Clayey soils with swell potentials are stabilized using an ionic chemical solution called AGSS-ICS. Existing structures that have been distressed due to swelling subgrade soils can be remediated by treating the soils with the AGSS-ICS ionic chemical solution. The results of the application of the AGSS-ICS chemical solution to the subgrade soils will reduce the swell and shrinkage potential of the soil, reduce the soil suction, and increase the strength of the clayey soils through the processes of isomorphic substitution within the clay lattice and cation exchange around the sides of the clay lattice particles. These physio-chemical processes reduce the negative charge of the clay particles (isomorphic substitution in the clay lattice) and also reduce the negative surface charge of the clay particles (cation exchange and increased cation density on the surface of the clay lattice). Reducing the negative charge within the clay lattice and on the surface of the clay lattice results in a clay structure that has more flocculent characteristics and less dispersed characteristics; and subsequently less swell potential, greater strength, and less soil suction.

The AGSS-ICS chemical solution is generally prepared by mixing (1) part concentrated AGSS-ICS ionic chemical with (300) parts water, producing a very diluted and safe ionic chemical solution. The resultant ionic chemical solution is injected into the soil subgrade at a rate such that (1) gallon of concentrated AGSS ionic chemical treats 11 cu.yds. of subgrade soil. This is equivalent to treating 11 cu.yds. of subgrade soils with (300) gallons of the diluted AGSS-ICS solution.

The methodology used to remediate (stabilize) swelling soils beneath existing structures is to inject the chemical solution to depths ranging from 7 feet to 11 feet in depth unless refusal is encountered. The determination of the injection depth will be dependent on factors such as the depth of swelling clay soils and also the swell potential and swell pressure of these clay soils. The chemical solution is injected into the subgrade clays beneath the distressed house using hydraulic jetting methods. The hydraulic jetting method uses a ½ inch steel wand emitting the AGSS-ICS solution into the soil at a pressure of 800 to 1000 psi. For the injection of the chemical solution around the perimeter of the structure the injection points are placed 3 feet apart along each row. The first row of injection points will be placed 9-inches outside the exterior of the foundation, the second row of injection points will be placed 21-inches outside the exterior of the foundation, and if a third row of injection points are required they will be placed 36-inches outside the exterior of the foundation. The injection points in each row will be offset or staggered relative to the adjacent rows. See Figure 1A in the Attachments for a design detail of the injection methodology and specifications for the chemical injection around the perimeter of a structure. Figure 1B presents a second injection option around the perimeter of the house. In this option there are only two rows of injection points with injection points in each row spaced 2 feet apart instead of 3 feet. The first row of injection points will be placed 9-inches outside the exterior of the foundation, the second row of injection points will be placed 21-inches outside the exterior of the foundation as illustrated in Figure 1B in the Attachments. The injection points in each row will be off-set or staggered relative to the adjacent rows. Photographs 1 and 2 in the Attachments shows the injection rig that is used for remediating existing structures. Photographs 3 and 4 shows the injection process around the perimeter of existing structures.
The injection pattern on the inside of the structure will be developed by spacing vertical injection points 3 feet apart along each row. Each row of injection points will be spaced 1.5 feet apart or less and off-set or staggered with respect to the adjacent rows injection points by 1.5 feet. The resultant spacing of the injection points will be approximately 2.1 feet or less. See Figure 2 in the Attachments to this document for a design detail of the injection methodology and specifications for the perimeter and interior of a structure. Photographs 5 and 6 shows the interior injection process through the concrete floor slab of the structure.

When injecting penetrate 1 foot at a time and continue injecting at each foot for a period that may vary between 50 seconds to 60 seconds. Total injection time per hole will be a minimum of 6 minutes for a 7 foot deep injection and a minimum 9 minutes for an 11 foot deep injection. Stop watches will also be required to ensure accurate time increments for each injection depth. Use 7 foot or 10 foot long vertical pole stands with 1 foot increments marked on the poles placed adjacent to the injection wands to ensure accuracy of injection depth increments.

