RABA KISTNER

GEOTECHNICAL ENGINEERING STUDY

FOR

VERAMENDI MASTER PLANNED DEVELOPMENT
ROADWAY C – PHASE 1
NEW BRAUNFELS, TEXAS

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Project No. ANA24-010-00
April 3, 2024

Mr. Garrett Mechler, P.E.
ASA Properties
387 West Mill Street, Suite 108
New Braunfels, Texas 78130

RE: Geotechnical Engineering Study - Pavements
Veramendi Master Planned Development
Roadway C – Phase 1
New Braunfels, Texas

Dear Mr. Mechler:

RABA KISTNER Inc. (RKI) is pleased to submit the report of our Geotechnical Engineering Study for the above-referenced project. This study was performed in accordance with RKI Proposal No. PNA22-024-00 Revised, dated March 20, 2024. The purpose of this study was to drill borings within the alignments of new roadway, to perform laboratory testing to classify and characterize subsurface conditions, and to prepare an engineering report presenting pavement design and construction guidelines.

The following report contains our design recommendations and considerations based on our current understanding of the project information provided to our office. There may be alternatives for value engineering of the foundation and pavement systems, and RKI recommends that a meeting be held with the Owner and design team to evaluate these alternatives.

We appreciate the opportunity to be of service to you on this project. Should you have any questions about the information presented in this report, or if we may be of additional assistance with value engineering or on the materials testing-quality control program during construction, please call.

Very truly yours,

RABA KISTNER, INC.

Santosh Shrestha, E.I.T.
Graduate Engineer

Ian Perez, P.E.
Vice President

STATE OF TEXAS
TERRANCE IAN PEREZ
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LICENSED
PROFESSIONAL ENGINEER

SS/TIP/mmd

Attachments

Copies Submitted: Above (1) – Email Only

GEOTECHNICAL ENGINEERING STUDY – PAVEMENTS

For

VERAMENDI MASTER PLANNED DEVELOPMENT
ROADWAY C – PHASE 1
NEW BRAUNFELS, TEXAS

Prepared for

ASA PROPERTIES, LLC
New Braunfels, Texas

Prepared by

RABA KISTNER, INC.
New Braunfels, Texas

PROJECT NO. ANA24-010-00

April 3, 2024

RABA KISTNER

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ATTACHMENTS

The following figures are attached and complete this report:

PROJECT DESCRIPTION

To be considered in this study is approximately 1,500 linear feet of roadway extending from Borchers Boulevard to the southwest property line east of Independence Drive within the Veramendi Master Planned Development in New Braunfels, Texas, as illustrated in Figure 1. The proposed roadway is planned to be 40 ft in width and was designed utilizing guidance from the City of New Braunfels and City of San Antonio's Pavement Design Guidance Manual. The residential roadway was designed in accordance with a Collector Street classification.

LIMITATIONS

This engineering report has been prepared in accordance with accepted Geotechnical Engineering practices in the region of south/central Texas and for the use of ASA Properties, LLC (CLIENT) and its representatives for design purposes. This report may not contain sufficient information for the purposes of other parties or other uses. This report is not intended for use in determining construction means and methods.

The recommendations submitted in this report are based on the data obtained from the 2 borings, a bulk sample collected at this site, and the information provided to us. This report may not reflect the actual variations of the subsurface conditions across the site. The nature and extent of variations across the site may not become evident until construction commences. The construction process itself may also alter subsurface conditions. If variations appear evident at the time of construction, it may be necessary to reevaluate our recommendations after performing on-site observations and tests to establish the engineering impact of the variations.

The scope of our Geotechnical Engineering Study does not include an environmental assessment of the air, soil, rock, or water conditions either on or adjacent to the site. No environmental opinions are presented in this report.

BORINGS AND LABORATORY TESTS

Subsurface conditions at the site were evaluated by 2 borings drilled at the locations shown on the Boring Location Map, Figure 1. These locations are approximate, and distances were measured using a recreational grade, hand-held, GPS Locator. The borings were drilled using a truck-mounted drilling rig to depths below the existing ground surface of approximately 6.5 ft due to auger refusal in limestone.

During drilling operations, split-spoon samples with Standard Penetration Testing (SPT) were collected, and where necessary, supplemental grab samples were taken where there was little or no recovery. In addition to the above samples, a bulk sample of the predominant subgrade soil was also collected for use in California Bearing Ratio (CBR) testing, pH-Lime Series testing, and sulfate content testing. The bulk sample was collected in the vicinity of Boring P-1. Each sample was visually classified in the laboratory by a member of our Geotechnical Engineering staff.

The results of all laboratory tests are presented in graphical or numerical form on the boring logs illustrated on Figures 2 and 3. A key to classification terms and symbols used on the logs is presented on Figure 4. The results of the laboratory and field testing are also tabulated on Figure 5 for ease of reference. The results of the CBR testing can be found on the Moisture Density Relationship Curve on Figure 6. The graph for Dry Density vs. Corrected CBR is presented on Figure 7. The pH-Lime Series Curve can be found on Figure 8.

Dynamic Cone Penetrometer (DCP) tests were also performed at select boring locations near proposed pavement areas from the existing ground surface to approximately 2 ft or practical equipment refusal and are the results are presented on Figure 9.

The results of the sulfate content testing are presented in the table below:

Sample Location (Boring No.)	Sulfate Content (ppm or mg/kg)	Aggressiveness
P-1	Less than 100	Negligible
P-2	Less than 100	Negligible

The range of aggressiveness for the sulfate content was determined using the table below.

Sulfate Attack Potential	
Sulfate Ion Concentration (ppm or mg/kg)	**Aggressiveness (1)**
>20,000	Very Severe
2,000 to 20,000	Severe
1,000 to 2,000	Moderate
< 1,000	Negligible

1) ACI 318-05/ACI 318R-05

Standard penetration test results are noted as "blows per ft" on the boring logs and Figure 5, where "blows per ft" refers to the number of blows by a falling hammer required for 1 ft of penetration into the soil/weak rock (N-value). Where hard or dense materials were encountered, the tests were terminated at 50 blows even if one foot of penetration had not been achieved. When all 50 blows fall within the first 6 in. (seating blows), refusal "ref" for 6 in. or less will be noted on the boring logs and on Figure 5.

Samples will be retained in our laboratory for 30 days after submittal of this report. Other arrangements may be provided at the request of the Client.

GENERAL SITE CONDITIONS

GEOLOGY

A review of the *Geologic Atlas of Texas, San Antonio Sheet*, indicates that this site is naturally underlain with the soils/rock (limestone) of the Edwards Group. Edwards limestone is generally considered hard in induration and typically contains harder zones/seams of chert and dolomite. Edwards limestone also typically contains karstic features in the form of open and/or clay-filled vugs, voids, and/or solution cavities that form as a result of solution movement through fractures in the rock mass.

Key geotechnical engineering considerations for development supported on this formation will be the depth to rock, the expansive nature of the overlying clays, the condition of the rock, and the presence/absence of karstic features.

STRATIGRAPHY

The natural subsurface stratigraphy can generally be described as a thin veneer of dark brown to reddish brown clay underlain by limestone which was encountered within the upper 3 to 4 ft of our borings and which extends to at least the boring termination depths.

Each stratum has been designated by grouping soils that possess similar physical and engineering characteristics. The boring logs should be consulted for more specific stratigraphic information. Unless noted on the boring logs, the lines designating the changes between various strata represent approximate boundaries. The transition between materials may be gradual or may occur between recovered samples. The stratification given on the boring logs, or described herein, is for use by RKI in its analyses and should not be used as the basis of design or construction cost estimates without realizing that there can be variation from that shown or described.

The boring logs and related information depict subsurface conditions only at the specific locations and times where sampling was conducted. The passage of time may result in changes in conditions, interpreted to exist, at or between the locations where sampling was conducted.

SWELL/HEAVE POTENTIAL

Subgrade soils that are highly expansive when water is introduced (i.e. highly plastic soils) will heave, causing the pavement to become rough or uneven over time. Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle costs, fuel consumption, and maintenance costs. Pavement heave can be reduced through various measures but cannot be totally eliminated without full removal of the problematic soil. Measures available for reducing heave include:

- Soil Treatment with Lime or Other Chemicals
- Removal and Replacement of High PI Soils
- Drains or Barriers to Collect or Inhibit Moisture Infiltration

Soil treatment with lime (or other chemicals) is typically used to reduce the swelling potential of the upper portion of the pavement subgrade containing moderately plastic soils. Lime and water are mixed with the top 6 to 12 inches (or possibly more) of the subgrade and allowed to mellow or cure for a period of time. After mellowing the soil-lime mixture is compacted to form a strong soil matrix that can improve pavement performance and potentially reduce soil heave. However, in highly plastic soils, lime treatment of only the top portion of the expansive subgrade may not provide an acceptable reduction in PVR. For a more substantial reduction in PVR, removal and replacement of the high PI soil may be the only method available to reduce the potential vertical rise of the pavement to an acceptable level. As stated previously, it must be recognized that partial removal of expansive clay soil only reduces the potential (or risk) of the damage swell can cause to a pavement and does not completely eliminate this risk.

In addition, capturing water infiltration via French drains, pavement edge drains, or inhibiting water through the use of vertical moisture barriers would reduce the potential for heave since one important component of the heaving mechanism, water, would be reduced. Geocomposite membranes, like geogrids, are also another tool available that may help reduce the damage that heaving subgrades cause to flexible pavements and may be considered in addition to or as an alternative to other mitigation techniques.

It should be noted that the pavement sections derived in the following sections are structurally adequate for the given traffic levels and existing clay subgrade strength, but do not consider the long-term effects of pavement roughness due to heave, which can only be addressed by the measures discussed in this section.

