

**RECOMMENDED GUIDELINES
FOR DESIGN AND CONSTRUCTION OF INGROUND SWIMMING POOLS
IN HOUSTON, TEXAS
PRESENTED AT THE FOUNDATION PERFORMANCE ASSOCIATION
SEPTEMBER 12, 2007 MEETING**



BY

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GEOTECH ENGINEERING AND TESTING

www.geotecheng.com

SEPTEMBER 2007

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By David A. Eastwood, P.E.⁽¹⁾**

Introduction

Many inground swimming pools are built in the Houston area. The author has observed many of these pools experiencing movements, cracking, etc. The purpose of this document is to highlight prudent practices and guidelines for design and construction of pools to protect the public and pool contractors against a faulty pool design and construction. Pool design and construction should always consider the effects of subsoil, groundwater, structural considerations, drainage, trees, slopes, etc.

Design

General. A design of the pool should consider the geotechnical considerations, groundwater, slopes, environmental conditions such as trees and drainage. In addition, structural issues should also be considered in the design of any pool. Pools should be designed in general accordance with the latest version of American National Standard for Residential Inground Swimming Pools (Ref. 1). The 2003 version of this document states that the structural design and materials used shall be in accordance with generally accepted structural engineering practices and methods.

Site Conditions. Site conditions are crucial in designing a pool. Typically, a site which is flat with no slopes provides the most favorable site condition. However, sites on slopes, next to ravines, provide the most arduous design considerations. Trees also affect the performance of pool structures.

Pools that are to be placed near slopes should consider the effects of slope geometry as well as erosion considerations. A geotechnical study should be conducted to address the issue of slope stability and erosion for pools designed and constructed on slopes steeper than 5(h):1 (v).

Geotechnical Considerations

Field Exploration. A geotechnical exploration and report by a geotechnical engineer licensed in the State of Texas should be conducted for design of any pool. The geotechnical exploration will involve drilling soil borings at the location of where the pool is going to be constructed. In general, the depth of the soil borings should be twice the depth of the pool with a minimum depth of 20-ft. A minimum of two borings should be conducted for pools of less than 3000 sq. ft. Additional borings should be performed if pools are larger than 3000 sq. ft. A minimum of one boring should be conducted for any additional 1500 sq. ft. of pool area. The borings should be sampled continuously from the surface to a minimum depth of 10-ft and at five-ft intervals, thereafter. All cohesive soils should be sampled in general accordance with ASTM D1587. The cohesionless soils should be sampled in accordance with ASTM D1586. Root fibers should be obtained in all borings to help evaluate the active zone.

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Laboratory Testing. Classification and strength tests should be conducted to develop a soils stratigraphy of the subsoil conditions. In general, all laboratory testing should be conducted in accordance with American Society for Testing Materials Standards (ASTM). The tests should include classification and strength tests. All subsoils should be classified in accordance with the unified soil classification system.

Site Conditions. The geotechnical engineer representative should observe and photograph the site conditions during the field exploration. He should address the site conditions if there are trees on the site in close proximity to the pool. He should address slopes, ravines, ponds, and other unusual site features that may result in adverse pool performance. Photograph(s) of the project site should be included in the geotechnical report.

Soil Stratigraphy. The geotechnical engineer should address the subsoil conditions at the project site. He should define a soils stratigraphy all the way to the bottom of the borings. The soils stratigraphy should also define how expansive the subsoils are as well as their strength and moisture contents.

Groundwater Level. The borings should be drilled dry to evaluate the presence of perched water to free water conditions. The level where free water is encountered in open boreholes during field exploration should be noted on the boring logs. Fluctuations in groundwater level generally occur as a function of seasonal variation, temperature, groundwater removal, and future activities near the project site. Therefore, the pool contractor should verify groundwater depth prior to start of construction on any new pool. This is because the time that a geotechnical study was conducted may be different than the time the pool is constructed. A pool designer should assume groundwater level at the surface for design of the pool system.

The groundwater levels in the Gulf Coast area vary significantly. The groundwater depth in the Houston area generally ranges from 0- to 25-ft±.

The groundwater measurements are usually evaluated by the use of a tape measure and weight at the end of the tape at the completion of drilling and sampling.

