test borings made in the production soil-cement columns shall be backfilled with grout using the tremie method. The grout shall be proportioned as specified in Section 648 of the Standard Specifications.

5. Acceptance Criteria for Soil-Cement Columns

a. The average of the test results from each tested soil-cement column shall meet or exceed the specified strength. A total of 80 percent of these test results shall equal or exceed the specified strength. However, no individual value shall be less than 70 percent of the specified strength.
b. If a strength specimen falls below the specified strength due to lack of strength, untreated and or variations in the mixed soil-cement column, than additional columns will be necessary to replace those not meeting project requirements. Contractor will be required to test soil-cement columns completed prior to and after the failed column until acceptable strengths are obtained. Corrective measures required will be at no additional cost to the Owner.

METHOD OF MEASUREMENT

Soil-cement columns will be measured based on the number of columns shown on the Contract Documents as a lump sum. No additional payment will be made for additional columns required to supplement columns not meeting the required design strength or cement addition rate. If additional columns are required, additional testing may be required at the discretion of the Engineer. No additional payment will be made for this testing.

BASIS OF PAYMENT

Payment for the ground improvement will be made at the contract lump sum price and will constitute full compensation for all labor, equipment and materials necessary to conduct ground improvement operations. Items incidental to the ground improvement shall include,

1. Subsurface explorations, including furnishing equipment, drilling bore holes, split barrel sample, drill hole and bore hole grouting.
2. Preconstruction sample collection and laboratory testing to determine the appropriate quantity of cement addition required to achieve the specified soil-cement unconfined compressive strength.
3. Cost to supply and install the vibrating wire piezometers and data logger.
4. Pressuremeter set-up and testing of boreholes.
5. Equipment, materials, cribbing timber mats or other support structures necessary to provide a stable surface for installation of soil-cement columns.
6. Excavation and exposure of one pair of test columns for observation as described in these specifications.
7. Cost to do vane testing and any other contractor quality assurance and quality control.

Partial payments will be made. The payment will be made in proportion of the number of soil-cement columns placed with the total number of columns shown on the plans.

Additional columns due to obstructions. Compensation per additional column required due to subsurface obstructions will be based upon the lump sum cost divided by the number of columns shown on the plans.