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05/10/22

GEOTECHNICAL REPORT

Conducted At:

Applicant ID: 0162580120014
7802 WILLOW STREET
HOUSTON, TEXAS 77088

Prepared For:

City of Houston
Housing and Community Development Department
2100 Travis Street, 9th Floor
Houston, TX 77002

JANUARY 12, 2021

Submitted by:

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Prepared By:

GEOTECH ENGINEERING AND TESTING
TEXAS BOARD OF PROFESSIONAL ENGINEERS
REGISTRATION NUMBER F-001183

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Project No. 20-1120E
Report No. 1
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January 12, 2021

Attention: Mr. Jake Wimberley

GEOTECHNICAL STUDY
PROPOSED RESIDENCE AT
7802 WILLOW STREET
HOUSTON, TEXAS

Gentlemen:

Submitted here are the results of Geotech Engineering and Testing (GET) geotechnical study for the proposed residence at the above referenced location. This study was authorized by Mr. Jake Wimberley on December 21, 2020.

1.0 INTRODUCTION

It is planned to construct a residence at the above referenced location. A geotechnical study was performed to evaluate the subsoil and groundwater conditions and to provide suitable foundation type, depth and allowable loading. We understand that drilled footings, helical piles system, or a floating slab type foundation will be used on this project.

This report briefly describes the field exploration and laboratory testing followed by our engineering analysis and recommendations.

2.0 FIELD EXPLORATION

At the request of the client, the soil conditions were explored by conducting two (2) soil borings (B-1 and B-2) located approximately as shown on Plate 1. The number of borings and depths were specified by the client. Soil samples were obtained continuously at the boring location from the ground surface to 10-ft and at five-ft intervals thereafter to the completion depth of the boring at 20-ft. The cohesive soils were sampled in general accordance with the ASTM D 1587.

Cohesionless soils were generally sampled with a split-spoon sampler driven in general accordance with the Standard Penetration Test (SPT), ASTM D 1586. This test is conducted by recording the number of blows required for a 140-pound weight falling 30 inches to drive the sampler 12 inches into the soil. Driving resistance for the SPT, expressed as blows per foot of sampler resistance (N), is tabulated on the boring logs.

Soil samples were examined and classified in the field, and cohesive soil strengths were estimated using a calibrated hand penetrometer. This data, together with a classification of the soils encountered and strata limits, is presented on the logs of borings, Plates 2 and 3. A key to the log terms and symbols is given on Plate 4.

The borings were drilled dry, without the aid of drilling fluids to more accurately estimate the depth to groundwater. Water level observations made during and after drilling are indicated at the bottom portion of the boring logs.

3.0 LABORATORY TESTS

3.1 General

Soil classifications and shear strengths were further evaluated by laboratory tests on representative samples of the major strata. The laboratory tests were performed in general accordance with ASTM Standards. Specifically, ASTM D 2487 is used for classification of soils for engineering purposes.

3.2 Classification Tests

As an aid to visual soil classifications, physical properties of the soils were evaluated by classification tests. These tests consisted of natural moisture content tests (ASTM D 4643), percent passing No. 200 sieve tests (ASTM D 1140) and Atterberg limit determinations (ASTM D 4318, Method B). Similarity of these properties is indicative of uniform strength and compressibility characteristics for soils of essentially the same geological origin. Results of these tests are tabulated on the boring logs at respective sample depths.

3.3 Strength Tests

Undrained shear strengths of the cohesive soils measured in the field were verified by calibrated hand penetrometer and torvane tests. These test results are also presented on the boring logs.

3.4 Soil Sample Storage

Soil samples tested or not tested in the laboratory will be stored for a period of seven days subsequent to submittal of this report. The samples will be discarded after this period, unless we are instructed otherwise.

4.0 GENERAL SOILS AND DESIGN CONDITIONS

4.1 Site Conditions

The project site and the surrounding areas are generally flat with a topographic variation of less than three-feet. Currently, the project site is covered with grass and some trees. Project site pictures were taken during our field exploration and are presented on cover page and Plate 5.

4.2 Soil Stratigraphy

Subsurface soils appear to be relatively variable across the lots. Details of subsurface conditions at both boring locations are presented on the boring logs. In general, the soils can be grouped into three (3) major strata with depth limits and characteristics as follows:

Stratum No.	Range of Depth, ft.	Soil Description*
I	0 – 1	SANDY SILT (ML), dark brown, dark gray, with root fibers
II	1 – 13	LEAN CLAY (CL), soft to very stiff, dark brown, reddish brown, brownish yellow, light gray, dark gray, with root fibers to 4', sands
III	13 – 20	SILTY SAND (SM), medium dense, light brown, light gray

* Classification in general accordance with the Unified Soil Classification System (ASTM D 2487)

4.3 Soil Properties

Soil strength and index properties and how they relate to foundation design are summarized below:

Stratum No.	Soil Type	PI(s)	SPT	Soil Expansivity	Soil Shear Strength, tsf	Remarks
I	Sandy Silt (ML)	–	–	Non-Expansive	–	Moisture Sensitive
II	Lean Clay (CL)	26 – 30	–	Moderately Expansive	0.15 – 1.50	–
III	Silty Sand (SM)	–	24 – 29	Non-Expansive	–	Moisture Sensitive

Legend: PI = Plasticity Index
SPT = Standard Penetration Tests

4.4 Water-Level Measurements

The soil borings were dry augered to evaluate the presence of perched or free-water conditions. The level where free water was encountered in the open borehole during the time of our field exploration is shown on the boring logs. Our groundwater measurements are as follows:

Boring Number	Groundwater Depth, ft. at the time of Drilling	Groundwater Depth, ft. at 0.33 Hour Later
B-1 and B-2	Dry	Dry

Fluctuations in groundwater generally occur as a function of seasonal moisture variation, temperature, groundwater withdrawal and future construction activities that may alter the surface and subdrainage characteristics of this site.

An accurate evaluation of the hydrostatic water table in the relatively impermeable clays and low permeable sands/silts requires long term observation of monitoring wells and/or piezometers. It is not possible to accurately predict the pressure and/or level of groundwater that might occur based upon short-term site exploration. The installation of piezometers/monitoring wells was beyond the scope of our study. We recommend that the groundwater level be verified just before construction if any excavations such as construction of drilled footings/underground utilities, etc. are planned.

We recommend that GET be immediately notified if a noticeable change in groundwater occurs from that mentioned in our report. We would be pleased to evaluate the effect of any groundwater changes on our design and construction sections of this report.

5.0 POTENTIAL VERTICAL MOVEMENT

A review of the subsoil conditions indicates the presence of expansive soils. The floating slab type foundation, if used, will experience heave. Foundations experiencing tilt as opposed to differential movements will not experience significant distress. Tilt is defined as a planar rotation, measured over the length or width of foundation.

We computed the potential vertical rise (PVR, Ref. 1) at this site. A PVR of about 1.5-inch can be expected during the life of the structure. Additional information on differential movements or tilt can be obtained from Foundation Performance Association Publication “Guidelines for the Evaluation of Foundation Movements for Residential and other Low-Rise Buildings”, (Ref. 2).

A review of American Society of Civil Engineers Guidelines for the Evaluation and Repair of Residential Foundations (Ref. 3) indicates slope of greater than one percent is usually noticeable. The Americans with Disabilities Act considers a two percent slope too large. Slope is defined as differential elevation (rise) between two points divided by the horizontal distance (run) between them.

Foundation tilt can be reduced if several feet of on-site expansive soils are removed and replaced with select structural fill. Alternatively, the select structural fill can be placed on top of existing soils. Additional recommendation on foundation tilt can be developed, if requested.

6.0 FOUNDATION RECOMMENDATIONS

6.1 Foundations and Risks

Many lightly loaded foundations are designed and constructed on the basis of economics, risks, soil type, foundation shape and structural loading. Many times, due to economic considerations, higher risks are accepted in foundation design. We recommend that the builder and architect/designer discuss foundations and risks with the owner. The proper foundation system should then be selected by the owner after all risks are discussed. It should be noted that some levels of risk are associated with all types of foundations and there is no such thing as a zero risk foundation. All of these foundations must be stiffened in the areas where expansive soils are present, and trees have been removed prior to construction. It should be noted that these foundations are not designed to resist soil and foundation movements as a result of sewer/plumbing leaks, excessive irrigation, poor drainage and water ponding near the foundation system. The following are the foundation types typically used in the area with increasing levels of risk and decreasing levels of cost:

FOUNDATION TYPE	REMARKS
Structural Slab with Piers or Helical Piles	This type of foundation (which also includes a pier and beam foundation with a void/crawl space) is considered to be a low risk foundation, provided it is built and maintained with positive drainage and vegetation control. A minimum space of four-inch or larger is required. Using this foundation, the floor slabs are not in contact with the subgrade soils. This type of foundation is particularly suited for the areas where expansive soils are present and where trees have been removed prior to construction. The drilled footings must be placed below the potential active zone to reduce potential drilled footing upheaval due to expansive clays. In the areas where non-expansive soils are present, spread footings can be used instead of drilled footings.
Slab-On-Fill Foundation Supported on Piers or Helical Piles	This foundation system is also suited for the area where expansive soils are present. This system has some risks with respect to foundation distress and movements, where expansive soils are present. However, if positive drainage and vegetation control are provided, this type of foundation should perform satisfactorily. The fill thickness is evaluated such that once it is combined with environmental conditions (positive drainage, vegetation control) the potential vertical rise will be reduced. The structural loads can also be supported on spread footings if expansive soils are not present.
Floating (Stiffened) Slab Supported on Piers. The Slab can either be Conventionally-Reinforced or Post-Tensioned	The risk on this type of foundation system can be reduced if it is built and maintained with positive drainage and vegetation control. Due to presence of piers, the slab cannot move down. However, if expansive soils are present, the slab may move up, behaving like a floating slab. In this case, the steel from the drilled piers should not be dowelled into the grade beams. The structural loads can also be supported on spread footings if expansive soils are not present.
Floating Super-Structural Slab Foundation (Conventionally-Reinforced or Post-Tensioned Slab)	The risk on this type of foundation system can be reduced if it is built and maintained with positive drainage and vegetation control. No piers are used in this type of foundation. Many of the lightly-loaded structures in the state of Texas are built on this type of foundation and are performing satisfactorily. In the areas where trees have been removed prior to construction and where expansive clays exist, these foundations must be stiffened to reduce the potential differential movements as a result of subsoil heave due to tree removal. The advantage of this foundation system is that as long as the grade beams penetrate a minimum of six-inch into the competent natural soils or properly compacted structural fill, no compaction of subgrade soils is required. The subgrade soils should, however, be firm enough to support the floor slab loads during construction. The structural engineer should design the floor slabs such that they can span in between the grade beams. The subsoils within which the grade beams are placed must have a minimum shear strength of 1000 psf and a minimum degree of compaction of 95 percent standard Proctor density (ASTM D 698) at a moisture content between optimum and +3% of optimum moisture content.
Floating Slab Foundation (Conventionally-Reinforced or Post-Tensioned Slab)	The risk on this type of foundation can be reduced if it is built and maintained with positive drainage and vegetation control. No piers are used in this type of foundation. Many of the lightly-loaded structures in the state of Texas are built on this type of foundation and are performing satisfactorily. In the areas where trees have been removed prior to construction and where expansive clays exist, these foundations must be stiffened to reduce the potential differential movements as a result of subsoil heave due to tree removal. However, foundation tilt can still occur even if the foundation system is designed stiff.

The above recommendations, with respect to the best foundation types and risks, are very general. The best type of foundation may vary as a function of structural loading and soil types. For example, in some cases, a floating slab foundation may perform better than a drilled footing type foundation. More information regarding foundations and risks can be found at the **Foundation Performance Association Document #FPA-SC-01-0** (Ref. 2).

6.2 Foundation Type

Foundations for the proposed addition should satisfy three independent design criteria. First, the maximum design pressure exerted at the foundation level should not exceed allowable net bearing pressure based on an adequate factor of safety with respect to soil shear strength. Secondly, the magnitude of total and differential settlements under sustained foundation loads must be such that the structure is not damaged or its intended use impaired. Thirdly, the footings should resist uplift loads due to presence of expansive soils.

We understand that the proposed structural loads will be supported on either deep foundations or shallow foundations. The deep foundation may consist of driller footings or helical piles. The shallow foundation may consist of a floating slab foundation.

The use of drilled footings at this site may be expensive due to presence of cohesionless soils and soft cohesive soils. **Drilled footings should be constructed, using a slurry method of construction.** This may make drilled footings more expensive than helical piles. The structural engineer may want to design the foundation system using helical piles, in addition to the drilled footings. There should be cost comparison between drilled footings, using a slurry method of construction and helical piles.

The decision as to what foundation type to be used should be made by the structural engineer, homeowner or the builder. Our recommendations for these foundation types are presented in the following report sections.

6.3 Drilled Footings Type Foundation

6.3.1 Depth and Allowable Bearing Pressure

Drilled footing foundation for the proposed residence should satisfy the three independent design criteria, as specified in Section 6.2 of this report. Specifically, the drilled footings should resist uplift due to the presence of expansive soils. Drilled footings should be embedded in the anchor zone as shown on Plate 6. The piers placed in the anchor zone will resist uplift loads due to expansive soils.

Based on the results of field exploration, laboratory testing and bearing capacity theory, allowable loads for drilled footings will be as follows:

Foundation Type	Depth, ft. (1)	Allowable Net Bearing Pressure, psf		Allowable Skin Friction Below 10-ft, psf
		Dead Load (2)	Total Load (Dead + Live)	
Drilled Footings:				
Underreams/ Straight Shafts	12	4,000	6,000	300

Notes: 1. With respect to existing grade
2. Dead load + sustained live load

Foundations proportioned in accordance with these values will have a factor of safety of 3.0 and 2.0 with respect to shearing failure for dead and total loading, respectively. Footing weight below final grade can be neglected in the determination of design loading. The allowable skin friction includes a safety factor of 2.0. We recommend that straight shafts be founded at least three shaft diameters away from each other to minimize group effect.

In order to develop the recommended bearing pressures and to control settlement, the drilled footings must satisfy the following two requirements. First, the maximum drilled footing bell diameter (or shaft diameter, in case of straight shafts) should be limited to one half of drilled footing depth. Secondly, a minimum clearance of one bell diameter (or shaft diameter, in case of straight shafts) should be provided between the drilled footings. If a clearance of one diameter cannot be maintained in every case, the above bearing capacities should be reduced by 20 percent for a clearance between one-half and one bell diameter (or shaft diameter, in case of straight shafts). Drilled footings closer than a clearance of one half of bell diameters (or shaft diameter, in case of straight shafts) are not recommended.

Based on the field and laboratory testing data, it is our opinion that the drilled footings should be designed and constructed as follows:

- The recommended bell to shaft ratio is 2.5:1.
- In case of borehole sloughing, use a straight shaft type foundation.
- Based on our current groundwater observations, the drilled footing excavations may not encounter groundwater. Any water inflow must be pumped out immediately using a sump-pump. The drilling contractor must be prepared for this condition.
- Due to (a) presence of cohesionless soils and soft cohesive soils, (b) potential seasonal variations in groundwater depth, (c) variations in the subsoils stratigraphy and strengths, and (d) corresponding potential caving problems, **a slurry method of construction will be required for the drilled footings installations**.

Due to the potential variability of the on-site soils and potential groundwater fluctuations, we recommend that the four corner piers be drilled first to better evaluate the constructability of the drilled footings recommended herein. Once this information is field verified, all other piers need to be constructed accordingly.

We recommend placement of tension steel in the drilled footings to resist uplift loads due to expansive soils. This item is discussed in following report section.

6.3.2 Uplift Force Due to Expansive Soils

Due to the presence of expansive soils, uplift force will be developed on perimeter of the drilled footing shaft within the active zone. This load is resisted by the weight of the structure as well as the weight of the drilled footings. The uplift force (Ref. 4) can be estimated using the following equation:

$$Q_u = 0.79 \times D_s \times z_a \times \sigma_s$$

Where: Q_u = Uplift force, ton
D_s = Pier shaft diameter, feet
z_a = Depth of active zone, feet
σ_s = Swelling pressure, tsf

Based on the on-site soil properties, an active zone depth of 10-ft and a swell pressure of 0.8 tsf can be applied to estimate uplift force due to on-site expansive soils.

6.3.3 Recommended Drilled Footings Reinforcement

We recommend placement of tension steel in the drilled footings to resist uplift loads. The minimum percent steel can be estimated (Ref. 5) using the following equation:

$$A_s(\%) = -0.03 \times \frac{(Q_w - Q_u)}{D_s^2}$$

Where: A_s = Minimum steel, percent
Q_w = Loading force from the structure and include the weight of the pier, ton
Q_u = Uplift force, ton
D_s = Pier shaft diameter, feet

We assume Q_u is larger than Q_w in the above equation. A minimum percent steel A_s of 1 percent of the concrete area is recommended in design. We recommend steel to meet ASTM 615 Grade 60 Reinforcing. The steel should extend from the bottom to the top of the drilled footings.

6.4 Helical Pile

The structural loads can also be supported on a helical pile system founded at a minimum depth of 20-ft below the existing grade. The helical pile system should be designed on the basis of design procedure, outlined in the "Basic Helical Screw Pile Design," (Ref. 7)

In general, the cost of Helical Pile System will be less than the cost of drilled footings, installed using casing or slurry method of construction. Furthermore, the construction time is significantly reduced. Further 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 pile capacity can be computed from the following:

$P = \Sigma A_H (9c)$ Piles in Clays

$P = \Sigma A_H (qN_q)$ Piles in Sands

Where: P = Ultimate Pile Capacity, lbs
ΣA_H = Sum of Helical Plate Areas, ft^2
c = Cohesion of Soil, psf
$q = \gamma h/2$ = Soil Overburden Pressure to Mid-Plate Depth, psf
γ = Soil Unit Weight of 60 pcf
h = Depth of Helical Piles, ft
N_q = Bearing Capacity Factor for Granular Soil

A factor of safety of 2.0 is recommended in calculating ultimate helical piles capacity. 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 inside a 12-inch diameter, 20-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.