Some of the groundwater problem areas in Houston include Southside Place, parts of Sugar Land, West University, etc. One should not confuse the perched water table with the groundwater table. A perched water table occurs when insufficient drainage exists in the areas with a surficial sand or silt layer, about two- to four-ft. thick, underlain by impermeable fat and lean clays. During the wet season, water can pond on the clays and create a perched water table. The surficial sands/silts become extremely soft, wet and may lose their load carrying capacity.

General Soils Conditions. Variable soil conditions occur in the Houston area. These soils are different in texture, plasticity, compressibility, and strength. It is very important that a pool structure be designed for subsoil conditions that exist at the specific site in order to reduce potential pool distress. Expansive soils can cause major damage to pool structures in the Gulf Coast area. Expansive soils are classified to be soils with liquid limit greater than 40 and plasticity index (PI) of greater than 20. Details of general subsoil conditions at various parts of the Houston area are described below. Significant variations from these descriptions can occur. The general soil conditions are as follows:

Location

Soil Conditions

Northwest and Northeast Houston, including The Woodlands, Cypresswood, Copperfield, Atascocita area, Fairfield, Worthom, and Oaks of Devonshire

Generally sandy surficial soils occur in these areas. The sands are generally loose and are underlain by relatively impermeable clays and sandy clays. This condition promotes perched water table formation which results in the loss of bearing capacity of the shallow soils.

South, Southwest, Southeast, and part of West Houston including, Kirbywoods, parts of the South Shore Harbour, Seinna Plantation, Clear Lake area, New Territory, Shadow Creek, Greatwood, River Park, Telfare, First Colony, Brightwater, Vicksburg, Pecan Grove, Woods Edge, Cinco Ranch, Lake Olympia, Kingwood, Walden and April Sound on Lake Conroe, etc.

Generally highly plastic clays and sandy clays are present in these areas. These clays can experience significant shrink and swell movements. The pools must be designed for this condition. Parts of Cinco Ranch has a surficial layer of sands, underlain by expansive clays.

Central Houston, including Bellaire, Memorial, Tanglewood, West University.

Highly expansive clays. These soils can cause pool failure. Soft soils are observed in some sites.

Heights, Spring Branch, Hunter's Creek, Bunker Hill, Piney Point, Hedwig Village, and River Oaks.

Moderately expansive lean clays, clays, and sands. Special pool foundations must be used for structures near ravines.

Weston Lakes, Oyster Creek.

Very sandy soils in some areas, variable soil conditions. Highly expansive soils at other areas.

Sugar Mill, Sugar Creek, Quail Valley, Sweetwater.

Highly expansive clays on top of loose silts and sands. Variable soil conditions. Shallow water table.

Geotechnical Design Information

The geotechnical report for the pool should provide the following information:

- Site conditions, photos, existing structures, trees, slopes, etc.
- Plan of borings.
- Soils stratigraphy.
- Groundwater depth.
- Whether or not subsoils are expansive.
- Lateral earth pressures against pool walls.

- OSHA soil classification system.
- Results of laboratory tests, including soil suction, if conducted.
- Skin friction along pool walls to resist buoyancy forces.
- Recommendations on compressive and uplift capacity of drilled footings or helical piles, if used.
- Dewatering recommendations.
- Potential Vertical Rise (PVR) at both deep end and shallow end.
- Edge moisture distance.
- Depth of active zone.
- Depth of root fibers.
- Are there trees at or near the pool (within 50-ft.)?
- Tree trunk diameters and species (if known or recognized by the field exploration staff).
- Recommendations on uplift resistance techniques.
- Whether the excavated soils can be used as fill.
- Maintenance programs, trees, drainage.
- Construction considerations.

Structural Consideration in Pool Design

A pool structure should be designed by a structural engineer licensed in the State of Texas. The structural engineer will review the geotechnical report for the pool structure and design a wall system and bottom that will resist the prescribed active earth pressures, buoyancy and effects of expansive soils on the pools. The structural engineer should also consider the effects of trees on the pool design. The structural engineer will design adequate steel reinforcement in the pool shell as well as, the proper gunite thickness. The structural engineer should also specify the required gunite compressive strength for the pool structure. The pool structure should be designed to resist buoyancy due to groundwater and expansive soils. The structural engineer should also develop plans and specifications for the construction of the pool. This should include earthwork, gunite, drainage and steel reinforcing specifications.