PAVEMENT RECOMMENDATIONS

Recommendations for both flexible and rigid pavements are presented in this report. The owner and/or design team may select either pavement type depending on the performance criteria established for the project. In general, flexible pavement systems have a lower initial construction cost as compared to rigid pavements. However, maintenance requirements over the life of the pavement are typically much greater for flexible pavements. This typically requires regularly scheduled observation and repair, as well as overlays and/or other pavement rehabilitation at approximately one-half to two-thirds of the design life. Rigid pavements are generally more "forgiving", and therefore tend to be more durable and require less maintenance after construction.

For either pavement type, drainage conditions will have a significant impact on long term performance, particularly where permeable base materials are utilized in the pavement section. Drainage considerations are discussed in more detail in a subsequent section of this report.

CITY OF NEW BRAUNFELS MINIMUM PAVEMENT RECOMMENDATIONS

The City of New Braunfels has adopted minimum pavement sections for streets classified as a Residential Collector, therefore, the following minimum pavement section should be used. Furthermore, RKI should be retained to evaluate our recommendations.

City of New Braunfels Street Classification	Layer Description	Layer Thickness
	Type D Surface Course	3.0 in.
	Flexible (Granular) Base	15.0 in.
Residential Collector	Treated Subgrade	6.0 in.
Parking Both Sides	**Combined Total**	**24.0 in.**

DESIGN PARAMETERS – FLEXIBLE PAVEMENTS

The roadway to be considered in this study is Roadway C in the Veramendi Master Planned Development. The proposed roadway is to be evaluated in accordance with the *City of San Antonio's Design Guidance Manual* regarding Collector streets. Based on information provided by the City of San Antonio, we understand that the following design parameters are required for use in the design of flexible pavements for this street.

Street Classification	Equivalent 18-kip Single Axle Load Applications (ESALs)	Reliability	Serviceability Initial/Terminal	Standard Deviation	Structural Number Minimum/Maximum
Collector	2,000,000	90	4.2/2.5	0.45	2.92/5.08

The required structural number is related to the CBR value of the pavement subgrade and the amount of traffic that the pavement will carry over its service life. The CBR provides an estimate of the relative strength of the subgrade and consequently indicates the ability of the pavement section to carry load. This site specific CBR value is utilized in conjunction with the above specified parameters to determine the required Structural Number (SN) for use in the design of the pavement section.

To determine the required design SN value, we utilized a method based on the 1993 edition of the AASHTO "Guide for the Design of Pavement Structures." The "required by design" SN values are presented in the tables of the pavement sections as well as the values subsequently determined in the design of the pavement sections for this site.

Subgrade Strength Characterization

We have assumed the pavement subgrade will consist of recompacted on-site clays or, native, intact limestone or rock millings. The CBR was measured using ASTM D 1883, *Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils* and was determined using the soaked sample methodology. Swell was also measured as part of the CBR procedure. The corrected CBR value is tabulated below:

Sample Location	Average Swell (%)	Laboratory CBR
P-1	0.3 %	4.3

These values were determined using 3-points compacted at varying efforts to determine the corrected CBR value at 95 percent of the maximum dry density as determined by TxDOT, Tex-114-E. The moisture-density relationship results are presented on Figure 6. Based on these results and our experience with the soils in this area, we have assumed a design CBR value of 4.0 for use in our pavement section analysis for the clay fill subgrade (hereafter referred to as the 'clay subgrade'). If clay soils are imported for the purpose of constructing the roadbed, then imported materials must be selected that have a CBR value of at least 4.0. If lower quality clay fill materials are utilized, the pavement sections will have to be increased based on the quality (tested CBR value) of the clays imported.

A 'rock subgrade' condition with a CBR of 10.0 may be utilized if native, intact rock is exposed prior to select fill placement (if necessary) or if the fill used to establish the finished grade are comprised of select fill materials or rock millings.

For areas that transition between a clay and rock subgrade, we recommend that geogrid be utilized to relieve stress concentrations at the subgrade transitions. The geogrid should be used as a transition for 5 ft or greater on either side of the transition.

Structural Number Recommendations

Structural number for the street classification and subgrade condition were calculated using the parameters provided in the table presented in the previous section. The resulting Structural Numbers are presented in the pavement section tables.

The following input variables are utilized to design flexible base pavements (commonly referred to as Asphaltic Cement Concrete or Asphalt pavements) when using the procedures detailed in the *1993 AASHTO Guide for Design of Pavement Structures*:

- Performance Period, years
- Roadbed Soil Resilient Modulus, psi
- Serviceability Indices
- Overall Standard Deviation
- Reliability, %
- Design Traffic, 18-kip ESALs

Performance Period, years

The pavement structure was designed for a 20-year performance period which is typical for most flexible pavements.

Roadbed Soil Resilient Modulus, psi

The Resilient Modulus (M_R) is the material property used to characterize the support characteristics of the roadbed soils in flexible pavement design. It is a measure of the soil's deformation response to cyclic applications of loads much smaller than a failure load.

To determine the resilient modulus (M_r) of the subgrade, we utilized the correlation equation shown below:

M_r = 1,500 x CBR

Serviceability Indices

Initial serviceability is a measure of the pavement's smoothness or rideability immediately after construction. Terminal serviceability is the minimum tolerable serviceability of a pavement. When the serviceability of a pavement reaches its terminal value, rehabilitation is required. See the recommended Initial and Terminal Serviceability Indices on the table presented in the *Design Parameters – Flexible Pavements* section of this report.

Overall Standard Deviation

Overall standard deviation accounts for both chance variation in the traffic prediction and normal variation in pavement performance prediction for a given traffic. Higher values represent more variability; thus, the pavement thickness increases with higher overall standard deviations. A value of 0.45 was utilized for the flexible pavement designs presented herein.

Reliability, %

The reliability value represents a "safety factor," with higher reliabilities representing pavement structures with less chance of failure. The AASHTO Guide recommends values ranging from 50 to 99.9%, depending on the functional classification and the location (urban vs. rural) of the roadway. See the recommended Reliability values on the table presented in the *Design Parameters – Flexible Pavements* section of this report.

Design Traffic, 18-kip ESALs

The 18-kip ESALs were determined from the traffic data specified in the Unified Development Code for the City of San Antonio. See the recommended values on the table presented in the *Design Parameters – Flexible Pavements* section of this report.

RECOMMENDED FLEXIBLE PAVEMENT SECTIONS

Appendix 10-A of the *City of San Antonio's Design Guidance Manual* states that subgrade soils with a PI greater than 20 must be treated with lime or other proven methods of treatment to reduce the PI of the soil to less than 20. Based on the results of our Atterberg Limits testing performed in the upper 5 ft of our borings, the PI of the surficial subgrade clays ranges from 16 to 41. We recommend that pavements at this site include a minimum of 6 in. of lime-treated subgrade. We recommend that the required lime content reduces the PI of the subgrade soil to less than 20 and increases the pH of the soil to 12.4 or greater. If the exposed soil has a natural PI of less than 20, consists of bedrock, or rock millings or select fill are utilized, then the lime treatment may be waived.

If on-site clay fill is utilized for fill grading, it should be placed and compacted as discussed in the *On-Site Clay Fill* section of this report. For areas that require fill and where pavement sections will utilize the clay subgrade recommendations, the final 6 in. of fill should be lime treated (see *Treatment of Subgrade*). If fill grading is not planned and clays remain in-place, then lime treatment of the stripped clay subgrade should be performed in conjunction with the scarifying, moisture conditioning, and recompaction process described in the *Site Preparation* section of the *Pavement Construction Considerations*.

If native, intact rock is exposed prior to fill placement (if necessary) or if the fill used to establish the finished grade are comprised of select fill materials or rock millings, the lime treated subgrade may be eliminated from the pavement section and the rock subgrade recommendations should be utilized. Per Appendix 10-A of the *City of San Antonio's Design Guidance Manual*, a rock credit can be given to those pavement sections overlying a rock subgrade. The rock credit provided should be equivalent to a 6 in. structural layer for stabilized subgrade.

For this site, we recommend the following options for pavement sections for the clay and rock subgrades described herein. Additional options are also available and can be provided upon request.

Clay Subgrade

Collector; (Roadway C) CBR = 4.0; Required SN = 4.21	Layer Description	Layer Thickness	Recommended SN Coeff.	SN Extension
Flexible Base Option	Type D Surface Course	2.0 in.	0.44	0.88
	Type C or D Binder Course	3.0 in.	0.44	1.32
	Flexible (Granular) Base	15.0 in.	0.14	2.10
	Treated Subgrade	6.0 in.	0.00	0.00
	Combined Total	**26.0 in.**		**4.30**
Mechanically Stabilized Layer Option	Type D Surface Course	2.0 in.	0.44	0.88
	Type C or D Binder Course	3.0 in.	0.44	1.32
	Mechanically Stabilized Layer	12.0 in.	0.17	2.04
	Treated Subgrade	6.0 in.	0.00	0.00
	Combined Total	**23.0 in.**		**4.24**

Rock Subgrade

Collector; (Roadway C) CBR = 10.0; Required SN = 2.99	Layer Description	Layer Thickness [1]	Recommended SN Coeff.	SN Extension
Flexible Base Option	Type D Surface Course	3.0 in.	0.44	1.32
	Flexible (Granular) Base	9.0 in.	0.14	1.26
	Rock Credit	0.0 in.	--	0.48
	Combined Total	**12.0 in.**		**3.06**
Mechanically Stabilized Layer Option	Type D Surface Course	3.0 in.	0.44	1.32
	Mechanically Stabilized Layer	7.0 in.	0.17	1.19
	Rock Credit	0.0 in.	--	0.48
	Combined Total	**10.0 in.**		**2.99**

1) Refer to minimum pavement section recommended by the City of New Braunfels provided in section *City of New Braunfels Minimum Pavement Recommendations.*

A Mechanically Stabilized Layer (MSL) is a composite layer consisting of flexible (granular) base and a geogrid product. Geogrid provides lateral restraint to the flexible base by confining aggregate particles within the plane of the geogrid, thereby creating a reinforced, or mechanically stabilized layer.