The spacing and location of the injection points can be adjusted if conditions warrant it. Typical justification for adjusting the injection locations will be an excessively wide footing below the ground surface, surface obstructions, large rocks or caliche, and excessive saturation. If adjustments to the injection spacing or location is desired, contact the engineer before adjusting the spacing.

If there is center lift on the slab or there is excessive heave of the slab then the interior injections are recommended. If the interior injections are performed then only inject two rows around the exterior of the structure. If there is no center lift and only edge lift then it may be possible to remediate the structure without injecting the interior of the structure and only inject around the exterior perimeter of the structure. In this case it will be necessary to inject three rows around the exterior perimeter of the structure. In this case the floor slab and exterior elevation brackets should be monitored every 6 months to determine if just injecting the perimeter was enough to stabilize the swelling clayey soils and to stop the movement of the structure.

The reduction in shrink/swell characteristics of the on-site clays will be an ongoing continuous process as the solution migrates in the soil through the process of soil suction and osmosis. The performance of the clay stabilization methodology using the AGSS-ICS injection is best evaluated by performing manometer surveys of the interior floor slab and exterior foundation surveys of the house on regular 6 month intervals for 2 years. These elevations surveys should be performed before the subgrade soils are injected.

The objective of the chemical injection treatment process is to significantly reduce the swell potential of the clayey soils in the injected soil horizon. If post-injection swell testing is performed on undisturbed samples of treated soils, they must be performed using ASTM D 4546, Method B at the moisture content of the undisturbed sample (no dry back). Do not perform swell tests on disturbed treated samples since the disturbance adversely affects the structure and swell potential of the treated soil. When performing swell tests on untreated and treated samples, this comparative testing must be performed at the same sample density and moisture content. The moisture content of the untreated and treated swell test samples should both be at the in-situ moisture content of the soil after injection. This will require the untreated swell test samples to be remolded at the same moisture content and dry density as the undisturbed treated swell test samples. Do not perform any testing until at least three months after the injection of the chemical solution; however, waiting for longer periods will provide for further migration of the ionic chemical solution in the soil due to soil suction and osmosis. After injection of the ionic chemical
solution to stabilize the subgrade clays there will be a slight adjustment to the structure as the moisture and cation concentrations in the injected subgrade will mobilize and become more uniform throughout the site due to the processes of osmosis and soil suction. Due to the hydrophobic characteristics of the chemically treated subgrade, the potential or tendency for the subgrade soil to suck or attract moisture from outside the injection zone of the subgrade will be significantly reduced resulting in less volume changes (swelling or shrinking) with time.

The AGSS-ICS ionic chemical solution can also be used in new construction to stabilize swelling clays. In this instance the chemical is mixed with water in either water pulls or water trucks in a ratio of (1) part chemical to (300) parts water. The soil is overexcavated to the depth recommended by the Geotechnical Engineer and then the same soil is used as fill in lifts that are no larger than 6 to 8 inch loose lifts. The chemical solution is applied to the loose lift with a water pull or water truck. Subsequent to this the chemical solution and soil is processed (mixed) using either a disk or reclaimer. The loose soil lift is then compacted with a wide rubber tired vehicle such as a scraper, water pull, or front end loader. The reason for using the large rubber tired vehicle to compact the loose soil is to achieve more of a flocculent clay structure instead of a dispersed clay structure. The chemical treatment of the clay will also produce a more flocculent clay structure with less swell potential, greater strength, and less soil suction.

Illustrations of the application of the ionic chemical solution for the remediation of existing structures are shown in the Attached Photographs. Photographs 1 through 2 shows the injection rig used to apply AGSS-ICS including pumps and tanks. Photographs 3 through 4 shows exterior injection around perimeter of building. Photographs 5 through 6 shows injection in interior of building. Photographs 7 through 8 shows injection process using a concrete vibrator attached to the top of the injection wand. These photographs also show a measurement stand with one foot markings.