Geotechnical Engineer will provide the Structural Engineer with alternative pool foundations and estimated pool movements. The Structural Engineer will consult with the owner to decide the acceptable level of movements and various pool foundations and their corresponding risks.

Pool Structure Foundations

General. Pool structure systems generally consist of a gunite shell. In case of presence of expansive soils, the pool structure should be isolated from the expansive soils to resist potential pool movements. In addition, in the areas where pools are built near the bayous or on slopes, a structural pool system should be designed. In areas of shallow groundwater, uplift of pool structure may occur as a result of buoyancy forces on the pool shell. Due to heavy rainfall in the Gulf Coast area and corresponding cyclical shallow groundwater, all pools should be designed assuming groundwater at grade to resist uplift loads. Alternatively, weep holes should be placed at pool bottom and along the pool walls to relieve hydrostatic pressures. The weep holes will be covered when the pool is full. The weep holes should be opened when the pool is empty. It should be noted that the use of weep holes will create a pool maintenance issue. Some pool builders punch holes at the bottom of pools when they are emptied to relieve hydrostatic pressures.

In the areas where expansive soils are present, the pool plumbing connections should be designed to allow for movements. Furthermore, alternative measures should be implemented to reduce pool movements. As a result of expansive soils, these alternatives in terms of increasing risk of pool movement are discussed in the following sections.

Subsoil Removal and Replacement with Select Structural Fill. In the areas where expansive soils are present, the subsoils around the pool and on the bottom of the pool should be removed and replaced with select structural fill. As part of a geotechnical exploration, the geotechnical engineer should determine the depth of active zone at a specific site. Active zone is defined as the depth above which soils experience seasonal changes in moisture conditions and corresponding vertical movements. Root fibers logged in the boring logs help to determine this depth. For example, if the pool is about six-ft, and the active zone is 10-ft, the soils to the bottom of the active zone depth (about 4-ft.) should be removed and be replaced with select structural fill. In addition, the soils around the perimeter of the pool to a distance of edge moisture variation distance from the perimeter of the pool should be removed to the active zone depth and replaced with select structural fill. Edge moisture variation is the distance from the edge of the pool outward when significant changes in moisture content of soil can occur. These soils can experience significant heave. Maximum edge moisture variation distance in Houston is about nine-ft. The select structural fill consists of lean clays with liquid limit of less than 40 and plasticity index between 12 and 20. All the select structural fill in the pool area should be compacted to a minimum of 95% standard proctor density (ASTM D698) at $\pm 2\%$ of optimum moisture. All the compaction work should be tested to assure proper compaction of the soils around the pool.

Vertical Moisture Barrier. The subsoils under and around pool can be isolated from change in soil suction and corresponding movements. Soil suction quantifies the energy level in the soil moisture system. An imbalance of total soil suction between the soil at the pool site and adjacent soil tends to drive moisture toward the high value of soil suction.

A vertical moisture barrier can be placed next to pool coping. It should extend deep enough to reduce soil suction changes. This depth may be about six- to seven-ft deep. The moisture barrier should totally isolate the pool shell and subsoils under it, and should be placed all around the pool.

A vertical moisture barrier will not work if (a) the pool shell has a crack in the gunite with corresponding pool leak or (b) there is a plumbing leak inside moisture barriers. All plumbing for the pool should be placed outside the moisture barrier. Vertical moisture barriers consist of impermeable geo-fabrics that are resistant to puncture and ultraviolet light. They can be placed by digging a vertical ditch around the pool. On-site clayey soils can be used to backfill the moisture barrier trench. Do not use sand or silt as backfill materials. All planter areas should be outside the vertical moisture barrier.