DESIGN PARAMETERS – RIGID PAVEMENTS

Based on information provided by the City of San Antonio, we understand that the following design parameters are required for use in the design of rigid pavements for the aforementioned street classifications.

Street Classification	Equivalent 18-kip Single Axle Load Applications (ESALs)	Reliability	Serviceability (Initial/Terminal)	Standard Deviation	Rigid Pavement Slab Thickness (Minimum/Maximum)
Collector	3,000,000	90	4.5/2.5	0.35	7.0/9.0

To calculate the required design rigid pavement thickness, we utilized a method based on the 1993 edition of the AASHTO "Guide for the Design of Pavement Structures."

The following input variables are utilized to design rigid pavements (commonly referred to as Portland Cement Concrete or PCC pavements) when using the procedures detailed in the *1993 AASHTO Guide for Design of Pavement Structures*:

- Performance Period
- 28-day Concrete Modulus of Rupture (M_r), psi
- 28-day Concrete Elastic Modulus, psi
- Effective Modulus of Subbase/Subgrade Reaction, (k-value) psi/in.
- Serviceability Indices
- Load Transfer Coefficient
- Drainage Coefficient
- Overall Standard Deviation
- Reliability, %
- Design Traffic, 18-kip ESALs

Performance Period

The pavement structure was designed for a 30-year performance period which is typical for most rigid pavements.

28-day Concrete Modulus of Rupture (M_r), psi

The M_r of concrete is a measure of the flexural strength of the concrete as determined by breaking concrete beam test specimens. An M_r of approximately 600 psi at 28 days was used in the analysis and is typical of local concrete production.

28-day Concrete Elastic Modulus, psi

An elastic modulus of concrete is an indication of concrete stiffness and varies depending on the coarse aggregate type used in the concrete. A modulus of 4,000,000 psi is used for this pavement design.

Effective Modulus of Subbase/Subgrade Reaction(k-value), psi/in.

Concrete slab support is characterized by the modulus of subgrade reaction, otherwise known as the k-value with units typically shown as psi/in. k-value of 120 was used in the rigid pavement design procedure for clay subgrade and are based upon the CBR value discussed above.

Serviceability Indices

Initial serviceability is a measure of the pavement's smoothness or rideability immediately after construction. Terminal serviceability is the minimum tolerable serviceability of a pavement. When the serviceability of a pavement reaches its terminal value, rehabilitation is required. See the recommended Initial and Terminal Serviceability Indices on the table presented in the *City of San Antonio Design Parameters – Portland Cement Concrete Pavements* section of this report.

Load Transfer Coefficient

The load transfer coefficient is used to incorporate the effect of dowels, reinforcing steel, tied shoulders, and tied curb and gutter on reducing the stress in the concrete slab due to traffic loading and therefore causing a reduction in the required concrete slab thickness.

The load transfer coefficients used in these pavement designs is 2.9 Collectors, using aggregate interlock reinforcement, with edge support (curbs) and given the traffic count for the street classifications (ESALs). We recommend dowels for Collectors roadways.

Drainage Coefficient

The drainage coefficient characterizes the quality of drainage of the subbase layers under the concrete slab. Good draining pavement structures do not give water the chance to saturate the subbase and subgrade; thus, pumping is not as likely to occur.

There is no subbase recommended for this pavement structure. Therefore, the drainage coefficient used in this pavement design is 1.01 and is based upon local design experience for slabs without subbases on expansive clay subgrade.

Overall Standard Deviation

Overall standard deviation accounts for both chance variation in the traffic prediction and normal variation in pavement performance prediction for a given traffic. Higher values represent more variability; thus, the pavement thickness increases with higher overall standard deviations. See the recommended Overall Standard Deviation on the table presented in the *Design Parameters – Rigid Pavements* section of this report.

Reliability, %

The reliability value represents a "safety factor," with higher reliabilities representing pavement structures with less chance of failure. The AASHTO Guide recommends values ranging from 50 to 99.9%, depending on the functional classification and the location (urban vs. rural) of the roadway. See the recommended Reliability on the table presented in the *Design Parameters – Rigid Pavements* section of this report.

Design Traffic 18-kip ESAL

The 18-kip ESALs were determined from the street classifications as discussed previously in the *Design Parameters – Rigid Pavements* section of this report.

RECOMMENDED RIGID PAVEMENT SECTIONS

Appendix 10-A of the *City of San Antonio's Design Guidance Manual* states that clay subgrade soils with a PI greater than 20 must be treated with lime or other proven methods of treatment to reduce the PI of the soil to less than 20. Based on the results of our Atterberg Limits testing performed in the surficial clays of our borings, the PI of the clay subgrade ranges from 16 to 41. We recommend that pavements on a clay subgrade at this site include a minimum of 6 in. of lime-treated subgrade. We recommend that the required lime content reduce the PI of the subgrade soil to 20 or less and increase the pH of the soil to 12.4 or greater. The recommended concrete slab thicknesses determined with the inputs discussed above are presented in the table below. Additional options are also available and can be provided upon request.

Portland Cement Concrete Design - Cross Section	Layer Description	Layer Thickness
Collector	PCC Surface (1) Treated Subgrade (2) **Combined Total**	8.5 in. 6.0 in. **14.5 in.**

1) The concrete design thickness for Collector roadways assumes load transfer devices (i.e. dowels) will be utilized at control joints.

2) Treated subgrade may be waived for rock subgrade condition.

PAVEMENT CONSTRUCTION CONSIDERATIONS

SITE PREPARATION

Preparation for the right-of-way (for streets, sidewalks, utilities, etc.) should be performed in accordance with the 2014 TxDOT Standard Specifications, Item 100 – *Preparing Right of Way*. Exposed subgrades should be thoroughly proofrolled in order to locate any weak, compressible zones. A minimum of 5 passes of a fully loaded dump truck or a similar heavily-loaded piece of construction equipment should be used for planning purposes. Proofrolling operations should be observed by the Geotechnical Engineer or his representative to document subgrade condition and preparation. Weak or soft areas identified during proofrolling should be removed and replaced with a suitable, compacted backfill.

In areas where clay will remain in place, the exposed subgrade should be moisture conditioned. This should be done after completion of the proofrolling operations and just prior to flexible base placement. Moisture conditioning is done by scarifying to a minimum depth of 6 in. and recompacting to a minimum of 95 percent of the maximum density determined from the Texas Department of Transportation Compaction Test (TxDOT, Tex-114-E). The moisture content of the subgrade should be maintained within the range of optimum moisture content to 3 percentage points above optimum until permanently covered.

Upon completion of fill grading using the on-site clays, the final 6 in. of fill should be lime treated (see *Treatment of Subgrade*). If fill grading is not planned, then lime treatment of the stripped clay subgrade should be performed in conjunction with the scarifying, moisture conditioning, and recompaction described previously.

SELECT FILL

If utilized beneath pavement sections, select fill preferably should be crushed stone or gravel aggregate. We recommend that materials specified for use as select fill meet the 2014 TxDOT Standard Specifications, Item 247 – *Flexible Base*, Type A, Grade 2.

Soils classified as CH, CL, MH, ML, SM, GM, OH, OL and Pt under the USCS are **not** considered suitable for use as select fill materials at this site. The native soils at this site are **not** considered suitable for use as select fill materials.

Select fill should be placed in loose lifts not exceeding 8 in. in thickness and compacted to at least 100 percent of maximum density as determined by TxDOT, Tex-113-E, Compaction Test. The moisture content of the fill should be maintained within the range of 2 percentage points below to 2 percentage points above the optimum moisture content until final compaction.

If select fill is placed over moisture conditioned clays, the first lift of select fill may be placed at 95 percent of the maximum density as determined by TxDOT, Tex 113-E, Compaction Test.

If excavations extend to significant depths into the limestone formation, consideration can be given to utilizing the excavated limestone as an "alternative select fill". However, processing of the excavated material will be required to reduce the maximum particle size to 4 in. Furthermore, special care will be required during excavation activities to separate organics and any plastic clay seams encountered. Alternative select fill materials shall have a maximum liquid limit not exceeding 40 and a plasticity index between 7 and 20. In addition, if these materials are utilized, grain size analyses and Atterberg Limits must be performed during placement at a rate of one test each per 5,000 cubic yards of material due to the high degree of variability associated with pit-run materials. If on-site materials cannot be processed to meet the required criteria, imported select fill materials should be utilized.

If the above listed alternative materials are being considered for bidding purposes, the materials should be submitted to the Geotechnical Engineer for pre-approval at a minimum of 10 working days or more prior to the bid date. Failure to do so will be the responsibility of the contractor. The contractor will also be responsible for ensuring that the properties of all delivered alternate select fill materials are similar to those of the pre-approved submittal. It should also be noted that when using alternative fill materials, difficulties may be experienced with respect to moisture control during and subsequent to fill placement, as well as with erosion, particularly when exposed to inclement weather. This may result in sloughing of beam trenches and/or pumping of the fill materials.

ON-SITE CLAY FILL

We recommend that the on-site soils be placed to conform to the 2014 TxDOT Standard Specifications, Item 132 – *Embankment*, Type B, and should be placed in compacted lifts not exceeding 6 in. in thickness and compacted to the requirements of Table 2 in Item 132 based on the maximum density and optimum moisture content as determined by TxDOT, Tex-114-E. The moisture content of the fill should be maintained to be at least equal to the optimum water content, but not exceed 3 percentage points above the optimum water content until permanently covered. Fill materials shall be free of roots and other organic or degradable material. We recommend that the maximum particle size not exceed 3 in. or one half the compacted lift thickness, whichever is smaller. If other import fill materials are utilized, RKI should be notified, as additional CBR testing and thicker pavement sections may be required.