ADVANCED GEOTECHNICAL SOIL STABILIZATION

William R. Sublette, Ph.D., P.E.
Principal Engineer

Attachments:
1. Figures
2. Photographs
ATTACHMENTS

Figure (drawings) and Photographs
AGSS-ICS CHEMICAL SPECIFICATION AND INJECTION METHODOLOGY DETAIL FOR STRUCTURE PERIMETERS (OPTION 1 - THREE ROWS OF INJECTIONS)

NOTES:

1. Inject a clay stabilization chemical called AGSS-ICS into the soil to reduce its swell and shrinkage potential, and also to reduce the soil suction of the clayey soil. The AGSS-ICS chemical is generally mixed (1) part chemical to (300) parts water, producing a very diluted and safe solution. The chemical is injected with ½-inch diameter steel wands to depths ranging from 7 to 11 feet and at a spacing of approximately 3 feet along each row. Three rows of injections will be made around the outside of the exterior foundation. The first row of injection points will be placed 8-inches outside the exterior foundation. Space the first row injection points 3 feet apart and incline the injection wand so the soil under the foundations are injected. Place the second row of injection points 3 feet apart and at a distance of 21-inches from the exterior foundation wall. The second row of injection points will be staggered relative to the first row. Place the third row of injection points 3 feet apart and at a distance of 36-inches from the foundation wall. The third row of injection points will be staggered relative to the second row. The spacing and location of the injection points can be adjusted if conditions warrant it. Typical justification for adjusting the injection locations will be an excessively wide footing below the ground surface, surface obstructions, large rocks or caliche, and excessive saturation. If adjustments to the injection spacing or location is desired, contact the engineer before adjusting the spacing.

2. The choice of injection depth will be dependent upon the depth of swelling clay soils and also the swell potential and swell pressure of these clay soils. The depth of injection is generally between 7 to 11 feet unless refusal is encountered. When injecting penetrate 1 foot at a time and continue injecting at each foot for a period that may vary between 50 seconds to 60 seconds. Total injection time per hole will be a minimum of 6 minutes for a 7 foot deep injection and 9 minutes for a 11 foot deep injection. Stop watches will also be required to ensure accurate time increments for each injection depth. Use 7 foot or 10 foot long vertical pole stands with 1 foot increments marked on the poles placed adjacent to the injection wands to ensure accuracy of injection depth increments.

3. Drill small ½ inch holes through existing exterior flatwork and extend injection wands through holes to inject chemical. Patch holes after injection.

Figure 1A: Chemical Injection Detail Illustrating AGSS-ICS Injection Methodology and Specifications for Structure Perimeter (Option 1 - three rows of injections around perimeter).
AGSS-ICS CHEMICAL INJECTION SPECIFICATION AND APPLICATION METHODOLOGY DETAIL FOR STRUCTURE PERIMETERS (OPTION 2 - TWO ROWS OF INJECTIONS)

NOTES:
1. Inject a clay stabilization chemical called AGSS-ICS into the soil to reduce its swell and shrinkage potential, and also to reduce the soil suction of the clayey soil. The AGSS-ICS chemical is generally mixed (1) part chemical to (300) parts water, producing a very diluted and safe solution. The chemical is injected with ½-inch diameter steel wands to depths ranging from 7 to 11 feet and at a spacing of approximately 2 feet along each row. Three rows of injections will be made around the outside of the exterior foundation. The first row of injection points will be placed 9-inches outside the exterior foundation. Space the first row injection points 2 feet apart and incline the injection wand so the soil under the foundations are injected. Place the second row of injection points 2 feet apart and at a distance of 21-inches from the exterior foundation wall. The second row of injection points will be staggered relative to the first row. Typical justification for adjusting the injection locations will be an excessively wide footing below the ground surface, surface obstructions, large rocks or caliche, and excessive saturation. If adjustments to the injection spacing or location is desired, contact the engineer before adjusting the spacing.

2. The choice of injection depth will be dependent upon the depth of swelling clay soils and also the swell potential and swell pressure of these clay soils. The depths of injection is generally between 7 to 11 feet unless refusal is encountered. When injecting penetrate 1 foot at a time and continue injecting at each foot for a period that may vary between 50 seconds to 60 seconds. Total injection time per hole will be a minimum of 6 minutes for a 7 foot deep injection and 9 minutes for a 11 foot deep injection. Stop watches will also be required to ensure accurate time increments for each injection depth. Use 7 foot or 10 foot long vertical pole stands with 1 foot increments marked on the poles placed adjacent to the injection wands to ensure accuracy of injection depth increments.