Pool Structure on Void Spaces. In areas where expansive soils are present, pool structures can also be constructed on void spaces. The design concept is as follows:

- Support the pool structure on drilled footings or helical piles.
- Place degradable and collapsible void spaces under the pool bottom. The size of void spaces should be determined by estimating the maximum Potential Vertical Rise (PVR) at pool bottom.
- Since expansive soils shrink and swell in three dimensions, place degradable void space against pool walls. In addition, place geosynthetics in between the void space and the pool walls to provide additional slippage plane between the void spaces and pool walls.
- Use select structural fill for a minimum of 18-inches around the pool (on the top) to reduce potential water infiltration into the void spaces. This fill should extend a distance equal to edge moisture distance variation away from the pool.
- The geotechnical engineer should provide recommendations on both compressive and uplift capacity of drilled footings or helical piles.

Chemical Stabilization. Subsoils within and around the pool can be chemically stabilized to reduce the potential pool movement. In general, the subsoils at the bottom and sides of the pool should be stabilized. The bottom chemical stabilization should extend to the depth of active zone. The pool perimeter to a distance of edge moisture variation (a maximum of about 9-ft) from the edge of the pool should also be chemically stabilized. The chemical stabilization may consist of lime-slurry pressure injection or ion exchange chemical injections. The lime-slurry injection should be conducted in the summer time when there are more cracks in the soil mass; otherwise, it may be ineffective. Ion exchange chemicals can be injected anytime of the year. In addition, contractor qualifications and project specifications should be developed for implementation of this technique. The project specification should be developed by the geotechnical engineer of record. The pool owner should be informed that chemical stabilization may kill some vegetation.

Helical Piles. The pool structure can also can also be supported on a helical pile system founded below a depth of 15-ft. The helical pile system should be designed on the basis of design procedure, outlined in the “Basic Helical Screw Pile Design,” (Refs. 2 and 3). The pile should resist uplift loads due to expansive soils and hydrostatic pressures acting on the bottom and the walls of the pool.

In general, the cost of Helical Pile System will be less than the cost of drilled footings, that are installed using casing or slurry method of construction. Furthermore, the construction time is significantly reduced. Additional information on design of helical pile system can be obtained from Geotech Engineering and Testing web site (www.geotecheng.com), under “Publications, Guidelines”.

The ultimate helical pile compressive and uplift (Ref. 4) capacity can be computed from the following:

$$P = \Sigma A_H (9c) \quad \text{Piles in Clays}$$
$$P = \Sigma A_H (qN_q) \quad \text{Piles in Sands}$$

Where: P = Ultimate Pile Capacity, lbs

ΣA_H = Sum of Helical Plate Areas, ft²

c = Cohesion of Soil, psf

N_q = Bearing Capacity Factors for Sands

q = Effective Soil Overburden Pressure from Ground Surface to Mid-Plate Depth, psf

(An estimate of q equal to 60H psf is recommended, where H is the mid-plate depth in feet.)

Helical plates found in clay should use the clay equation. Helical plates in sand, should use the sand equation. We recommend that the helical plates be separated at a distance of three plate diameters. Furthermore, the structural engineer should also check for buckling, using a soil modulus of subgrade reaction (k). Buckling can usually be a problem in soft soils. One way to reduce the potential for buckling is to install the helical shafts through a 12-inch diameter, 10-ft deep hole which is backfilled with concrete after helical pile installation. The helical pile should be placed at a distance of at least five largest plate diameters between each other to reduce group action. Pile spacing that is closer than 5 largest plate diameters will result in axial capacity reduction.

The helical pile should be designed to resist the “punch-through” failure in areas where soft soils occur below strong soils. We recommend a distance of greater than five times the diameter of the lowest helical plate exists from the soft soils to prevent the helical piles from puncturing through into the soft soil stratum.

Structural Pool. Pools built near bayous, soft soils, or on slopes may be constructed as structural pools. This means that the pool structure is totally supported on drilled footings. The depth of the drilled footings should be below the active zone as determined by the geotechnical engineer. For pools on slopes, the pier depth should extend below the potential failure surface to resist lateral movements due to potential slope failure. This depth should be determined by modeling the pool and the slope using computer software. Alternatively, a retaining wall should be placed on the side of the pool which is facing the slope. The retaining wall should be designed to prevent slope failure as well as pool movements. In the event that a retaining wall is used to prevent slope movements, the pool can be designed as if it is on a flat ground. Reinforcing steel should be placed in the drilled footings to resist uplift loads due to expansive soils and sliding movements due to unstable slopes. A slope-stability analysis should be conducted by the geotechnical engineer to evaluate the global stability of pools on slopes.