We recommend the following designparameters (Ref. 10) for this project:

c = 2,000 psf
k = 80 pci
$N_q = 15$

The helical pile should be designed to resist the "punch-through" failure in areas where soft soils encounter 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.

Some of the helical pile contractors are as follows:

Company Name	Telephone No.	Contact Person
Ram Jack Foundations	713-599-0102	Mr. Brian Buchanan
R.L. Nelson Construction Foundation Repair	713-473-2382	Ms. Ann Nelson
Rock Solid Helical Pile, LLC	713-417-9053	Mr. Ward Taylor
Du-West Foundation Repair	713-473-7156	Mr. Jim Dutton
Olshan Foundation Repair	713-213-1900	Mr. Chris Cates

6.5 Floor Slabs Supported on Drilled Footings or Helical Piles

6.5.1 General

The floor slabs may consist of a structural slab with a void space or a slab-on-fill supported on drilled footings or helical piles. The decision as to what type of floor slab to use should be in accordance with our recommendations in the Foundations and Risks Section of this report, presented earlier.

6.5.2 Structural Slab on Drilled Footings or Helical Piles

This type of floor slab is highly recommended on sites with expansive soil. In the event that a void space is used, we recommend a minimum void space of about four-inch under the floor slabs. In the event that a crawl space is used, we recommend that (a) positive drainage be maintained in the crawl space area at all times, and (b) the area in the crawl space be properly vented.

6.5.3 Slab-On-Fill with Drilled Footings or Helical Piles

The project site has the potential for construction problems related to the presence of surficial sandy silt soils. These permeable surficial soils are underlain by relatively impermeable clay soils. Thus, due to poor site drainage, wet season or site geohydrology, water ponds on the clays soils and creates a "perched water table condition". The surficial sandy silt soils become extremely soft when wet. Sometimes this condition may result in moisture migration (vapor) through the foundation slab. We recommend removing the surficial sandy silt soils (Stratum I) and replacing it with select structural fill. The structural fill should extend five-ft beyond the structure footprint in accordance with our "Site Preparation" section.

We recommend that the floor slabs be separated from the on-site expansive soils using 36 inches of uniform thickness of select structural fill. The select structural fill should extend at least 5-ft beyond the footprint of the structure. It should be noted that bank sands should not be used as structural fill in the floor slab area. The fill thickness must be verified after the completion of the building pad.

We recommend that the upper eight-inch of subgrade soils in the floor slab areas be compacted to at least 95% standard density (ASTM D 698) at a moisture content between optimum and +3% of optimum.

A bedding layer of leveling sand, one- to two-inches in thickness, may be planned under the slab for leveling purposes only. A layer of high-performance polyethylene moisture barrier should be used above the sands to prevent moisture migration through the slab.

6.6 Void Spaces

Void spaces under the grade beams and floor slabs are used to provide a void space in between the foundation and the on-site expansive soils. Void spaces should collapse when underlying expansive soils heave; therefore, the load from expansive soil heave will not be transmitted to the foundation system. Some void spaces will not collapse; however, they will allow the expansive soils to heave into them. There is also degradable void spaces (carton form) system. The carton forms degrade as they absorb moisture, leaving void between the foundation system and the expansive soils.

During the past 30 years, there have been a lot of discussions about the use of void spaces under the grade beams. Experience has shown that void spaces may create a path for water to get into the grade beam excavations and allow the water to get into the interior of the slab, causing heaving of the expansive subsoils. This water may come from surface drainage (poor drainage), sprinkler system leak, plumbing leak, underground utility leak, etc.

We recommend the use of void spaces under the floor slabs when a structural slab foundation with void is going to be used. Furthermore, a void space of four-inch is recommended. The decision on whether or not to put void spaces under grade beams should be made by the owner after discussions with the structural engineer, builder, or the architect about the risks associated with the placement of void spaces under the grade beams.

Additional information regarding specifications and application of void spaces below concrete foundations can be obtained from **Foundation Performance Association Document #FPA-SC-11-0** (Ref. 2).

6.7 Floating Slab Foundation

We understand that the structural loads could be supported either on a post-tensioned slab type foundation (Ref. 6) or a conventionally reinforced slab (Ref. 7). Our recommendations for the design of conventionally reinforced slab or post-tensioned slabs are in general accordance with the PTI DC10.1-08, Third Edition with 2008 supplement (Ref. 6). Our recommendations for conventionally reinforced slab as well as the post-tensioned slab are presented below:

Minimum Grade Beam Depth Below the Final Grade	:	1.5-ft
Minimum Grade Beam Width	:	10-inch
Allowable Net Bearing Capacity Total (Dead + Live) Loading Dead + Sustained Live Loads	 : :	 1,350 psf 900 psf
Slab Subgrade Coefficient Slab-on-Vapor Sheeting over Sand	 :	 0.75
Depth of Deepest Root Fibers	:	4-ft
Edge Moisture Variation, e_m, feet Edge Lift Center Lift	 : :	 4.8 8.0
Differential Swell, y_m, inches Edge Lift Center Lift	 : :	 1.2 1.4
Effective Plasticity Index (PI)	:	30
Structural Fill Type	:	See Site Preparation Section
The Required Minimum Fill Undrained Shear Strength	:	1,000 psf
Support Index	:	0.91
Climatic Rating	:	26
Thornthwaite Moisture Index	:	18
Design Suction Profile	:	Post-Equilibrium
Potential Vertical Rise (PVR)	:	1.5-inch

Grade beams proportioned in accordance with the above bearing capacity values will have a factor of safety of 3.0 and 2.0 with respect to shearing failure for dead and total loadings, respectively. Footing weight below final grade can be neglected in the determination of design loading.

The allowable grade beam bearing pressures for the post-tensioned slab foundations in the area should be reduced by 50 percent if the surficial sandy silt soils become saturated during the life of the structure.

The differential movement values presented in this report are based on climate-controlled soil conditions and are not valid when influenced by significant other conditions, such as trees, poor drainage, slope, cut and fill sections, etc. Due to the presence of expansive soils on the site, we recommend the floating slabs be stiffened such that minimum differential movements occur once a portion of the slab is lifted as a result of tree removal and expansive soils. The foundation system may experience tilt if designed as a stiff slab.

The project site has the potential for construction problems related to the presence of surficial sandy silt soils. These permeable surficial soils are underlain by relatively impermeable clay soils. Thus, due to poor site drainage, wet season or site geohydrology, water ponds on the clays soils and creates a "perched water table condition". The surficial sandy silt soils become extremely soft when wet. Sometimes this condition may result in moisture migration (vapor) through the foundation slab. We recommend removing the surficial sandy silt soils (Stratum I) and replacing it with select structural fill. The structural fill should extend five-ft beyond the structure footprint in accordance with our "Site Preparation" section.

A bedding layer of leveling sand, one- to two-inch in thickness, may be placed beneath the floor slab. A layer of high-performance polyethylene moisture barrier should be used above the sands to prevent moisture migration through the slab. The excavations for the grade beams should be free of loose materials prior to concrete placement.

Information was not available on whether fill will be used to raise site grade prior to slab construction. In the event that fill is placed on the site, specifications should require placement in accordance with our recommendations given in the "Site Preparation" section. Lack of proper site preparation may result in additional stress and inferior slab performance. The on-site soils, with the exception of sand sand silts (if available), free of root organics, can be used as fill, under a floating slab foundation. Sands should not be used as fill materials at this site (with the exception of top two-inches of leveling sand under the slab).

6.8 Foundation Settlement

A settlement analysis was not within the scope of this study. It is anticipated that footings, grade beams and slabs designed using the recommended allowable bearing pressures will experience small settlements that will be within the tolerable limit for the proposed residence.

6.9 Vegetation Control

6.9.1 Existing Trees

Tree roots tend to desiccate the soils. In the event that a tree has been removed prior to building construction, during the useful life of the structure, or if a tree dies, subsoil swelling may occur in the expansive soil areas for several years. Studies (Ref. 8) have shown that this process can take an average of five years in the area where highly expansive clays are present. Depending on availability of water, this time period could be shorter or longer. In this case, the foundation for the structure should be designed for the anticipated maximum heave. Furthermore, the drilled footings, if used, must be placed below the zone of influence of tree roots. In the event that a floating slab foundation is used, we recommend the slab be stiffened to resist the subsoil movements due to the presence of trees. 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 faster in the areas that poor drainage, excessive irrigation or plumbing/sewer leak is occurring.

The effects of trees on foundations are covered with much more detail in the recommended Homeowner Foundation Maintenance Program for Residential Projects document at the end of this report.

6.9.2 New Trees

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 barriers must be placed near the exterior grad ebeams to minimize tree root movements under the floor slab. This will minimize possible foundation movements as a result of tree root systems.

6.10 Foundation Maintenance

Long term performance of structures depends not only on the proper d esignand construction, but also on the proper foundation maintenance program.

A properly designed and constructed foundation may still experience distress from the vegetation and expansive soil which will undergo volume change when correct drainage is not established or incorrectly controlled water source, such as plumbing/sewer leaks, excessive irrigation, and water ponding near the foundation becomes available.