It is imperative that the subgrade modulus utilized in the pavement design process be met or exceeded by the fill material. In the event that the clay fill used is different than the existing subgrade, the recommendations in this report could be invalidated and the design engineer must be consulted to determine if additional CBR testing and thicker pavement sections are required.

TREATMENT OF SUBGRADE

Treatment of the natural subgrade soils should be in accordance with the TxDOT Standard Specifications, Item 260 (Lime treatment) or Item 275 (cement treatment). A sufficient quantity of product should be mixed with the subgrade soils to reduce the soil mixture plasticity index to 20 or less and increase the pH to 12.4 or greater. Based on the results of the pH-Lime Series Curves and lime treated Atterberg limit tests, we recommend that at least 3 percent hydrated lime or 3 percent cement treatment by weight be used to increase the pH of the subgrade clays to 12.4 or higher and decrease the plasticity index to 20 or below. **For construction purposes, we recommend that the optimum lime or cement content of the subgrade soils be determined by laboratory testing with representative samples of the subgrade materials being used for this project.** If lime or cement treatment is utilized, we also recommend that soluble sulfate content testing be completed to determine the susceptibility of the soils to sulfate-induced heave in lime-treated soils.

Lime or cement-treated subgrade soils should be compacted to a minimum of 95 percent of the maximum density at a moisture content within the range of optimum moisture content to 3 percentage points above the optimum moisture content as determined by Tex-113-E, Compaction Test.

GEOGRID REINFORCEMENT

The geogrid reinforcement should be selected and placed in accordance with a Type II TxDOT approved geogrid that conforms to DMS 6240. The geogrid should be placed at the bottom of the flexible (granular) base section in all cases. An alternative to the above geogrid should not be considered without approval from RKI.

GRANULAR BASE COURSE

The flexible base course should be crushed limestone conforming to the 2014 TxDOT Standard Specifications, Item 247 – *Flexible Base*, Type A, Grade 1. The base course should be placed in lifts with a maximum compacted thickness of 8 in. (10 inches loose) and compacted to a minimum of 95 percent of the maximum density determined by Tex-113-E at a moisture content within the range of 2 percentage points below to 2 percentage points above the optimum moisture content as determined by Tex-113-E.

PRIME COAT

A prime coat should be placed on top of the flexible base course (if used) and should be a MC-30, AE-P, EAP&T, or PCE conforming to the 2014 TxDOT Standard Specifications, Item 310 – *Prime Coat* or Item 314 – *Emulsified Asphalt Treatment* as well as Item 300 – *Asphalts, Oils and Emulsions*. Prime coat application rates are typically between 0.1 to 0.3 gal/yd^2 and are generally dependent upon the absorption rate of the granular base and other environmental conditions at the time of placement. The prime coat layer should be placed on the prepared flexible base as soon as possible. This will facilitate plugging the capillary voids in the flexible base surface to reduce migration of moisture and provide a water-resistant surface. The asphalt layer should be placed as soon as possible after the prime coat has been properly set/cured.

TACK COAT

A tack coat should be placed between asphaltic concrete base and/or surface lifts and should be a PG binder with a minimum high-temperature grade of PG 58, SS-1H, CSS-1H, or EAP&T conforming to the 2014 TxDOT Standard Specifications, Item 300 – *Asphalts, Oils and Emulsions*. See additional requirements for tack coats in the appropriate TxDOT Standard Specifications for Asphaltic Concrete Materials.

ASPHALTIC CONCRETE SURFACE AND/OR BINDER[1] COURSES

The asphaltic concrete surface and/or binder courses should conform to the 2014 TxDOT Standard Specifications, Item 341 – *Dense Graded Hot Mix Asphalt or Item 341 Paragraph 2.6.2 Warm Mix Asphalt (WMA)*, Types C or D for the surface and binder, and Type B for the base, if the full depth asphalt section is selected for construction. Recycled asphalt pavement (RAP) should be limited to 20 percent of the total weight of the mix for Types C and D mixes and 30 percent for Type B mixes. Higher percentages of RAP may be permissible depending on the material source. If higher percentages of RAP are desired, contact RKI for consideration. Asphalt cement grades should conform to the table shown below, which conforms to the requirements of Item 341.

Street Classifications	Minimum PG Asphalt Cement Grade		
	Surface Courses	Binder and Level Up Courses	Base Courses
Collector Streets	PG 70-22	PG 70-22	PG 64-22

The asphaltic concrete should be compacted on the roadway to contain from 5 to 9 percent air voids computed using the maximum theoretical specific gravity (Rice) of the mixture determined according to Test Method Tex-227-F. Pavement specimens, which shall be either cores or sections of asphaltic pavement, will be tested according to Test Method Tex-207-F. The nuclear-density gauge or other methods which correlate satisfactorily with results obtained from project roadway specimens may be used when approved by the Engineer. Unless otherwise shown on the plans, the Contractor shall be responsible for obtaining the required roadway specimens at their expense and in a manner and at locations selected by the Engineer.

It is recommended that the asphalt concrete pavement be placed with a paving machine only and not with a motor grader unless prior approval is granted by the Engineer for special circumstances. The asphalt layer should preferably be placed as soon as possible after the flexible base has been accepted and the prime coat has been placed. This will further protect the flexible base and subgrade from undue moisture fluctuation due to precipitation or sheet flow from rain events.

PORTLAND CEMENT CONCRETE

The Portland cement concrete should conform to the requirements of the 2014 TxDOT Standard Specifications, Item 360 – *Concrete Pavement*, for a Hydraulic Cement Concrete Class P. Liquid membrane-forming curing compound should be applied as soon as practical after broom finishing the concrete

[1] A binder course is defined as the asphalt concrete layer placed directly beneath the AC surface or wearing course but is not an asphalt treated base layer.

surface and should conform to Section 2.4, Curing Materials. The curing compound will help reduce the loss of water from the concrete. The reduction in the rapid loss in water will help reduce shrinkage cracking of the concrete.

CONCRETE PAVEMENT CONSTRUCTION CONTROL

Construction of Portland Cement Concrete Pavements should be controlled by the 2014 TxDOT Standard Specifications, Item 341 – *Concrete Pavement*. The surface of all concrete pavements should be textured or tined. Texturing using carpet dragging or tining should be in accordance with Item 360, Sections 3.4.1 and 3.4.2. Other texturing techniques may be utilized as described in ACI 330.1-03, Section 3, Subparagraph 9.

CONCRETE PAVEMENT TYPE

Jointed Plain Concrete Pavement (which is referred to by TxDOT as Concrete Pavement Contraction Design or CPCD) is suggested for roadways with crosswalks, adjacent parking, or sidewalks and is recommended as the pavement type for this city street.

JOINT SPACING AND DETAILS

Construction joint spacing should not exceed 15 ft in either the longitudinal or transverse direction. The depth of sawcut should be a minimum of 1/4 of the slab depth (1/3 the slab depth is recommended) if utilizing a conventional saw or 1 in. when using an early entry saw (early entry sawing is recommended). The width of the joint will be a function of the sealant chosen to seal the joint. It is recommended that a joint seal be utilized to minimize the introduction of incompressible material into the joint.

It is recommended that dowel bars be used to provide load transfer and reduce differential movement (or faulting) across transverse joints. Dowels should be smooth #9 bars (Grade 60 steel) spaced 12 in. on center with an embedment length of at least 8 in.

Tie bars should be used to tie longitudinal joints within the pavement lanes and at the shoulder. Tie bars should be deformed #4 bars at a minimum (Grade 60 steel) spaced 36 in. on center with a minimum length of 30 in.

Isolation joints must be used around fixed structures including light standard foundations and drainage inlets to offset the effects of differential horizontal and vertical movements. Premolded joint fillers should be used around the fixed structures prior to placing the concrete pavement to prevent bonding of the slab to the structure and should extend through the depth of the slab but slightly recessed from the pavement surface to provide room for the joint sealant.

Proper curing of the concrete pavement should be initiated immediately after finishing. All control joints should be formed or sawed to a depth of at least 1/4 the thickness of the concrete slab and should extend completely through monolithic curbs (if used). Sawing of control joints should begin as soon as the concrete will not ravel, preferably within 1 to 3 hours using an early entry saw or 4 to 8 hours with a conventional saw. Timing will be dictated by site conditions.

SUGGESTED PAVEMENT DETAILS

Suggested details that can be utilized for construction are:

- TxDOT CPCD-14, Concrete Paving Details, Contraction Design, T-6 to 12 inches
- TxDOT JS-14, Concrete Paving Details, Joint Seals

MISCELLANEOUS PAVEMENT RELATED CONSIDERATIONS

Drainage Considerations

As with any soil-supported structure, the satisfactory performance of a pavement system is contingent on the provision of adequate surface and subsurface drainage. Insufficient drainage which allows saturation of the pavement subgrade and/or the supporting granular pavement materials will greatly reduce the performance and service life of the pavement systems.

Surface and subsurface drainage considerations crucial to the performance of pavements at this site include (but are not limited to) the following:

- Any known natural or man-made subsurface seepage at the site which may occur at sufficiently shallow depths as to influence moisture contents within the subgrade should be intercepted by drainage ditches or below grade French drains.
- Final site grading should eliminate isolated depressions adjacent to curbs, which may allow surface water to pond and infiltrate into the underlying soils. Curbs should be installed to a sufficient depth to reduce infiltration of water beneath the curbs and into the pavement base materials.
- Pavement surfaces should be maintained to help minimize surface ponding and to provide rapid sealing of any developing cracks. These measures will help reduce infiltration of surface water downward through the pavement section.