Pool Bottom. The soils supporting the pool bottom should be inspected for any weak and compressible zones. These areas should be compacted to at least 95% standard proctor density (ASTM D698).

Pool Walls. Pool walls should be designed using a lateral earth pressure corresponding to active earth pressures and any surcharge load. At rest earth pressure coefficients should be used to evaluate the active earth pressure. Walls should be constructed to prevent moisture migration, since seepage can occur through backfill soil. Backfill soils behind the walls should consist of inorganic lean clays with a liquid limit of less than 40 and plasticity indices between 12 and 20. Other types of select structural fill available locally, and acceptable to the geotechnical engineer, can also be used. These soils should be compacted to at least 95% standard proctor density (ASTM D 698). Groundwater should be assumed to be at the surface when designing the pool walls.

Buoyancy. A pool structure can experience uplift loads from the groundwater during flood conditions. The pool structure should perform satisfactorily if a design factor of safety against uplift of 2.0 is used. Furthermore, the structure should be assumed to be empty for the purpose of these calculations, unless the design includes a means of relieving the external hydro-static forces during pool maintenance. The pool structure can resist the uplift loads due to buoyancy by using one of the following alternative measures:

- Extend the bottom pool foundation beyond the pool wall to create a toe extension and to provide sufficient weight of overburden soil to resist hydrostatic uplift at the bottom of the pool. Only the submerged weight of the soils mass directly above the toe extension and the dead weight of structure should be considered when calculating the uplift resistance due to unbalance piezometric pressures.
- Increase the mass of the pool structure by using a thick gunite foundation.
- In the event that a drilled footing or helical pile foundation is used, uplift resistance from these foundations can be considered as reaction forces.

The submerged soil unit weight of 60 pound per cubic foot (pcf) can be used to compute the soil resistance to uplift loads. A dry unit weight of 150 pcf should be used for gunite and reinforcing. The pool decking should be keyed and doweled into the coping beams. That is its weight may also be used to prevent pool uplift.

The structural engineer can disregard buoyancy forces if he can relieve groundwater uplift loads during the life of the pool. This may be accomplished by using properly installed weep holes. However, weep holes may result in a water leak maintenance issue. Some pool builders punch holes at the bottom of the pool, when the pool is emptied for maintenance or repair purposes to relieve hydrostatic pressures. Again, this may result in pool leak and corresponding uplift due to expansive soils if the pool is located in areas where expansive soils are present. The pool owner should be made aware of the risks involved with these alternatives.

A french drain or similar system can also be placed around the bottom of the pool to relieve external hydrostatic pressures. The french drain should be connected to a sump-pump system and water should be pumped out. French drains must be properly designed so that they would not be clogged up. Furthermore, the sump-pump area should be always maintained for the system to work.

Flat Work. The concrete flat work should be placed around pools, especially in the areas where expansive soils are present. The flat work should be crowned such that it would slope about 2% away from the pool structure. Control joints should be placed at generally no more than eight-ft spacing. Isolation joints should be placed between the coping and flat work. The flat work should be reinforced with at least No. 3 bars at 18-inch spacing. Chairs should be placed directly underneath the steel. The steel should be in the middle of the flat work. Furthermore, concrete should have a minimum compressive strength of 2100 psi at seven days.

The subgrade underneath the flat work should be compacted to a minimum of 95% standard proctor density (ASMT D698). All compactions should be verified by all field density tests. A set of concrete cylinders should be made for each pour or every 25 yards of flat work. The flat work should be designed and constructed in general accordance with Portland Cement Association document “Building Concrete Walks, Driveways, Patios, and Steps” (Ref. 5).

Effect of Trees/Planter Areas on Pools

Existing Trees. Tree roots tend to desiccate the soils. In the event that a tree has been removed prior to pool construction, or if a tree dies, subsoil swelling may occur in the expansive soil areas for several years. Studies (Ref. 6) have shown that this process can take as much as 20 years in the area where highly expansive clays are present. In this case, the pool structure should be designed for the anticipated maximum heave. One way that pool movement is reduced is by removal and replacement of expansive soils as discussed in the previous section. In addition, the area within the tree root zone may have to be chemically stabilized to reduce the potential movements. Alternatively, the site should be left alone for several years so that the moisture regime in the desiccated areas of the soils (where tree roots used to be) becomes equal/stabilized to the surrounding subsoil moisture conditions.