Our general recommendations on foundation maintenance are presented in the article at the end of this report. More foundation maintenance information can be found at **Foundation Performance Association Document #FPA-SC-07-0** (Ref. 2).

6.11 Site Drainage

It is recommended that site drainage be well developed. Surface water should be directed away from the foundation soils (use a slope of about 5% in the grass within 10-ft of foundation). No ponding of surface water should be allowed near the structure.

In the event that sprinkler systems are used, we recommend that the sprinkler system be placed all around the structure to provide a uniform moisture condition throughout the year. This will red ucefluctuations in subsoil moisture and corresponding movement.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 General

Our recommendations for the construction and maintenance of the post-tensioned slab foundations should be in accordance with the procedures presented in the publication "Construction and Maintenance Procedures Manual for Post-Tensioned Slabs-on-Ground" (Ref. 9).

7.2 Site Preparation

The project site has the potential for construction problems related to the surficial layer of sandy silt soils. These permeable surficial soils are underlain by relatively impermeable clay soils. Thus, due to poor site drainage, wet season or site geohydrology, water ponds on the clays soils and creates a "perched water table condition". The surficial sandy silt soils could become extremely soft when wet, and must be stabilized, aerated, or replaced. In the event that the sandy silt soils become wet, they will experience rutting and pumping. Therefore, these soils may have to be improved. Our recommendations on subgrade improvements are presented in the earthwork section of this report. Our site preparation recommendations are presented below:

1. In general, remove all vegetation, tree roots, organic topsoil, existing foundations, paved areas and any undesirable materials from the construction area. Tree trunks and tree roots under the floor slabs should be removed to a root size of less than 0.5-inch. We recommend that the stripping depth be evaluated at the time of construction by a soil technician.

2. Any on-site fill soils, encountered in the structure and pavement areas during construction, must have records of successful compaction tests signed by a licensed professional engineer that confirms the use of the fill and record of construction and earthwork testing. These tests must have been performed on all the lifts for the entire thickness of the fill. In the event that no compaction test results are available, the fill soils must be removed, processed and recompacted in accordance with our site preparation recommendations. Excavation should extend at least two-feet beyond the structure and pavement area. Alternatively, the existing fill soils should be tested comprehensively to evaluate the degreeof compaction in the fill soils.

3. The subgrade areas should then be proofrolled with a loaded dump truck or similar pneumatic-tired equipment with loads ranging from 25- to 50-tons. The proofrolling serves to compact surficial soils and to detect any soft or loose zones. The proofrolling should be conducted in accordance with TxDOT Standard Specification Item 216. Any soils deflecting excessively under moving loads should be undercut to firm soils and recompacted. Any subgrade stabilization should be conducted after site proofrolling is completed and approved by the geotechnical engineer. The proofrolling operations should be observed by an experienced geotechnician.

4. Scarify the subgrade, add moisture, or dry if necessary, and recompact to 95% of the maximum dry density as determined by ASTM D 698 (Standard Proctor). The moisture content at the time of compaction of subgrade soils should be between optimum and +3% of the Proctor optimum value. We recommend that the degree of compaction and moisture in the subgrade soils be verified by field density tests at the time of construction. We recommend a minimum of four field density tests per lift or one every 2500 square feet of floor slab areas, whichever is greater.

5. Structural fill beneath the building area may consist of off-site inorganic lean clays with a liquid limit of less than 40 and a plasticity index between 12 and 20. Other types of structural fill available locally, and acceptable to the geotechnical engineer, can also be used.

   These soils should be placed in loose lifts not exceeding eight-inches in thickness and compacted to 95 percent of the maximum dry density determined by ASTM D 698 (Standard Proctor). The moisture content of the fill at the time of compaction should be between optimum and +3% of the optimum value. We recommend that the degree of compaction and moisture in the fill soils be verified by field density tests at the time of construction. We recommend that the frequency of density testing be as stated in Item 4.

6. The backfill soils in the trench/underground utility and root excavation areas should consist of select structural fill, compacted as described in Item 4. In the event of compaction difficulties, the trenches should be backfilled with cement-stabilized sand or other materials approved by the Geotechnical Engineer. Due to high permeability of sands and potential surface water intrusion, bank sands should not be used as backfill material in the foundation forms, trench/underground utility and tree root excavation areas.

7. In cut areas, the soils should be excavated to grade and the surface soils proofrolled and scarified to a minimum depth of six-inches and recompacted to the previously mentioned density and moisture content.

8. The subgrade and fill moisture content and density must be maintained until paving or floor slabs are completed. We recommend that these parameters be verified by field moisture and density tests at the time of construction.

9. In the areas where expansive soils are present, rough grade the site with structural fill soils to insure positive drainage. Due to high permeability of sands, sands should not be used for site grading where expansive soils are present.

10. We recommend that the site and soil conditions used in the structural design of the foundation be verified by the engineer's site visit after all of the earthwork and site preparation has been completed and prior to the concrete placement.

7.3 Suitability of On-Site Soils for Use as Fill

7.3.1 General

The on-site soils can be used as fill. There are typically three types of fill at a site. These fills can be classified as described in the following report sections.

7.3.2 Select Structural Fill

This is the type of fill that can be used under the floor slabs, paving, etc. These soils should consist of lean clays with liquid limit of less than 40 and plasticity indices between 12 and 20.

7.3.3 Structural Fill

This type of fill does not meet the Atterberg limit requirements for select structural fill. This fill should consist of lean clays or fat clays. They can be used under a floating slab foundation or paving.

7.3.4 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). Furthermore, these soils erode easily. Their use is not recommended under the floor slabs or pavements. They can be used in the planter areas at least 5-ft away from the structure. They can also be used for site grading outside the structure and pavement areas.

7.3.5 Use of On-Site Soils as Fill

The on-site soils can be used as fill materials as described below:

		Use as Fill			
Stratum No.[1]	Soil Type	Select Structural Fill	Structural Fill	General Fill	Notes
I	Sandy Silt (ML)	–	–	✓	2, 3
II	Lean Clay (CL)	–	✓	✓	2, 4
III	Silty Sand (SM)	–	–	✓	2, 3

Notes:
1. See soil stratigraphy and design conditions sections of this report for strata description.
2. All fill soils should be free of organics, roots, etc.
3. The on-site cohesionless soils are moisture sensitive and erode easily. These soils will pump when they get wet. Compaction difficulties will occur in these soils in a wet condition.
4. These soils, once lime modified (4% by dry weight), can be used as select structural fill.

7.4 Drilled Footings Installations

The drilled footings installations must be in accordance with the American Concrete Institute (ACI) Reference Specifications (Ref. 10) 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. 11).

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

Due to the potential variability of the on-site soils and potential groundwater fluctuations, we recommend that the four corner piers be drilled first to better evaluate the constructability of the depth and bell to shaft ratios recommended herein. Once this information is field verified, all other piers need to be constructed accordingly.

Detailed observations of pier construction should be required by a qualified engineering technician to assure 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.

7.5 Helical Pile Installations

Experience indicates that torque required to install a helical pile can be used to estimate its compressive capacity (Ref. 12). 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.

7.6 Earthwork

7.6.1 General

Difficult access and workability problems will most likely occur in the surficial sandy silt soils due to poor site drainage, wet season, or site geohydrology. Considering the soils stratigraphy, the construction of this project should be conducted during the dry season to avoid major earthwork problems. The subgrade soils should be improved if they become wet and experience pumping problems. This condition can be improved by (a) improving drainage, (b) opening up to dry up, (c) soil mixing, (d) removing and replacing with dry cohesive soils, or (e) chemically modifying or stabilizing the soils. These alternatives are discussed in the following report sections.

7.6.2 Improving Drainage

The project site drainage in the pumping soils can be accomplished by placing several shallow bleeder ditches (about 18-inches ±) in the surficial cohesionless soils. These bleeder ditches should be directed to a low area, such as a hole (detention pond) or another ditch in the lowest elevation area of the site. This will allow the surficial cohesionless soils to drain the water and make the drying process faster. The hole/low area should not be under the building areas. The excess water can be pumped out of the hole and moved off-site.

7.6.3 Subgrade Drying

The on-site wet soils can be opened up so that it would dry up. However, opening up the surficial cohesionless soils for drying purposes may not be practical, due to cyclic rainfall in the Gulf-Coast area.

7.6.4 Soil Mixing

The on-site cohesionless soils (sandy silt, Stratum I) can be mixed with on-site cohesive soils (lean clay, Stratum II) to reduce subgrade pumping. GET can do a mix design to come up with soil mix percentages, if this option is considered.

7.6.5 Removal and Replacement

The surficial cohesionless soils can be removed and replaced with select structural fill. The actual depth of removal and replacement should be evaluated in the field, but it should reach level of dry and stable subgrade. This procedure will include removal of the surficial cohesionless soils, proofrolling and compacting the subgrade soils to a minimum of 95 percent standard Proctor density (ASTM D 698). The site can then be backfilled with select structural fill, compacted to a minimum of 95 percent of standard Proctor density. The proofrolling should be in accordance with the site preparation section of this report. All of the fill soils should be placed and tested in accordance with the site preparation section of this report.