Utilities

Our experience indicates that significant settlement of backfill can occur in utility trenches, particularly when trenches are deep, when backfill materials are placed in thick lifts with insufficient compaction, and when water can access and infiltrate the trench backfill materials. The potential for water to access the backfill is increased where water can infiltrate flexible base materials due to insufficient penetration of curbs, and at sites where geological features can influence water migration into utility trenches (such as fractures within a rock mass or at contacts between rock and clay formations). It is our belief that another factor which can significantly impact settlement is the migration of fines within the backfill into the open voids in the underlying free-draining bedding material.

To reduce the potential for settlement in utility trenches, we recommend that consideration be given to the following:

- All backfill materials should be placed and compacted in controlled lifts appropriate for the type of backfill and the type of compaction equipment being utilized, and all backfilling procedures should be tested and documented.
- Consideration should be given to wrapping free-draining bedding gravels with a geotextile fabric (similar to Mirafi 140N) to reduce the infiltration and loss of fines from backfill material into the interstitial voids in bedding materials.

Longitudinal Cracking

It should be understood that asphalt pavement sections in expansive soil environments, such as those encountered at this site, can develop longitudinal cracking along unprotected pavement edges. In the semi-arid climate of south-central Texas this condition typically occurs along the unprotected edges of pavements where moisture fluctuation is allowed to occur over the lifetime of the pavements.

Pavements that do not have a protective barrier to reduce moisture fluctuation of the highly expansive clay subgrade between the exposed pavement edge and that beneath the pavement section tend to develop longitudinal cracks 1 to 4 ft from the edge of the pavement. Once these cracks develop, further degradation and weakening of the underlying granular base may occur due to water seepage through the cracks. The occurrence of these cracks can be more prevalent in the absence of lateral restraint and steep embankments. This problem can best be addressed by providing either a horizontal or vertical moisture barrier at the unprotected pavement edge.

A horizontal barrier is commonly in the form of a paved shoulder extending 8 feet or greater beyond the edge of the pavement. Other methods of shoulder treatment, such as using geofabrics beyond the edge of the roadway, are sometimes used in an effort to help reduce longitudinal cracking. Although this alternative does not eliminate the longitudinal cracking phenomenon, the location of the cracking is transferred to the shoulder rather than within the traffic lane.

Vertical barriers installed along the unprotected edges of roadway pavements are also effective in preventing non-uniform drying and shrinkage of the subgrade clays. These barriers are typically in the form of a vertical moisture barrier/membrane extending 6 feet or greater below the top of the subgrade at the pavement edge. Both types of barriers must be sealed at the edge of the pavement to prevent a crack that would facilitate the drying of the subgrade clays.

At a minimum, we recommend that the curbs are constructed such that the depth of the curb extends through the entire depth of the granular base material and into the subgrade to act as a protective barrier against the infiltration of water into the granular base.

In most cases, a longitudinal crack does not immediately compromise the structural integrity of the pavement system. However, if left unattended, infiltration of surface water runoff into the crack will result in isolated saturation of the underlying base. This will result in pumping of the flexible base, which could lead to rutting, cracking, and potholes. For this reason, we recommend that the owner of the facility immediately seal the cracks and develop a periodic sealing program.

Pavement Maintenance

Regular pavement maintenance is critical in maintaining pavement performance over a period of several years. All cracks that develop in asphalt pavements should be regularly sealed. Areas of moderate to severe fatigue cracking (also known as alligator cracking) should be sawcut and removed. The underlying base should be checked for contamination or loss of support and any insufficiencies fixed or removed and the entire area patched. All cracks that develop in concrete pavements should be routed and sealed regularly. Joints in concrete pavements should be maintained to reduce the influx of incompressible materials that restrain joint movement and cause spalling and/or cracking. Other typical TxDOT or City of San Antonio/New Braunfels maintenance techniques should be followed as required.

Construction Traffic

Construction traffic on prepared subgrade, granular base or asphalt treated base (black base) should be restricted as much as possible until the protective asphalt surface pavement is applied. Significant damage to the underlying layers resulting in weakening may occur if heavily loaded vehicles are allowed to use these areas.

CONSTRUCTION RELATED SERVICES

CONSTRUCTION MATERIALS TESTING AND OBSERVATION SERVICES

As presented in the attachment to this report, *Important Information About Your Geotechnical Engineering Report*, subsurface conditions can vary across a project site. The conditions described in this report are based on interpolations derived from a limited number of data points. Variations will be encountered during construction, and only the geotechnical design engineer will be able to determine if these conditions are different than those assumed for design.

Construction problems resulting from variations or anomalies in subsurface conditions are among the most prevalent on construction projects and often lead to delays, changes, cost overruns, and disputes. These variations and anomalies can best be addressed if the geotechnical engineer of record, **RKI** is retained to perform construction observation and testing services during the construction of the project. This is because:

- **RKI** has an intimate understanding of the geotechnical engineering report's findings and recommendations. **RKI** understands how the report should be interpreted and can provide such interpretations on site, on the client's behalf.
- **RKI** knows what subsurface conditions are anticipated at the site.
- **RKI** is familiar with the goals of the owner and project design professionals, having worked with them in the development of the geotechnical workscope. This enables **RKI** to suggest remedial measures (when needed) which help meet the owner's and the design teams' requirements.
- **RKI** has a vested interest in client satisfaction, and thus assigns qualified personnel whose principal concern is client satisfaction. This concern is exhibited by the manner in which contractors' work is tested, evaluated, and reported, and in selection of alternative approaches when such may become necessary.

- **RKI** cannot be held accountable for problems which result due to misinterpretation of our findings or recommendations when we are not on hand to provide the interpretation which is required.

BUDGETING FOR CONSTRUCTION TESTING

Appropriate budgets need to be developed for the required construction testing and observation activities. At the appropriate time before construction, we advise that **RKI** and the project designers meet and jointly develop the testing budgets, as well as review the testing specifications as it pertains to this project.

Once the construction testing budget and scope of work are finalized, we encourage a preconstruction meeting with the selected contractor to review the scope of work to make sure it is consistent with the construction means and methods proposed by the contractor. **RKI** looks forward to the opportunity to provide continued support on this project and would welcome the opportunity to meet with the Project Team to develop both the scope and budget for these services.

* * * * * * * * * * * * * * * * * *

ATTACHMENTS

RABA KISTNER

211 Trade Center, Suite 300
New Braunfels, Texas 78130
(830)214-0544 TEL
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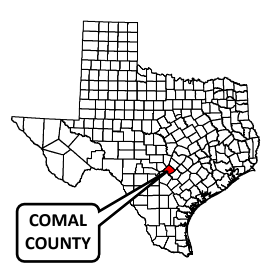
www.rkci.com
TBPE Firm Number 3257

SOURCE: Aerial imagery from Google Earth Pro - 2023

BORING LOCATION MAP

Veramendi Master Planned Development
Roadway C – Phase 1
New Braunfels, Texas



PROJECT No.:	ANA24-010-00
ISSUE DATE:	3/21/2024
DRAWN BY:	BM
CHECKED BY:	SS
REVIEWED BY:	TIP

FIGURE

1

NOTE: This Drawing is Provided for Illustration Only, May Not be to Scale and is Not Suitable for Design or Construction Purposes

LOG OF BORING NO. P-1

Veramendi Master Planned Development
Roadway C - Phase 1
New Braunfels, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

DRILLING METHOD: Straight Flight Auger

LOCATION: N 29.71972; W 98.15649

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WEIGHT, pcf	PLASTICITY INDEX	% -200
	CHIP SEAL (1 in.)				
	BASE MATERIAL (5 in.)				
	FAT CLAY, Hard, Dark Brown, with limestone fragments	50/11"			
	LEAN CLAY, Hard, Reddish-Brown, with limestone fragments and ferric staining	ref/6"		16	
	LIMESTONE, Hard, Tan	ref/1"			
5		ref/1"			
	Auger Refusal at 6.6 ft				
10					
15					

SHEAR STRENGTH, TONS/FT^2: 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT: 10 20 30 40 50 60 70 80

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

DEPTH DRILLED:	6.6 ft	**DEPTH TO WATER:**	Dry	**PROJ. No.:**	ANA24-010-00
DATE DRILLED:	3/26/2024	**DATE MEASURED:**	3/26/2024	**FIGURE:**	2

LOG OF BORING NO. P-2

Veramendi Master Planned Development
Roadway C - Phase 1
New Braunfels, Texas

RABA KISTNER
TBPE Firm Registration No. F-3257

DRILLING METHOD: Straight Flight Auger

LOCATION: N 29.72202; W 98.15453

SHEAR STRENGTH, TONS/FT^2: 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT: 10 20 30 40 50 60 70 80

DEPTH, FT	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WEIGHT, pcf	PLASTICITY INDEX	% -200
	CHIP SEAL (1 in.)				
	BASE MATERIAL (5 in.)				
	FAT CLAY, Hard, Dark Brown, with limestone fragments	50/11"		41	
	LEAN CLAY, Hard, Reddish-Brown, with limestone fragments and ferric staining	ref/4"			
	LIMESTONE, Hard, Tan	ref/2"			
5					
		ref/2"			
	Auger Refusal at 6.7 ft				
10					
15					

NOTE: THESE LOGS SHOULD NOT BE USED SEPARATELY FROM THE PROJECT REPORT

DEPTH DRILLED:	6.7 ft	**DEPTH TO WATER:**	Dry	**PROJ. No.:**	ANA24-010-00
DATE DRILLED:	3/26/2024	**DATE MEASURED:**	3/26/2024	**FIGURE:**	3

KEY TO TERMS AND SYMBOLS

MATERIAL TYPES

SOIL TERMS

- CALCAREOUS
- CALICHE
- CLAY
- CLAYEY
- GRAVEL
- GRAVELLY
- PEAT
- SAND
- SANDY
- SILT
- SILTY
- FILL

ROCK TERMS

- CHALK
- CLAYSTONE
- CLAY-SHALE
- CONGLOMERATE
- DOLOMITE
- IGNEOUS
- LIMESTONE
- MARL
- METAMORPHIC
- SANDSTONE
- SHALE
- SILTSTONE

