

TECHNICAL NOTE NO. 14.6.5

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Procedures and Specifications - GeoConcrete® Column Construction in Heaving Soil

This Technical Note provides construction guidance for constructing GeoConcrete® Column (GCC) elements in soil conditions where appreciable site heaving may occur. Heaving soil conditions can cause unacceptable tensile forces on green or cured GCC elements, and special construction methods are required when working in select soil profiles.

PROBLEMATIC SOIL PROFILES AND CONSTRUCTION SEQUENCING

A “Heave Susceptible Site” is where heave related tensile stresses need to be considered. These sites have a very soft (SPT N-Values on the order of 2 bpf or less) and clay layer with thickness of more than 10 ft. In addition, heave can occur in saturated clay/silt sites with an average pier spacing of 8 ft or less across large areas. Note that pier spacing and area have an inverse relationship in that tighter spacings will instigate heave over a smaller footprint. Large mats and or foundations consisting of closely spaced, heavily loaded strip footings are particularly susceptible.

Sites with these soil and pier layout conditions tend to experience volume expansion during pier installations due to the inability of the soils to change volume quickly, resulting in upward movement of the working pad and tensile stresses applied to the GCC elements. Careful construction sequencing and changes to installation procedures need to be considered on heave susceptible sites where ground heave could have a detrimental effect on the GCC integrity.

Soil conditions that tend to experience less volume expansion and are not susceptible to these mechanisms are sandy soil and non-plastic silt, organic silt and peat. Profiles comprised of those soil types are not considered to be heave susceptible sites.

Additional soil profiles may warrant special installation considerations with respect to site heave and will be identified in the Design Review.

CONSTRUCTION PROCEDURES FOR CONDITIONS WITH HEAVE AND INADEQUATE TENSILE CAPACITY

Design/construction modifications are required if the project is identified as a heave susceptible site. One or more of the following construction modifications must be utilized:

- Implement a construction sequence that avoids installing elements within a 20-foot radial distance from previously installed “weak concrete” elements. GCC elements are defined as “weak” during the time spanning a window from when it first

becomes rigid and 36 hours after installation. Without site specific verification, 2 hours should be considered the maximum time allowance prior to a GCC being considered rigid. Note, however, that weather conditions, supplier admixtures, batch times, concrete mixes, and other factors can shorten or lengthen this time. On-site quality control personnel must verify and document that concrete is still fluid if the 2-hour time limit is exceeded. In no case should a 4-hour time limit be exceeded.

- Use a larger diameter (e.g.: 16-inch) GCC element to increase the available tensile resistance of elements during curing, or
- Use a concrete mix design that provides a retarder to delay curing time sufficiently to allow installations with 20 radial feet of previously installed elements within a 2-to-36-hour time window, or
- Use a sufficiently sized rebar installed in the GCC elements to at least 2 feet below the depth of the soft clay layer to provide added tensile resistance when adjacent piers are installed within the time window noted above, or
- Use a pre-drill with a volume equal to that of the GCC concrete volume. The pre-drilled diameter will be larger than that of the GCC and provide a preferential path for soil movement. The pre-drill depth should be enough to equal the anticipated GCC volume or to the top of the soft layer, whichever is deeper.

The steps below are required if a project is identified as a heave susceptible site:

1. During preparation of the proposal, review the Geopier design and layout with the GFC AM to confirm which of the design/construction modification options listed above is the most desirable to mitigate the impact of heave. Develop a primary plan to address mitigate heave as well as contingency plans in the event the preferred option does not adequately address the heave concern at the site.
2. Monitor heave of at least 4 sacrificial or production GCC elements at the beginning of a project to verify that the construction procedures and / or mix design is adequately mitigating heave and that upward movement of the rigid inclusion elements is less than 1 inch. Note that more than 1 inch may be allowed based on the observed upward movement of a successfully tested pier that has heaved.
 - a. The monitoring of the top of the GCC elements may be accomplished using a short #6 bar installed to depths of 5 ft. The purpose of the rebar is for elevation monitoring and not to provided added tensile resistance. Suitable settlement monitoring techniques such as settlement plates installed in direct contact with GCC elements is also acceptable.
 - b. The survey is for relative movement only and can be accomplished with a laser level provided it is located outside of the heave area.

- c. The locations of these elements must be reviewed and agreed upon with the GFC AM.
3. If the results of the survey performed in Step 2 indicate upward movement in excess of 1 inch or the acceptable limit, the GFC AM must be notified so the contingency plan can be implemented.
4. If only a construction sequencing approach is being implemented to mitigate heave, a minimum of 1 adjacent pier per group of installed piers must be elevation monitored during installation of the subsequent adjacent pier groups within a 20 ft zone to verify heave, if occurring, is within project tolerance. The piers to be surveyed must be agreed upon with the Geopier AM prior to construction.

ADDITIONAL CONSTRUCTION BEST PRACTICES

Care should be made to implement the following best practices during GCC installations:

- Monitor GCC squeeze of “wet” concrete to verify that there is not appreciable reduction of shaft diameters of the GCC elements
- Predrilling may be considered for sites that have very stiff or dense crusts or very stiff clay layers to help reduce the effects of heave and tensile resistance of the GCC elements.
- Project specific test programs may be useful to help modify these best practices on a case-by-case basis.

CONCRETE TENSILE STRENGTH

Instrumented 12-inch diameter rigid inclusions have shown that as much as 30 kips tensile force in is generated from installation of pre-drilled 16-inch diameter GCC elements during heave. Instrumented 16-inch diameter rigid inclusions have shown as much as 70 kips of tensile force from installation of adjacent 16-inch diameter GCCs. These tensile forces may be resisted by a sufficiently sized rebar installed in the GCC elements or by the available tensile capacity of the cured concrete. Table 1 shows the tensile capacities (assumed to be $0.1 \times f'_c$) for various pier diameters after curing.

Table 1. Tensile Capacities of 12-inch, 14-inch and 16-inch GCCs.

f'_c (psi)	f_t (psi)	Tensile Capacity ^[1] of Piers ^[2] (kips)		
		12" Diameter GCC	14" Diameter GCC	16" Diameter GCC
1000	100	8.6	11.9	15.9
2000	200	17.1	23.9	31.8
3000	300	25.7	35.8	47.7
4000	400	34.2	47.8	63.6
5000	500	42.8	59.7	79.5

Notes: 1. Considers a strength reduction factor of 0.9.
 2. Considers a 1" diameter reduction from wet squeeze.