7.6.6 Modification/Stabilization

We recommend that the on-site cohesionless soils be modified (to dry up), using 5 to 10 percent fly ash by dry weight. The fly ash stabilization should be in accordance to Texas Department of Transportation (TxDOT) Specification, Item 265. The estimated amounts of fly ash per depth of modification are as follows:

Modification Depth, in.	Fly Ash Weight Range, lbs. per Square Yard	
	5%	10%
6	23	45
12	46	90
18	69	135
24	92	180

We recommend that five percent fly ash be used if the surficial soils are relatively moist at the time of application. Higher levels (10 percent) of fly ash should be used if wet and soggy subgrade soils are encountered.

The subgrade soils should be removed to a depth of 24-inches (or more) below existing grade. These soils should be stockpiled. The soils below a depth of 24-inches should be modified to a depth of 12-inches. These soils should be compacted to a minimum of 95 percent of standard Proctor density (ASTM D 698). The stockpiled soils should then be modified and replaced in six-inch lifts and compacted to 95 percent of maximum dry density as determined by ASTM D 698 at moisture contents within ±2 percent of optimum.

Due to poor drainage and the depth of the cohesionless soils, the depth of stabilization may be as deep as depth of cohesionless soils. A test section can be implemented for this purpose. The subgrade soils should be modified in six-inch lifts and compacted within four hours of mixing and placement. All of the subgrade soils should be compacted to a minimum of 95 percent of the standard Proctor density at the moisture content with optimum. The degree of compaction for the lifts, below a depth of 24-inches can be relaxed to 90 percent of maximum dry density to ease the construction procedures.

The subcontractor who will be doing the subgrade modification or stabilization should be experienced with stabilization procedures and methods. Furthermore, all of the earthwork at this project should be monitored by our geotechnician to assure compliance with the project specifications.

Once the subgrade is constructed, the soils at the top of subgrade should be slicked and the subgrade needs to be crowned such that the all surface water would drain away. No low areas should be left within the subgrade areas, since these areas would hold water and destroy the subgrade structure.

7.7 Construction Surveillance

Construction surveillance and quality control tests should be planned to verify materials and placement in accordance with the specifications. The recommendations presented in this report were based on a discrete number of soil test borings. Soil type and properties may vary across the site. As a part of quality control, if this condition is noted during the construction, we can then evaluate and revise the design and construction to minimize construction delays and cost overruns. We recommend the following quality control procedures be followed by a qualified engineer or technician during the construction of the facility:

- Observe the site stripping and proofrolling.
- Verify the type, depth, and amount of stabilizer.
- Verify the compaction of subgrade soils.
- Evaluate the quality of fill and monitor the fill compaction for all lifts.
- Monitor and test the foundation excavations for, strength, cleanness, depth, size, etc.
- Observe the foundation make-up prior to concrete placement.
- Monitor concrete placement, conduct slump tests and make concrete cylinders.
- Conduct after pour observations, including post-tensioned slab cable stress monitoring, if used.
- Monitor installation of drilled footings or helical piles, if used.

- Conduct after construction site visit to evaluate the site landscaping, drainage and the presence of trees near the structure.

It is the responsibility of the client, to notify GET of when each phase of the construction is taking place so that proper quality control and procedures are implemented. More information regarding construction quality control can be found at the **Foundation Performance Association Documentation #FPA-SC-10-1** (Ref. 2).

8.0 RECOMMENDED ADDITIONAL STUDIES

We recommend the following additional studies be conducted:

1. This report has been based on assumed conditions/characteristics of the proposed development where specific information was not available. It is recommended that the architect, civil engineer and structural engineer along with any other design professionals involved in this project carefully review these assumptions to ensure they are consistent with the actual planned development. When discrepancies exist, they should be brought to our attention to ensure they do not affect the conclusions and recommendations provided herein. We recommend that GET be retained to review the plans and specifications to ensure that the geotechnical related conclusions and recommendations provided herein have been correctly interpreted as intended.

2. **Conduct site characterization studies.** These studies will include the following separate studies:

   - Phase I Geologic Fault Study to look for geologic faults at or near the site.
   - Phase I Environmental Site Assessment Study to evaluate the risk of contamination at the site.
   - Review aerial photos of the project site.
   - Review site topography.
   - Conduct a site visit to look for drainage features, slopes, seeps, trees and other vegetation; fence lines, ponds, stock tanks; areas of fill, etc.

3. We recommend obtaining baseline micro-elevations of the floor slabs after floor covering is installed. This information will be valuable in the event of future foundation movements.

9.0 STANDARD OF CARE

The recommendations described herein were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical engineering profession practicing contemporaneously under similar conditions in the locality of the project. No other warranty or guarantee, expressed or implied, is made other than the work was performed in a proper and workmanlike manner.

10.0 REPORT DISTRIBUTION

This report was prepared for the sole and exclusive use by our client, based on specific and limited objectives. All reports, boring logs, field data, laboratory test results, maps and other documents prepared by GET as instruments of service shall remain the property of GET. Reuse of these documents is not permitted without written approval by GET. GET assumes no responsibility or obligation for the unauthorized use of this report by other parties and for purposes beyond the stated project objectives and work limitations.

We appreciate the opportunity to assist on this project. Please call if there should be any questions.

Very truly yours.

GEOTECH ENGINEERING AND TESTING
TBPE Registration Number F-001183

Vincent Yin, M.S. Geology
Project Manager

STATE OF TEXAS
DAVID A. EASTWOOD
51419
LICENSED
PROFESSIONAL ENGINEER

Harry Nguyen, PhD. E.I.T.
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David A. Eastwood
1/12/21

David A. Eastwood, P.E., D.GE, DFE, C.A.P.M., F. FPA, F. ASCE.
Principal Engineer

VY/HN/DAE/vy

Copies Submitted: (1) Hard Copy – Tetra Tech – Mr. Jake Wimberley
(1) PDF Copy Email – Mr. Jake Wimberley

11.0 ILLUSTRATIONS

12.0 REFERENCES

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2. Committee Papers from Foundation Performance Association (FPA), see FPA Website: http://www.foundationperformance.org/committee_papers.cfm.

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6. "Design of Post-Tensioned Slab-on-Ground", Post-Tensioning Institute, Phoenix, Arizona, Third Edition with 2008 Supplement, 2008.

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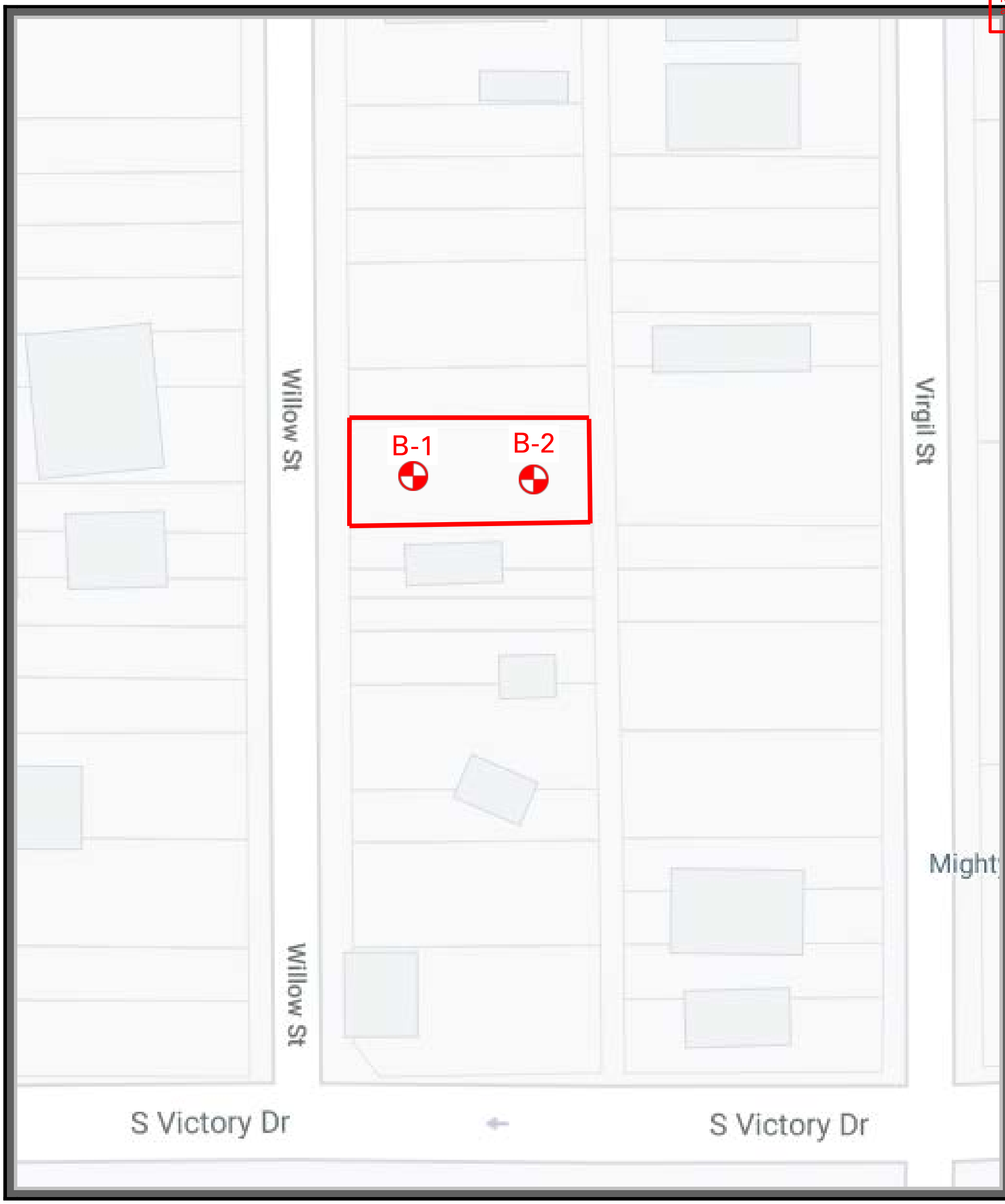
9. "Construction and Maintenance Procedures Manual for Post-Tensioned Slabs-on-Ground", 2nd Edition, Post-Tensioning Institute, Phoenix, Arizona, September 1998.