OTHER

- ASPHALT
- BASE
- CONCRETE/CEMENT
- BRICKS / PAVERS
- WASTE
- NO INFORMATION

WELL CONSTRUCTION AND PLUGGING MATERIALS

- BLANK PIPE
- SCREEN
- BENTONITE
- CEMENT GROUT
- BENTONITE & CUTTINGS
- CONCRETE/CEMENT
- CUTTINGS
- GRAVEL
- SAND
- VOLCLAY

SAMPLE TYPES

- AIR ROTARY
- GRAB SAMPLE
- CORE
- GEOPROBE SAMPLER
- ROTOSONIC -DAMAGED
- MUD ROTARY
- NO RECOVERY
- NX CORE
- PITCHER
- ROTOSONIC -INTACT
- SHELBY TUBE
- SPLIT BARREL
- SPLIT SPOON
- TEXAS CONE PENETROMETER
- DISTURBED

STRENGTH TEST TYPES

- POCKET PENETROMETER
- TORVANE
- UNCONFINED COMPRESSION
- TRIAXIAL COMPRESSION UNCONSOLIDATED-UNDRAINED
- TRIAXIAL COMPRESSION CONSOLIDATED-UNDRAINED

NOTE: VALUES SYMBOLIZED ON BORING LOGS REPRESENT SHEAR STRENGTHS UNLESS OTHERWISE NOTED

PROJECT NO. ANA24-010-00

KEY TO TERMS AND SYMBOLS (CONT'D)

TERMINOLOGY

Terms used in this report to describe soils with regard to their consistency or conditions are in general accordance with the discussion presented in Article 45 of SOILS MECHANICS IN ENGINEERING PRACTICE, Terzaghi and Peck, John Wiley & Sons, Inc., 1967, using the most reliable information available from the field and laboratory investigations. Terms used for describing soils according to their texture or grain size distribution are in accordance with the UNIFIED SOIL CLASSIFICATION SYSTEM, as described in American Society for Testing and Materials D2487-06 and D2488-00, Volume 04.08, Soil and Rock; Dimension Stone; Geosynthetics; 2005.

The depths shown on the boring logs are not exact, and have been estimated to the nearest half-foot. Depth measurements may be presented in a manner that implies greater precision in depth measurement, i.e 6.71 meters. The reader should understand and interpret this information only within the stated half-foot tolerance on depth measurements.

RELATIVE DENSITY

Penetration Resistance Blows per ft	Relative Density
0 - 4	Very Loose
4 - 10	Loose
10 - 30	Medium Dense
30 - 50	Dense
> 50	Very Dense

COHESIVE STRENGTH

Resistance Blows per ft	Consistency	Cohesion TSF
0 - 2	Very Soft	0 - 0.125
2 - 4	Soft	0.125 - 0.25
4 - 8	Firm	0.25 - 0.5
8 - 15	Stiff	0.5 - 1.0
15 - 30	Very Stiff	1.0 - 2.0
> 30	Hard	> 2.0

PLASTICITY

Plasticity Index	Degree of Plasticity
0 - 5	None
5 - 10	Low
10 - 20	Moderate
20 - 40	Plastic
> 40	Highly Plastic

ABBREVIATIONS

B = Benzene
T = Toluene
E = Ethylbenzene
X = Total Xylenes
BTEX = Total BTEX
TPH = Total Petroleum Hydrocarbons
ND = Not Detected
NA = Not Analyzed
NR = Not Recorded/No Recovery
OVA = Organic Vapor Analyzer
ppm = Parts Per Million

Qam, Qas, Qal = Quaternary Alluvium
Qat = Low Terrace Deposits
Qbc = Beaumont Formation
Qt = Fluviatile Terrace Deposits
Qao = Seymour Formation
Qle = Leona Formation
Q-Tu = Uvalde Gravel
Ewi = Wilcox Formation
Emi = Midway Group
Mc = Catahoula Formation
El = Laredo Formation
Kknm = Navarro Group and Marlbrook Marl
Kpg = Pecan Gap Chalk
Kau = Austin Chalk

Kef = Eagle Ford Shale
Kbu = Buda Limestone
Kdr = Del Rio Clay
Kft = Fort Terrett Member
Kgt = Georgetown Formation
Kep = Person Formation
Kek = Kainer Formation
Kes = Escondido Formation
Kew = Walnut Formation
Kgr = Glen Rose Formation
Kgru = Upper Glen Rose Formation
Kgrl = Lower Glen Rose Formation
Kh = Hensell Sand

KEY TO TERMS AND SYMBOLS (CONT'D)

TERMINOLOGY

SOIL STRUCTURE

Slickensided	Having planes of weakness that appear slick and glossy.
Fissured	Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical.
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	Inclusion less than 1/8 inch thick extending through the sample.
Seam	Inclusion 1/8 inch to 3 inches thick extending through the sample.
Layer	Inclusion greater than 3 inches thick extending through the sample.
Laminated	Soil sample composed of alternating partings or seams of different soil type.
Interlayered	Soil sample composed of alternating layers of different soil type.
Intermixed	Soil sample composed of pockets of different soil type and layered or laminated structure is not evident.
Calcareous	Having appreciable quantities of carbonate.
Carbonate	Having more than 50% carbonate content.

SAMPLING METHODS

RELATIVELY UNDISTURBED SAMPLING

Cohesive soil samples are to be collected using three-inch thin-walled tubes in general accordance with the Standard Practice for Thin-Walled Tube Sampling of Soils (ASTM D1587) and granular soil samples are to be collected using two-inch split-barrel samplers in general accordance with the Standard Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). Cohesive soil samples may be extruded on-site when appropriate handling and storage techniques maintain sample integrity and moisture content.

STANDARD PENETRATION TEST (SPT)

A 2-in.-OD, 1-3/8-in.-ID split spoon sampler is driven 1.5 ft into undisturbed soil with a 140-pound hammer free falling 30 in. After the sampler is seated 6 in. into undisturbed soil, the number of blows required to drive the sampler the last 12 in. is the Standard Penetration Resistance or "N" value, which is recorded as blows per foot as described below.

SPLIT-BARREL SAMPLER DRIVING RECORD

Blows Per Foot	Description
25	25 blows drove sampler 12 inches, after initial 6 inches of seating.
50/7"	50 blows drove sampler 7 inches, after initial 6 inches of seating.
Ref/3"	50 blows drove sampler 3 inches during initial 6-inch seating interval.

NOTE: To avoid damage to sampling tools, driving is limited to 50 blows during or after seating interval.

RESULTS OF SOIL SAMPLE ANALYSES

PROJECT NAME: Veramendi Master Planned Development
Roadway C - Phase 1
New Braunfels, Texas

FILE NAME: ANA24-010-00 GINT.GPJ 4/2/2024

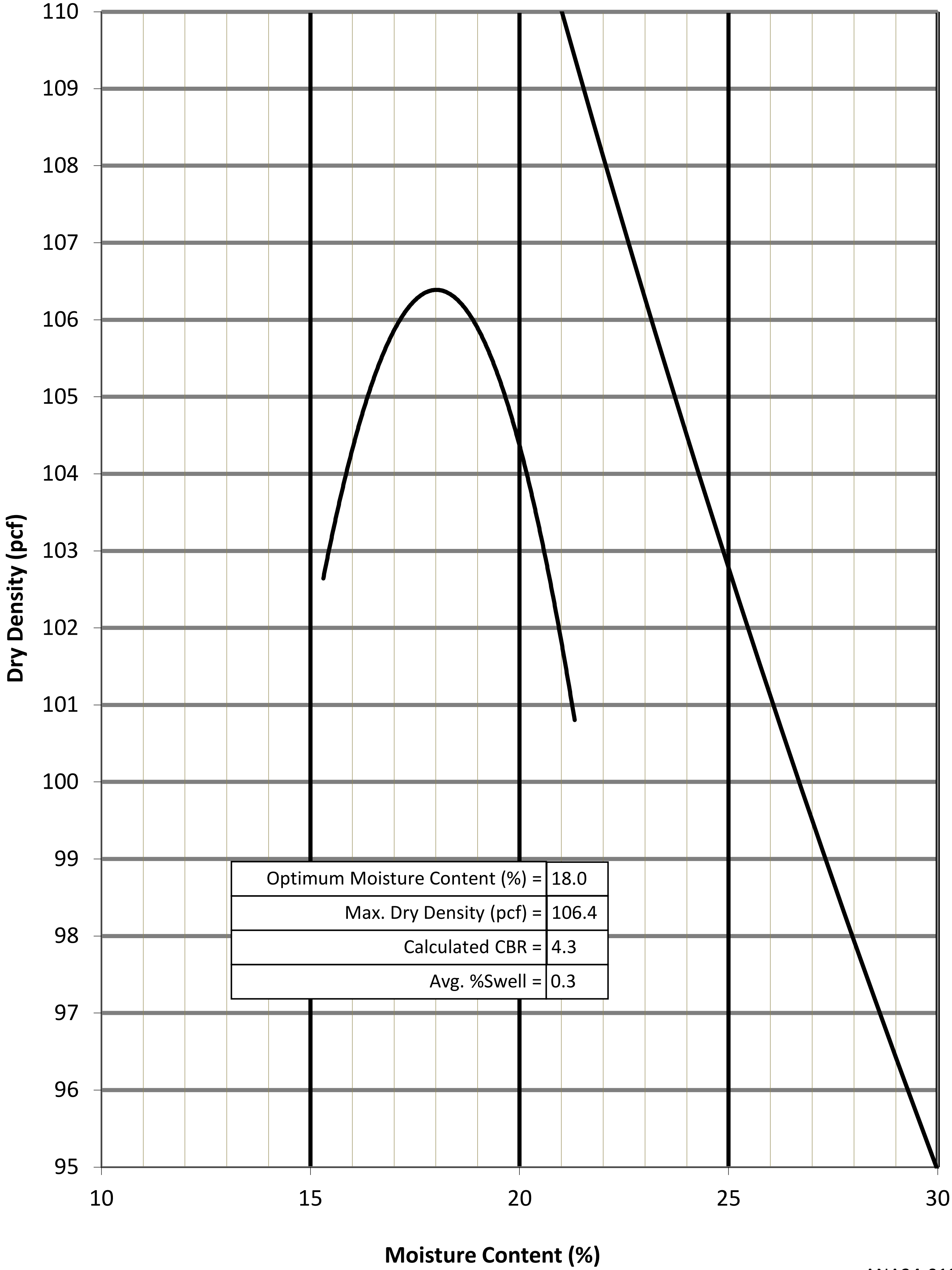
Boring No.	Sample Depth (ft)	Blows per ft	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	USCS	Dry Unit Weight (pcf)	% -200 Sieve	Shear Strength (tsf)	Strength Test
P-1	1.0 to 2.4	50/11"									
	1.0 to 1.5		30								
	2.5 to 3.0	ref/6"	9	26	10	16	CL				
	4.0 to 4.5		3								
	4.5 to 4.6	ref/1"									
	6.0 to 6.5		1								
	6.5 to 6.6	ref/1"									
P-2	1.0 to 2.4	50/11"	24	59	18	41	CH				
	2.5 to 2.8	ref/4"	14								
	4.0 to 4.5		6								
	4.5 to 4.7	ref/2"									
	6.0 to 6.5		5								
	6.5 to 6.7	ref/2"									