3. Drill small ¼ inch holes through existing exterior flatwork and extend injection wands through holes to inject chemical. Patch holes after injection.

Figure 1B: Chemical Injection Detail Illustrating AGSS-ICS Injection Methodology and Specifications for Structure Perimeter (Option 2 - two rows of injections around perimeter).
AGSS-ICS CHEMICAL INJECTION SPECIFICATION AND APPLICATION METHODOLOGY DETAIL FOR STRUCTURE PERIMETER AND INTERIOR (OPTION 3)

NOTES:

1. Inject a clay stabilization chemical called AGSS-ICS into the soil to reduce its swell and shrinkage potential, and also to reduce the soil suction of the clayey soil. The AGSS-ICS chemical is generally mixed (1) part chemical to (300) parts water, producing a very diluted and safe solution. The chemical is injected with 5/8-inch diameter steel wands to depths ranging from 7 to 11 feet and at a spacing of approximately 3 feet along each row. Two rows of injections will be made around the outside of the exterior foundation. The first row of injection points will be placed 9-inches outside the exterior foundation. Space the first row injection points 3 feet apart and incline the injection wand so the soil under the foundations are injected. Place the second row of injection points 3 feet apart and at a distance of 21-inches from the exterior foundation wall. The second row of injection points will be staggered relative to the first row. The interior injections will also be spaced 3 feet apart along each row, however, the adjacent rows will be spaced 18-inches apart with each injection location staggered relative to the adjacent rows. This results in an effective spacing of 2.1 feet for the interior injection points and 1.8 feet for the exterior injection points. The spacing and location of the injection points can be adjusted if conditions warrant it. Typical justification for adjusting the injection locations will be an excessively wide footing below the ground surface, surface obstructions, large rocks or calcite, and excessive saturation. If adjustments to the injection spacing or location is desired, contact the engineer before adjusting the spacing.

2. The choice of injection depth will be dependent upon the depth of swelling clay soils and also the swell potential and swell pressure of these clay soils. The depth of injection is generally between 7 to 11 feet unless refusal is encountered. When injecting penetrate 1 foot at a time and continue injecting at each foot for a period that may vary between 5 hours to 60 seconds. Total injection time per hole will be a minimum of 6 minutes for a 7 foot deep injection and 9 minutes for a 11 foot deep injection. Stop watches will also be required to ensure accurate time increments for each injection depth. Use 7 foot or 10 foot long vertical pole stands with 1 foot increments marked on the poles placed adjacent to the injection wands to ensure accuracy of injection depth increments.

3. Drill small 5/8 inch holes through existing exterior flatwork and extend injection wands through holes to inject chemical. Patch holes after injection.

Figure 2: Chemical Injection Detail Illustrating AGSS-ICS Injection Methodology and Specifications for Structure Perimeter and Interior (Option 3 – perimeter and interior injections).
Photograph 1: AGSS-ICS chemical injection rig. Four pumps and (2) 500 gallon tanks.

Photograph 2: AGSS-ICS chemical injection rig. Four pumps and (2) 500 gallon tanks.
Photograph 3: Injection of AGSS-ICS beneath perimeter of structure with steel wand.

Photograph 4: Injection of AGSS-ICS beneath perimeter of structure with steel wand.
Photograph 5: Injection of AGSS-ICS beneath interior floor slab using steel wand.

Photograph 6: Injection of AGSS-ICS beneath interior floor slab using steel wand.
Photograph 7: Injection into hard ground adjacent to wall using both hydrojetting and vibration. A concrete vibrator is duct taped to the top of an injection wand in areas that are hard to penetrate.
Photograph 8: Quality control of the injection process is very important. The wand penetrates the soil at a rate of approximately 50 seconds/foot and injects the chemical solution at a rate of 4.5 gallons/minute. The technician uses a stop watch and the white pole with the 1 foot blue tape intervals to control the injection process.