10. "Reference Specifications for the Construction of Drilled Piers (ACI 336.1) and Commentary (ACI 336.1R-98)", American Concrete Institute, Farmington Hills, Michigan.

11. Federal Highway Administration, US-DOT "Drilled Shafts; Construction Procedures and Design Methods", Publication FHWA-IF-99-025, September 2010.

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



PLAN OF BORINGS (boring locations are approximate)

PROJECT: G/S for Proposed Residence at 7802 Willow Street
Houston, Texas

SCALE: NOT TO SCALE	DATE: JANUARY 2021	PROJECT NO.: 20-1120E

NORTH

LOG OF BORING NO. B-1

Sheet

GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for Proposed Residence at 7820 Willow Street
LOCATION: Houston, Texas
PROJECT NO.: 20-1120E STATION NO.:
DATE: 12-30-20 COMPLETION DEPTH: 20.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			SANDY SILT (ML), dark brown, dark gray, with root fibers	17				53				
1			LEAN CLAY (CL), soft, dark gray, dark brown, with root fibers to 4', sands									
4			- very stiff, light gray 4' to 10', reddish brown 4' to 6'									
6			- brownish yellow 6' to 10'									
9				18	48	18	30					
13			SILTY SAND (SM), medium dense, light brown, light gray									
14	26											
19	29											

UNDRAINED SHEAR STRENGTH, tsf
▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL
0.5 1.0 1.5 2.0 2.5

WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 20 ft.
WET ROTARY: ___ TO ___ ft.

DRILLED BY: GET (T)
LOGGED BY: Daniel

OVM2 20-1120E.GPJ OVM.GDT 1/5/21

City of Houston
21119664
REVIEWED FOR COMPLIANCE
Performance of this review does not relieve the applicant from full responsibility to comply with all applicable code and regulations.
05/10/22

LOG OF BORING NO. B-2

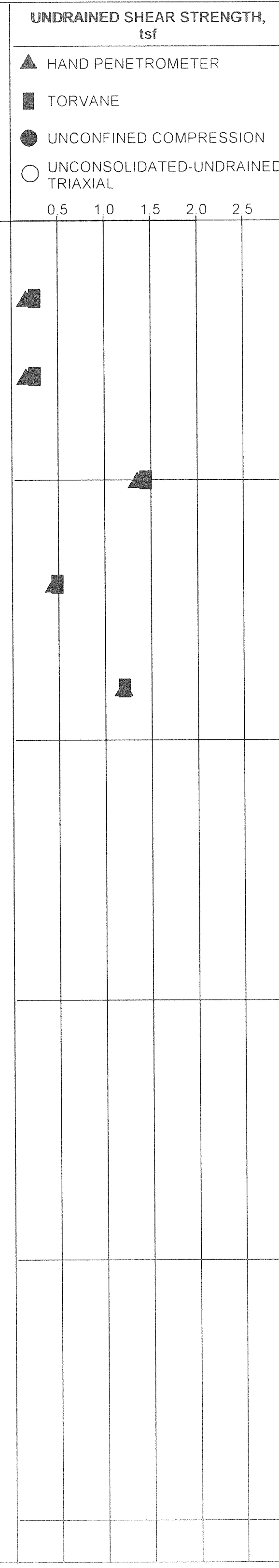
Sheet

GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for Proposed Residence at 7820 Willow Street
LOCATION: Houston, Texas
PROJECT NO.: 20-1120E STATION NO.:
DATE: 12-30-20 COMPLETION DEPTH: 20.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			SANDY SILT (ML), dark brown, dark gray, with root fibers									
			LEAN CLAY (CL), soft, dark gray, dark brown, with root fibers to 4', sands									
			- very stiff 4' to 6', brownish yellow, light gray 4' to 10'									
5				16	44	18	26					
			- firm 6' to 8'									
			- very stiff 8' to 10'									
10												
			SILTY SAND (SM), medium dense, light brown, light gray									
	24											
15												
	25											
20												
25												



WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 20 ft.
WET ROTARY: ___ TO ___ ft.

DRILLED BY: GET (T)
LOGGED BY: Daniel

OVM2 20-1120E.GPJ OVM.GDT 1/5/21

KEY TO LOG TERMS AND SYMBOLS

UNIFIED SOIL CLASSIFICATIONS

Symbol	Material Descriptions
GW	WELL GRADED-GRAVELS, GRAVEL-SAND MIXTURES LITTLE OR NO FINES
GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM	SILTY GRAVELS, GRAVEL-SAND SILT MIXTURES
GC	CLAY GRAVELS, GRAVEL-SAND CLAY MIXTURES
SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP	POORLY GRADED SANDS, OR GRAVELLY SANDS, LITTLE OR NO FINES
SM	SILTY SANDS, SAND-SILT MIXTURES a
SC	CLAYEY SANDS, SAND-SILT MIXTURES b
ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENT
	FILL SOILS

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	-	Having incline planes of weakness that are slick and glossy in appearance.
Fissured	-	Containing shrinkage cracks frequently filled with fine sand or silt: usually vertical.
Laminated	-	Composed of thin layers of varying colors and soil sample texture.
Interbedded	-	Composed of alternate layers of different soil types.
Calcareous	-	Containing appreciable quantities of calcium carbonate.
Well Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly Graded	-	Predominantly of one grain size, or having a range of sizes with some intermediate sizes missing.
Pocket	-	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	-	Inclusion less than ⅛-inch thick extending through the sample.
Seam	-	Inclusion ⅛- to 3-inch thick extending through the sample.
Layer	-	Inclusion greater than 3-inch thick extending through the sample.
Interlayered	-	Soils sample composed of alternating layers of different soil types.
Intermixed	-	Soil samples composed of pockets of different soil type and layered or laminated structure is not evident.

COARSE GRAINED SOILS (major portion retained on No. 200 Sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Conditions rated according to standard penetration test (SPT)* as performed in the field.

Descriptive Terms	Blows Per Foot*
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 – 50
Very Dense	over 50

* 140 pound weight having a free fall of 30-inch

FINE GRAINED SOILS (major portion passing No. 200 Sieve): Include (1) inorganic or organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by hand penetrometer readings or by unconfined compression tests.

Descriptive Term	Undrained Shear Strength Ton/Sq. Ft.	Descriptive Term	Blows Per Foot*
Very Soft	Less than 0.13	Very Soft	< 2
Soft	0.13 to 0.25	Firm	2 – 8
Firm	0.25 to 0.50	Stiff	8 – 15
Stiff	0.50 to 1.00	Very Stiff	15 – 30
Very Stiff	1.00 to 2.00	Hard	> 30
Hard	2.00 or higher		

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above because of weakness or cracks in the soil. The consistency ratings of such soils are based on hand penetrometer readings.