PP = Pocket Penetrometer TV = Torvane UC = Unconfined Compression FV = Field Vane UU = Unconsolidated Undrained Triaxial

CU = Consolidated Undrained Triaxial

MOISTURE DENSITY RELATIONSHIP CURVE - TEX-114-E

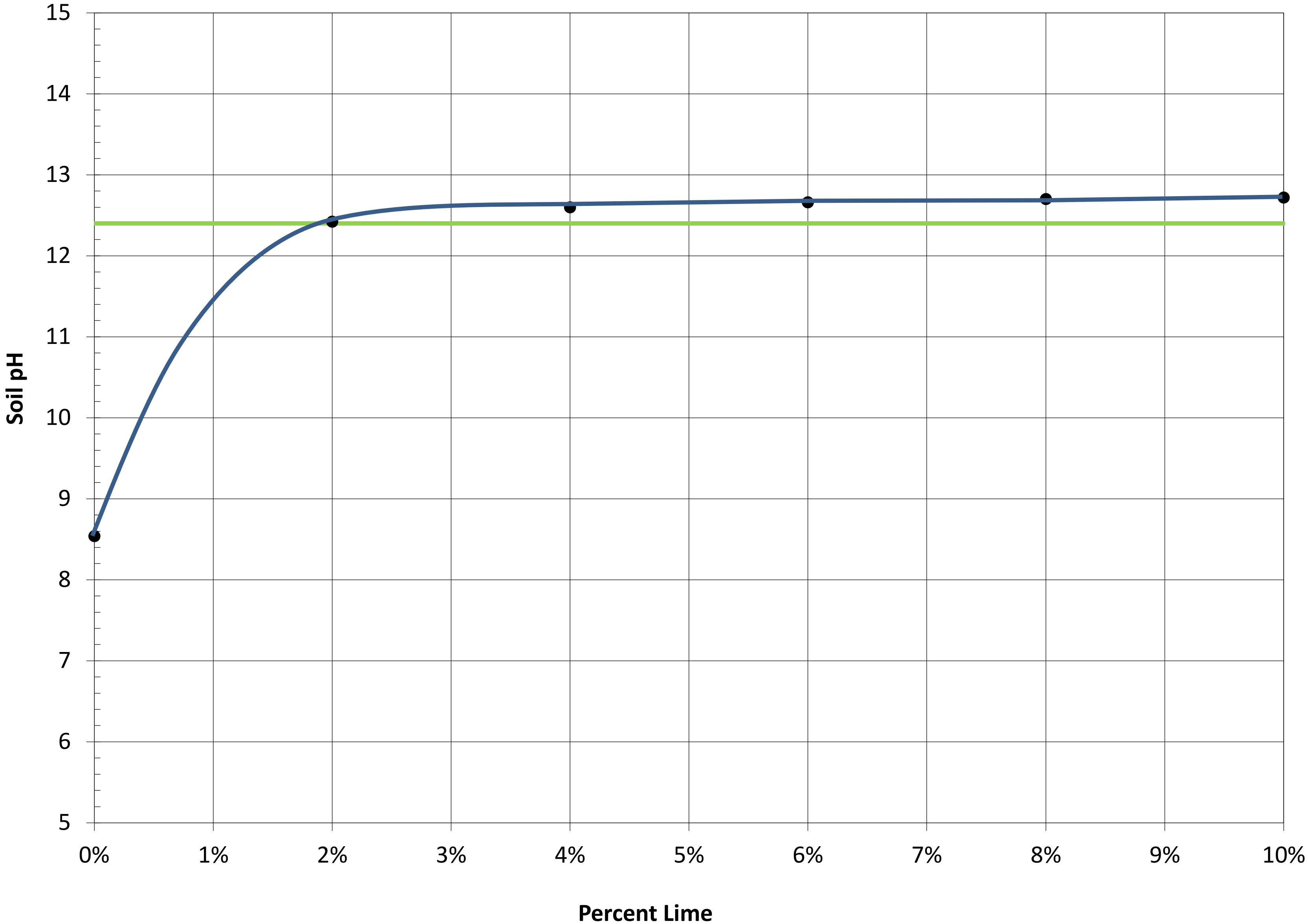
Veramendi Master Planned Development, Roadway C – Phase 1, New Braunfels, Texas

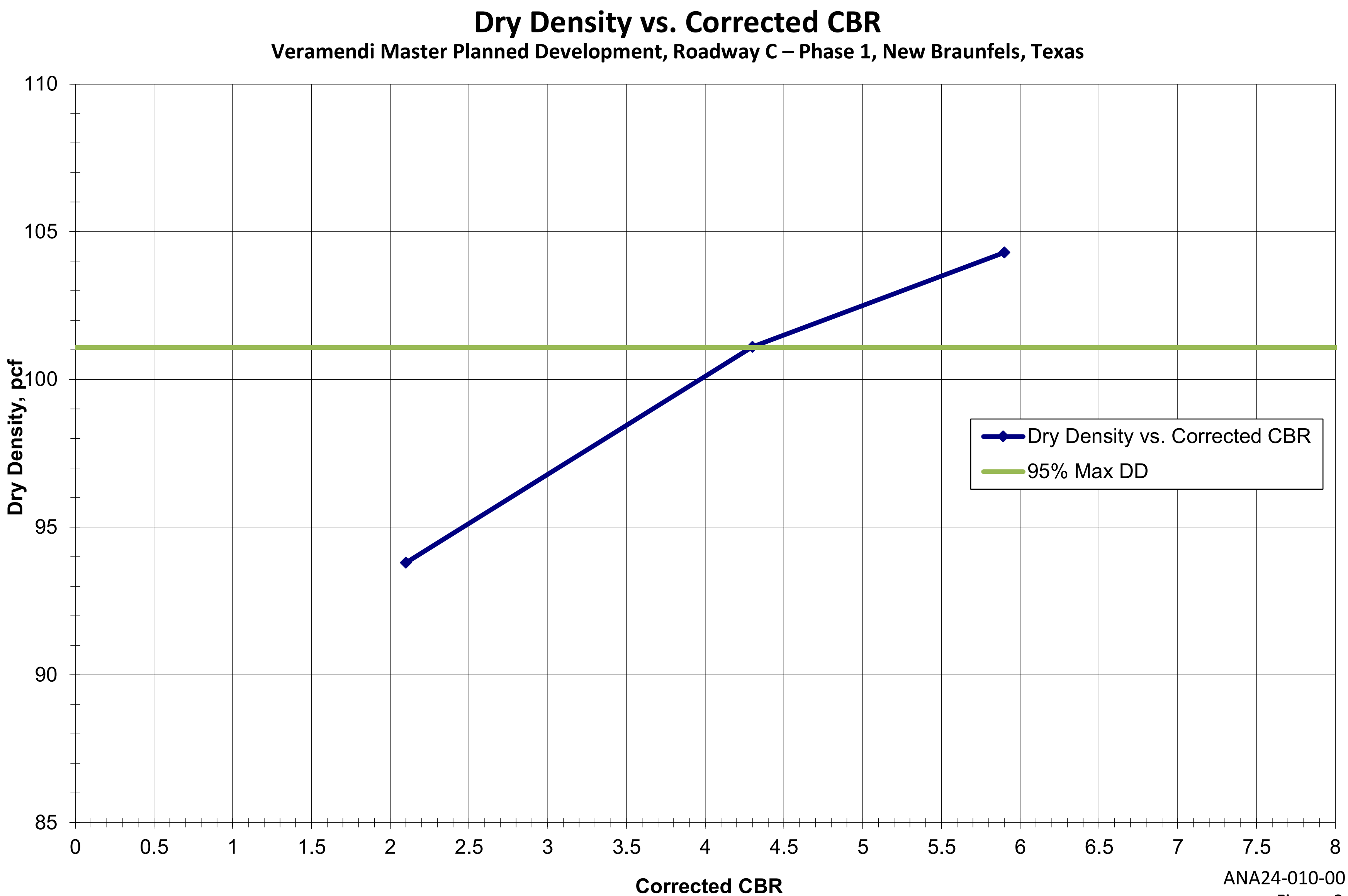


Optimum Moisture Content (%) =	18.0
Max. Dry Density (pcf) =	106.4
Calculated CBR =	4.3
Avg. %Swell =	0.3