It should be noted that the upheaval in the expansive clays (where trees have been removed or trees have died) occurs predominantly faster in the areas that have poor drainage, excessive irrigation or when a plumbing/sewer leak is occurring.

New Trees. Shallow pools of less than 3-ft can experience potential settlement (shrinkage of soils) due to trees sucking water from soils underneath the pools. We recommend trees not be planted or left in place (existing trees) closer than half the canopy diameter of mature trees from the grade beams, typically a minimum of 20-ft. Alternatively, root systems from some tree species can go under the shallow portion of a pool and cause uplift in the area. Vertical root barriers can be placed near the coping to minimize the effects of tree root movements under the pool shell. These retardants can reduce possible pool movements as a result of tree root systems.

Planter Areas. Planter areas should be placed away from pools where expansive soils are present. In the event planter areas are built near pools, design approaches should be implemented to reduce potential pool movements due to wetting caused by planter areas. These design concepts may include using moisture barriers, etc.

Construction Considerations

Pool Excavation. Typically, temporary (less than 24 hours), open trenched, non-surcharged and unsupported excavations for a pool can be built on vertical slopes. Flatter slopes may be required in the areas where soft soils or a large amount of sands are encountered. Vertical cuts can be constructed for shallow pools or where shoring and bracing is used for excavation wall stability. In all cases, excavation construction should conform to OSHA (Occupational Safety and Health Administration) guidelines. In general, the subsoils in the pool area are classified as Type C soils in accordance with the OSHA Soil Classification System. Specification should require that water not be allowed to pond in excavations. If gunite is not placed the same day that the excavations are completed, place a thin layer of gunite (flash) over the base and the walls of the pool.

Groundwater Control. The geotechnical report should address groundwater control during pool construction. In the event that groundwater is encountered during construction, where cohesive soils are present, the groundwater should be removed using a sump-pump system. In the areas where cohesionless soils are present with shallow groundwater, dewatering may have to be conducted, using a wellpoint system. The groundwater should be removed to a minimum depth of 3-ft below the pool bottom. The pool excavation dewatering and retention techniques are the responsibility of the general contractor.

Fill Characteristics

Select Structural Fill. This is the type of fill that can be used around and at the bottom of the pool. These soils should consist of lean clays, free of root organics, with liquid limit less than 40 and plasticity indices between 12 and 20.

Structural Fill. This type does not meet the Atterberg limit requirements for select structural fill. This fill should consist of lean clays or fat clays. These soils should not be used under or around a pool.

General Fill. This type of fill consists of sands and silts. These soils are moisture sensitive and are difficult to compact in a wet condition (they may pump). Their use is not recommended under or around the pool. They can be used in the planter areas at least 5-ft away from the pool. They can also be used for site grading outside the buildings and pavement areas.

Drilled Footings Installations

Where structural pool is used, the drilled footings installations shall be done in accordance with the American Concrete Institute (ACI) Reference Specifications (Ref. 7) for the construction of drilled piers (ACI 336.1) and commentary (ACI 336.1R-98). Furthermore, it should comply with U.S. Department of Transportation, drilled shafts construction procedures and design methods (Ref. 8).

The drilled footing excavations should be free of loose materials and water prior to concrete placements, and concrete should be placed immediately after drilling the holes.

Helical Pile Installations

Experience indicates that torque required to install a helical pile can be used to estimate its compressive capacity (Ref. 9). The contractor should screw the pile into ground to desired torque. Do not over-torque. Furthermore, grout can be placed if specified in the design and brackets can also be installed.

In general, the ultimate compressive capacity of helical pile can be estimated in the field, using a value of 9 to 10 times the value of the torque, for square base products. The ultimate compressive capacity will be 6 to 9 times of the field torque, if tubular products are used. The structural engineer should consult with the helical pile manufacturers for piles that can resist corrosion.