* 140 pound weight having a free fall of 30-inch

SOIL SAMPLERS

- SHELBY TUBE SAMPLER
- STANDARD PENETRATION TEST
- AUGER SAMPLING

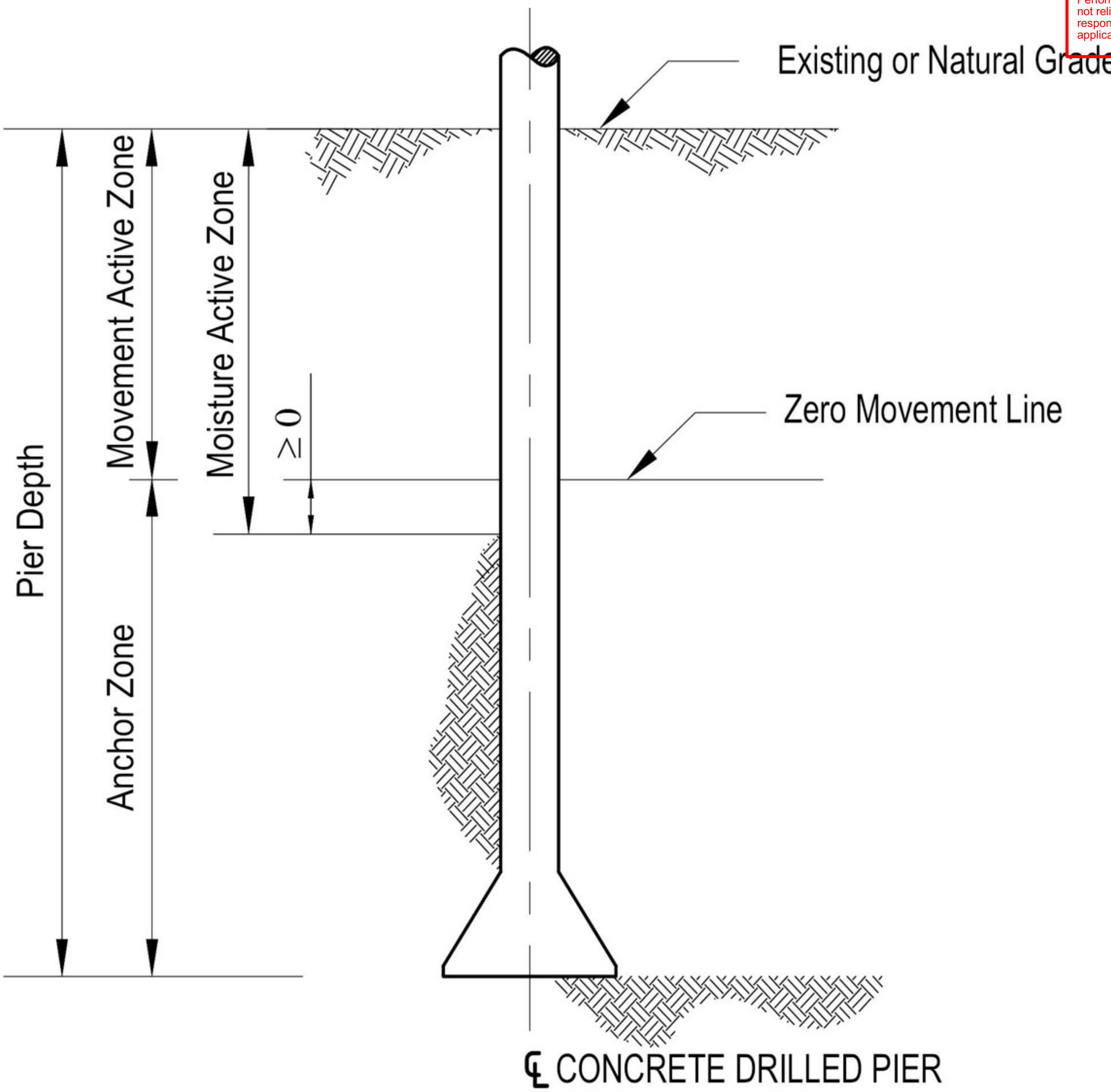
TERMS CHARACTERIZING ROCK PROPERTIES

VERY SOFT OR PLASTIC	Can be remolded in hand: corresponds in consistency up to very stiff in soils.
SOFT	Can be scratched with fingernail.
MODERATELY HARD	Can be scratched easily with knife; cannot be scratched with fingernail. Difficult to scratch with knife.
VERY HARD	Cannot be scratched with knife.
POORLY CEMENTED OR FRIABLE	Easily crumbled.
CEMENTED	Bounded Together by chemically precipitated materials.
UNWEATHERED	Rock in its natural state before being exposed to atmospheric agents.
SLIGHTLY WEATHERED	Noted predominantly by color change with no disintegrated zones.
WEATHERED	Complete color change with zones of slightly decomposed rock.
EXTREMELY WEATHERED	Complete color change with consistency, texture, and general appearance or soil.

PROJECT PICTURES
Project No. 20-1120E

Note: The above picture(s) indicate a snap shot of the project and the surroundings. We request that the client review the picture(s) and make sure that they represent the project area. We must be contacted immediately if any discrepancy exists.

DRILLED FOOTING DEPTH IN EXPANSIVE SOILS



Definition

Pier Depth: See the Drawing.

Moisture Active Zone: Depth of an active soil measured from the ground surface downward, wherein moisture fluctuations occur.

Movement Active Zone: Depth of an active soil measured from the ground surface downward where movement can occur due to volumetric moisture changes.

Zero Movement Line: The bottom of movement active zone.

Anchor Zone: Depth to anchor the footing such that it will be sufficient to resist uplift loads.

RECOMMENDED HOMEOWNER FOUNDATION MAINTENANCE PROGRAM FOR RESIDENTIAL PROJECTS IN THE HOUSTON AREA

BY

DAVID A. EASTWOOD, P.E.

02-16

Introduction

Performance of residential structures depends not only on the proper design and construction, but also on the proper foundation maintenance program. Many residential foundations have experienced major foundation problems as a result of owner's neglect or alterations to the initial design, drainage, or landscaping. This has resulted in considerable financial loss to the homeowners, builders, and designers in the form of repairs and litigation.

A properly designed and constructed foundation may still experience distress from vegetation and expansive soil which will undergo volume change when correct drainage is not established or incorrectly controlled water source becomes available.

The purpose of this document is to present recommendations for maintenance of properly designed and constructed residential projects in Houston. It is recommended that the builder submit this document to his/her client at the time that the owner receives delivery of the house.

Typical Foundations

Foundations for support of residential structures in the Houston area consist of pier and beam type foundation, spread footing foundation, conventionally reinforced slab, or a post-tensioned slab. A soils exploration must be performed before a proper foundation system can be designed.

General Soil Conditions

Variable subsoil conditions exist in the Houston Metro area. Highly expansive soils exist in the West University, Bellaire, Southwest Houston, Clear Lake, Friendswood, Missouri City, and First Colony areas.

Sandy soils with potential for severe perched water table problems as a result of poor drainage are present in the North and West Houston, including portions of Piney Point, Hedwig Village, The Woodlands, Kingwood, Atascocita, Cypresswood, Fairfield, etc.

A perched water table condition can occur in an area consisting of surficial silty sands or clayey sands underlain by impermeable clays. During the wet (rainy) season, water can pond on the clays (due to poor drainage) and create a perched water table condition. The sands become extremely soft, wet, and lose their load carrying capacity.

Drainage

The initial builder/developer site grading (positive drainage) should be maintained during the useful life of the residence. In general, a civil engineer develops a drainage plan for the whole subdivision. Drainage sewers or other discharge channels are designed to accommodate the water runoff. These paths should be kept clear of debris such as leaves, gravel, and trash.

In the areas where expansive soils are present, positive drainage should be provided away from the foundations. Changes in moisture content of expansive soils are the cause of both swelling and shrinking. Positive drainage should also be maintained in the areas where sandy soils are present.

Positive drainage is extremely important in minimizing soil-related foundation problems.

The homeowner’s berm the flowerbed areas, creating a dam between the berm and the foundation, preventing the surface water from draining away from the structure. This condition may be visually appealing but can cause significant foundation damage as a result of negative drainage.

The most commonly used technique for grading is a positive drainage away from the structure to promote rapid runoff and to avoid collecting ponded water near the structure which could migrate down the soil/foundation interface. This slope should be about 3 to 5 percent within 10-feet of the foundation.

Should the owner change the drainage pattern, he should develop positive drainage by backfilling near the grade beams with select fill compacted to 90 percent of the maximum dry density as determined by ASTM D 698-91 (standard proctor).

This level of compaction is required to minimize subgrade settlements near the foundations and the subsequent ponding of the surface water. The select fill soils should consist of silty clays and sandy clays with liquid limits less than 40 and plasticity index (PI) between 10 and 20. Bank sand or top soils are not a select fill. The use of Bank sand or top soils to improve drainage away from a house is discouraged; because, sands are very permeable. In the event that sands are used to improve drainage away from the structure, one should make sure the clay soils below the sands have a positive slope (3 - 5 Percent) away form the structure, since the clay soils control the drainage away from the house.

The author has seen many projects with an apparent positive drainage; however, since the drainage was established with sands on top of the expansive soils the drainage was not effective.

Depressions or water catch basin areas should be filled with compacted soil (sandy clays or silty clays not bank sand) to have a positive slope from the structure, or drains should be provided to promote runoff from the water catch basin areas. Six to twelve inches of compacted, impervious, non-swelling soil placed on the site prior to construction of the foundation can improve the necessary grade and contribute additional uniform surcharge pressure to reduce uneven swelling of underlying expansive soil.

Pets (dogs, etc.) sometimes excavate next to the exterior grade beams and created depressions and low spots in order to stay cool during the hot season. This condition will result in ponding of the surface water in the excavations next to the foundation and subsequent foundation movements. These movements can be in the form of uplift in the area with expansive soils and settlement in the areas with sandy soils. It is recommended as a part of the foundation maintenance program, the owner backfills all excavations created by pets next to the foundation with compacted clay fill.

Grading and drainage should be provided for structures constructed on slopes, particularly for slopes greater than 9 percent, to rapidly drain off water from the cut areas and to avoid ponding of water in cuts or on the uphill side of the structure. This drainage will also minimize seepage through backfills into adjacent basement walls.