pH-LIME SERIES CURVE

Veramendi Master Planned Development, Roadway C – Phase 1, New Braunfels, Texas





ANA24-010-00
Figure 8

Project Number: ANA24-010-00

Test Date: March 26, 2024

DCP TEST DATA

P-1

Veramendi Master Planned Development

Roadway C – Phase 1

New Braunfels, Texas

Type of Ham.	No. of Blows	Penetration		CBR	M_R	q_{ult}
		Incre. (mm)	Cumm. (in)	(%)	(ksi)	(ksf)
1	1	10	0.4	22	33	4.25
1	1	20	1.2	10	15	2.52
1	1	15	1.8	14	21	3.15
1	1	10	2.2	22	33	4.25
1	1	10	2.6	22	33	4.25
1	1	15	3.1	14	21	3.15
1	1	10	3.5	22	33	4.25
1	1	5	3.7	48	72	7.14
1	1	5	3.9	48	72	7.14
1	2	5	4.1	105	157.5	12.01
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
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-	-	-	-	-	-	-
-	-	-	-	-	-	-
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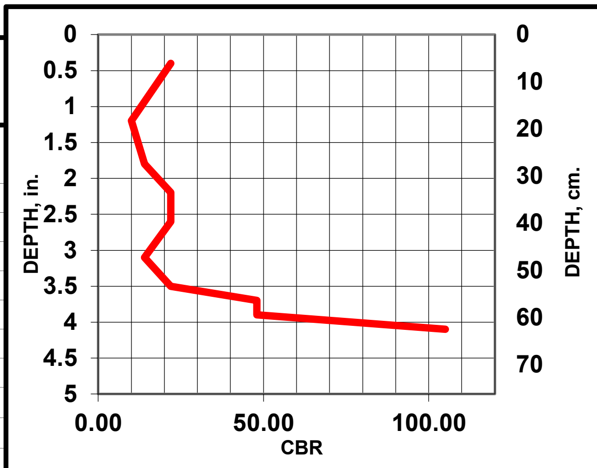
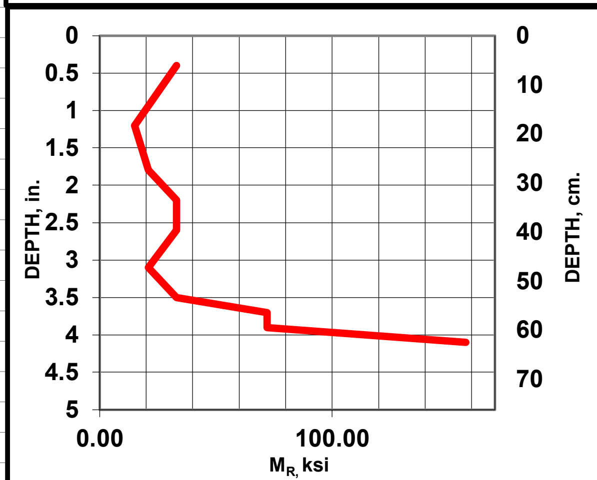
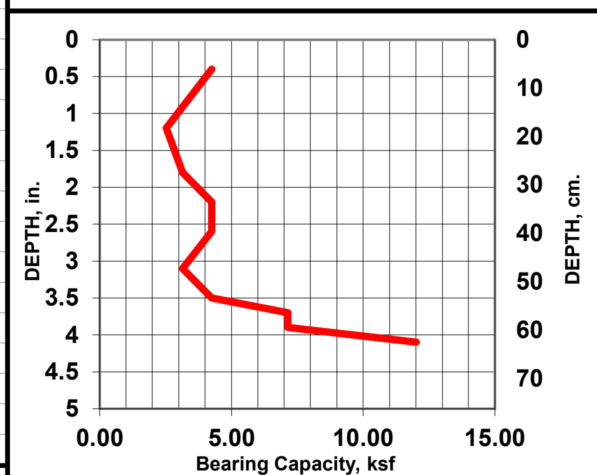
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

NOTES: Hammer 17.6 lbs = 1 Hammer 10.1 lbs = 2







Project Number: ANA24-010-00
Test Date: March 26, 2024

DCP TEST DATA

P-2
Veramendi Master Planned Development
Roadway C – Phase 1
New Braunfels, Texas

Type of Ham.	No. of Blows	Penetration Incre. (mm)	Penetration Cumm. (in)	CBR (%)	M_R (ksi)	q_{ult} (ksf)
1	1	10	0.4	22	33	4.25
1	1	10	0.8	22	33	4.25
1	1	10	1.2	22	33	4.25
1	1	20	2	10	15	2.52
1	5	5	2.2	292	438	23.69
1	3	10	2.6	76	114	9.69
1	5	5	2.8	292	438	23.69
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
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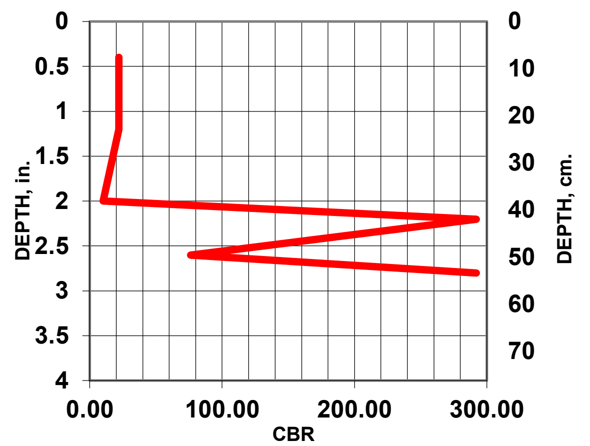
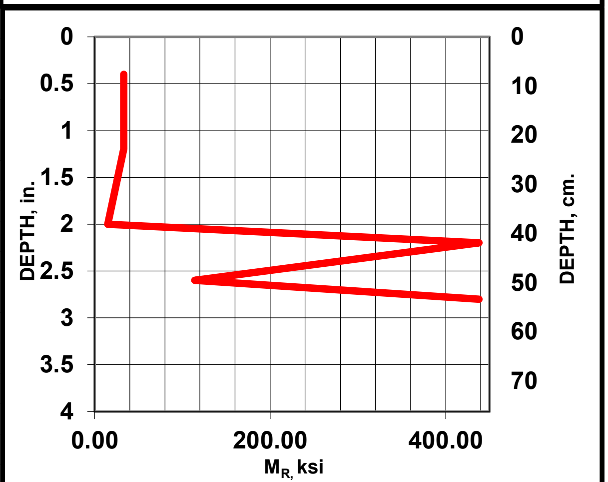
-	-	-	-	-	-	-
-	-	-	-	-	-	-

NOTES: Hammer 17.6 lbs = 1 Hammer 10.1 lbs = 2





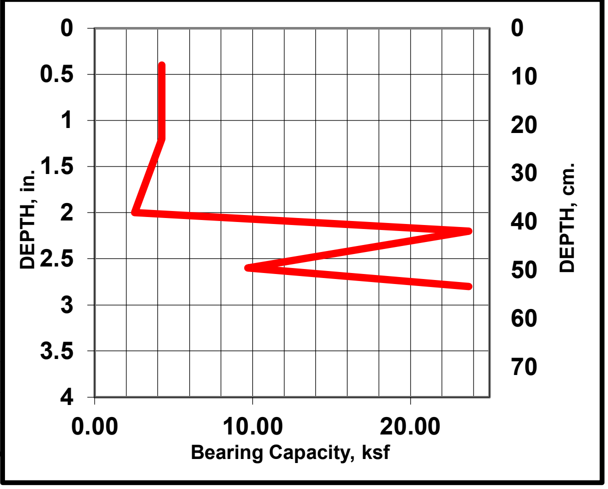


Figure 9b

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a civil engineer may not fulfill the needs of a constructor — a construction contractor — or even another civil engineer. Because each geotechnical- engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. No one except you should rely on this geotechnical-engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply this report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical-engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

Geotechnical Engineers Base Each Report on a Unique Set of Project-Specific Factors

Geotechnical engineers consider many unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk-management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical-engineering report that was:

- not prepared for you;
- not prepared for your project;
- not prepared for the specific site explored; or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical-engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse;
- the elevation, configuration, location, orientation, or weight of the proposed structure;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical-engineering report is based on conditions that existed at the time the geotechnical engineer performed the study. *Do not rely on a geotechnical-engineering report whose adequacy may have been affected by*: the passage of time; man-made events, such as construction on or adjacent to the site; or natural events, such as floods, droughts, earthquakes, or groundwater fluctuations. *Contact the geotechnical engineer before applying this report to determine if it is still reliable.* A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ — sometimes significantly — from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide geotechnical-construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are Not Final

Do not overrely on the confirmation-dependent recommendations included in your report. *Confirmation-dependent recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations *only* by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's confirmation-dependent recommendations if that engineer does not perform the geotechnical-construction observation required to confirm the recommendations' applicability.*

A Geotechnical-Engineering Report Is Subject to Misinterpretation

Other design-team members' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Constructors can also misinterpret a geotechnical-engineering report. Confront that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing geotechnical construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical-engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make constructors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give constructors the complete geotechnical-engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise constructors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure constructors have sufficient time* to perform additional study. Only then might you be in a position to give constructors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and constructors fail to recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Environmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform an *environmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical-engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold-prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, many mold- prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical- engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; *none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.*

Rely, on Your GBC-Member Geotechnical Engineer for Additional Assistance

Membership in the Geotechnical Business Council of the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you GBC-Member geotechnical engineer for more information.

GBC GEOTECHNICAL BUSINESS COUNCIL
of the Geoprofessional Business Association

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