Surface Water Drainage

To minimize ponding of surface water, proper site drainage should be established early in project construction so that this condition will be controlled. Water should not be allowed to pond next to the pool structure.

Quality Control

Earthwork. The earthwork testing around the pool should be conducted by the geotechnical engineer. Select structural fill should be compacted as described in the design section of this document. Fill materials should be placed in loose lifts not exceeding eight-inches in thickness and compacted to 95% of the maximum dry density determined by ASTM D698 (standard proctor). The moisture content of the fill soils at the time of compaction should be within $\pm 2\%$ of optimum value. We recommend that the degree of compaction and moisture of the fill soils be verified by fill density tests at the time of construction. The frequency of testing be a minimum of four field density tests per lift.

Drilled Footing Observations. Detailed observations of pier construction should be required by a qualified geotechnical engineering technician so that the piers are (a) founded in the proper bearing Stratum, (b) have the proper depth, (c) have the correct size, and (d) that all loose materials have been removed prior to concrete placement.

Steel Observations. Pool construction requires care in the spacing and arrangement of reinforcing, as heavy concentrations of steel interfere with proper gunite placement. Reinforcements should be free from oil, loose rust, mill scale or after surface deposits that may affect bonding to gunite. Reinforcement should be constructed in general accordance with ACI 506. Steel placement, chair placement, steel grade, steel size and spacing should be observed by a geotechnical or structural engineer prior to gunite placement.

Gunite. The gunite should be mixed and placed per ACI 506. All the gunite equipment and procedures should meet the ACI requirements. In addition, grout samples of the gunite should be made and tested for compressive strength in accordance with ASTM C42. Obtain a minimum of four grout samples from each 400 sq. ft. of pool foot print or 50 cubic yards placed, whichever results in more grout samples.

Site Visit. After the pool has been constructed, the geotechnical engineer should be consulted to conduct a site visit and discuss placement of landscaping around the pool structure. Landscaping should be placed in such a way that it will not cause pool movements due to expansive soils. All drainage in the landscaping should be away from the pool structure. In the event that sprinkler systems are used for landscaping, they should be placed around the pool to provide a uniform moisture condition.

Qualifications of the Geotechnical Firm

The geotechnical firm who is developing design recommendations for the pool structure should be familiar with design and construction of pools. They should develop recommendations that are site specific to the project. Furthermore, the firm should be accredited by American Association of Laboratory Accreditation (A2LA) in geotechnical engineering. This way the firm has proper personal and quality assurance procedure to handle the project properly. In addition, the geotechnical firm should have errors and omissions insurance with a minimum coverage of \$500,000 annual claims made.

Acknowledgements

The author thanks the following individuals for reviewing this document and making comments:

<u>Name</u>	<u>Company</u>
Karl Breckon, P.E	BEC Engineering
John Clark, P.E.	Clark Engineers, Inc.
Eric Green, P.E.	Walter P. Moore & Associates, Inc.
Ron Kelm, P.E.	Forensic Engineers, Inc.
Michael Turner	SureVoid Products, Inc.

Distribution

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References

1. American National Standard for Residential Inground Swimming Pools, American National Standards Institute, Publication ANSI/NSPI-5 2003.
2. "Basic Helical Screw Pile Design", Donald J. Clayton, P.E., Earth Contac Products, February 2005.
3. "Basic Guidelines for Design Helical Piers for Underpinning," A.B. Chance Company, January 1993 (Bulletin 01-9202).
4. "Uplift Capacity of Helical Anchors in Soil", A.B. Chance Company, 1990.
5. Building Concrete Walks, Driveways, Patios and Steps, Portland Cement Association 1979.
6. Eastwood, et. al., "Design of Foundations with Trees in Mind", Presented at the ASCE Texas Section Meeting, 1997.
7. "Reference Specifications for the Construction of Drilled Piers (ACI 336.1) and Commentary (ACI 336.1R)", American Concrete Institute, Farmington Hills, Michigan.
8. Drilled Shafts: Construction Procedures and Design Methods, U.S. Department of Transportation, Federal Highway Administration, Volumes I and II, August 1999.

9. "Repairing Existing Structures, Using Steel Piers or Helical Piles," Donald J. Clayton, P.E., Earth Contact Products, February 2005.