Subsurface drains may be used to control a rising water table, groundwater and underground streams, and surface water penetrating through pervious or fissured and highly permeable soil. Drains can help control the water table in the expansive soils.

Furthermore, since drains cannot stop the migration of moisture through expansive soil beneath foundations, they will not prevent long-term swelling. Moisture barriers can be placed near the foundations to minimize moisture migration under the foundations. The moisture barriers should be at least five-feet deep in order to be effective.

Area drains can be used around the house to minimize ponding of the surface water next to the foundations. The area drains should be checked periodically to assure that they are not clogged.

The drains should be provided with outlets or sumps to collect water and pumps to expel water if gravity drainage away from the foundation is not feasible. Sumps should be located well away from the structure. Drainage should be adequate to prevent any water from remaining in the drain (i.e., a slope of at least 1/8 inch per foot of drain or 1 percent should be provided).

Positive drainage should be established underneath structural slabs with crawl space. This area should also be properly vented. Absence of positive drainage may result in surface water ponding and moisture migration through the slab. This may result in wood floor warping and tile unsticking.

It is recommended that at least six-inches of clearing be developed between the grade and the wall siding. This will minimize surface water entry between the foundation and the wall material, in turn minimizing wood decay.

Poor drainage at residential projects in North and West Houston can result in saturation of the surficial sands and development of a perched water table. The sands, once saturated, can lose their load carrying capacity. This can result in foundation settlements and bearing capacity failures. Foundations in these areas should be designed assuming saturated subsoil conditions.

In general, roof drainage systems, such as gutters or rain dispenser devices, are recommended all around the roof line when gutters and downspouts should be unobstructed by leaves and tree limbs. In the area where expansive soils are present, the gutters should be connected to flexible pipe extensions so that the roof water is drained at least 10-feet away from the foundations. Preferably the pipes should direct the water to the storm sewers. In the areas where sandy soils are present, the gutters should drain the roof water at least five-feet away from the foundations.

If a roof drainage system is not installed, rain-water will drip over the eaves and fall next to the foundations resulting in subgrade soil erosion, and creating depression in the soil mass, which may allow the water to seep directly under the foundation and floor slabs.

The home owner must pay special attention to leaky pools and plumbing. In the event that the water bill goes up suddenly without any apparent reason, the owner should check for a plumbing leak.

The introduction of water to expansive soils can cause significant subsoil movements. The introduction of water to sandy soils can result in reduction in soil bearing capacity and subsequent settlement. The home owner should also be aware of water coming from the air conditioning drain lines. The amount of water from the condensating air conditioning drain lines can be significant and can result in localized swelling in the soils, resulting in foundation distress.

Landscaping

General. A house with the proper foundation and drainage can still experience distress if the homeowner does not properly landscape and maintain his property. One of the most critical aspects of landscaping is the continual maintenance of properly designed slopes.

Installing flower beds or shrubs next to the foundation and keeping the area flooded will result in a net increase in soil expansion in the expansive soil areas. The expansion will occur at the foundation perimeter. It is recommended that initial landscaping be done on all sides, and that drainage away from the foundation should be provided and maintained. Partial landscaping on one side of the house may result in swelling on the landscaping side of the house and resulting differential swell of foundation and structural distress in a form of brick cracking, windows/door sticking, and slab cracking.

Landscaping in areas where sandy, non-expansive soils are present, with flowers and shrubs should not pose a major problem next to the foundations. This condition assumes that the foundations are designed for saturated soil conditions. Major foundation problems can occur if the planter areas are saturated as the foundations are not designed for saturated (perched water table) conditions. The problems can occur in a form of foundation settlement, brick cracking, etc.

Sprinkler Systems. Sprinkler systems can be used in the areas where expansive soils are present, provided the sprinkler system is placed all around the house to provide a uniform moisture condition throughout the year.

The use of a sprinkler system in parts of Houston where sandy soils are present should not pose any problems, provided the foundations are designed for saturated subsoil conditions with positive drainage away from the structure.

The excavations for the sprinkler system lines, in the areas where expansive soils are present, should be backfilled with impermeable clays. Bank sands or top soil should not be used as backfill. These soils should be properly compacted to minimize water flow into the excavation trench and seeping under the foundations, resulting in foundation and structural distress.

The sprinkler system must be checked for leakage at least once a month. Significant foundation movements can occur if the expansive soils under the foundations are exposed to a source of free water.

The homeowner should also be aware of damage that leaking plumbing or underground utilities can cause, if they are allowed to continue leaking and providing the expansive soils with the source of water.

City of Houston

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REVIEWED FOR COMPLIANCE

Performance of this review does not relieve the applicant from full responsibility to comply with all applicable code and regulations.

05/10/22

<u>Effect of Trees</u>. The presence of trees near a residence is considered to be a potential contributing factor to the foundation distress. Our experience shows that the presence or removal of large trees in close proximity to residential structures can cause foundation distress. This problem is aggravated by cyclic wet and dry seasons in the area. Foundation damage of residential structures caused by the adjacent trees indicates that foundation movements of as much as 3- to 5-inches can be experienced in close proximity to residential foundations.

This condition will be more severe in the periods of extreme drought. Sometimes the root system of trees such as willow, elm, or oak can physically move foundations and walls and cause considerable structural damage. Root barriers can be installed near the exterior grade beams to a minimum depth of 60-inches, if trees are left in place in close proximity to foundations. It is recommended that trees not be planted closer than half the canopy diameter of the mature tree, typically 20-feet from foundations. Any trees in closer proximity should be thoroughly soaked at least twice a week during hot summer months, and once a week in periods of low rainfall. More frequent tree watering may be required.

Tree roots tend to desiccate the soils. In the event that the tree has been removed prior to house construction, during the useful life of the house, or if tree dies, subsoil swelling can occur for several years. Studies have shown that this process can last as much as 20 years in the area where highly expansive clays are present. In the areas where sandy soils are present this process does not occur.

In this case the foundation for the house should be designed for the anticipated maximum heave. Alternatively, the site should be left alone for several years so that the moisture regime in the desiccated area of the soils (where roots used to be) become equal/stabilized to the surrounding subsoil conditions.

Tree removal can be safe provided the tree is no older than any part of the house, since the subsequent heave can only return the foundation to its original level. In most cases there is no advantage to a staged reduction in the size of the tree and the tree should be completely removed at the earliest opportunity. The areas where expansive soils exist and where the tree is older than the house, or there are more recent extensions to the house, it is not advisable to remove the tree because the danger of inducing damaging heave; unless the foundation is designed for the total computed expected heave.

In the areas where non-expansive soils are present, no significant foundation distress will occur as a result of the tree removal.

In the areas where too much heave can occur with tree removal, some kind of pruning, such as crown thinning, crown reduction or pollarding should be considered. Pollarding, in which most of the branches are removed and the height of the main trunk is reduced, is often mistakenly specified, because most published advice links the height of the tree to the likelihood of damage. In fact, the leaf area is the important factor. Crown thinning or crown reduction, in which some branches are removed or shortened, is therefore generally preferable to pollarding. The pruning should be done in such a way as to minimize the future growth of the tree, without leaving it vulnerable to disease (as pollarding often does) while maintaining its shape. This should be done only by a reputable tree surgeon or qualified contractor working under the instructions of an arbor culturist.

You may find there is opposition to the removal or reduction of an offending tree; for example, it may belong to a neighbor or the local authority or have a Tree Preservation Order on it. In such cases there are other techniques that can be used from within your own property.

One option is root pruning, which is usually performed by excavating a trench between the tree and the damaged property deep enough to cut most of the roots. The trench should not be so close to the tree that it jeopardizes its stability. In time, the tree will grow new roots to replace those that are cut; however, in the short term there will be some recovery as the degree of desiccation in the soil under the foundations reduces.

Where the damage has only appeared in a period of dry weather, a return to normal weather pattern may prevent further damage occurring. Permission from the local authority is required before pruning the roots of a tree with preservation order on it.

Root barriers are a variant of root pruning. However, instead of simply filling the trench with soil after cutting the roots, the trench is either filled with concrete or lined with an impermeable layer to form a "permanent" barrier to the roots. Whether the barrier will be truly permanent is questionable, because the roots may be able to grow round or under the trench. However, the barrier should at least increase the time it takes for the roots to grow back.

<u>Foundations/Flat Works</u>

Every homeowner should conduct a yearly observation of foundations and flat works and perform any maintenance necessary to improve drainage and minimize infiltrations of water from rain and lawn watering. This is important especially during the first six years of a newly built home because this is usually the time of the most severe adjustment between the new construction and its environment. We recommend that all of the separations in the flat work and paving joints be immediately backfilled with joint sealer to minimize surface water intrusion and subsequent shrink/swell.

Some cracking may occur in the foundations. For example, most concrete slabs can develop hairline cracks. This does not mean that the foundation has failed. All cracks should be cleaned up of debris as soon as possible. The cracks should be backfilled with high-strength epoxy glue or similar materials. If a foundation experiences significant separations, movements, cracking, the owner must contact the builder and the engineer to find out the reason(s) for the foundation distress and develop remedial measures to minimize foundation.

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