CHAPTER 2
SITE CHARACTERIZATION

2.1 INTRODUCTION

Site characterization is the process of defining subsurface soil and rock units and their physical and engineering properties. For drilled shafts, site characterization information is used for two general purposes: (1) analyzing shaft resistance and load-deformation response for design, and (2) evaluating construction feasibility, costs, and planning. A well planned site characterization makes it possible to design reliable, economical, and constructible drilled shaft foundations that will meet performance expectations. Inadequate site characterization can lead to uneconomical designs, costly construction disputes and claims, and foundations that fail to meet performance expectations. This chapter describes information requirements specific to the design and construction of drilled shafts, considerations for developing appropriates scopes for site characterization investigations, and special site characterization requirements for drilled shafts to promote effective selection, design, and construction. Means and methods for characterizing sites and for establishing important geotechnical design parameters are not addressed in the chapter. Comprehensive guidance regarding means and methods for conducting site investigations is provided in the AASHTO Subsurface Investigations Manual (AASHTO, 1988). FHWA's Geotechnical Engineering Circular No. 5 (GEC 5) – Geotechnical Site Characterization (Loehr, et al., 2017) provides comprehensive guidance for planning and executing site characterization investigations, for establishing appropriate values for design parameters, and for documenting and communicating results from site characterization investigations. These references should be consulted along with the guidance provided in this chapter when planning and executing site characterization for projects involving drilled shafts.

2.2 INFORMATION REQUIRED FOR DESIGN OF DRILLED SHAFTS

Effective site characterization programs should provide all information needed to develop practical and efficient designs for drilled shafts for costs that are commensurate with the risks involved. Table 2-1 summarizes site characterization information that is commonly needed for design of drilled shafts. The required information is divided into four general categories: (1) subsurface stratigraphy, (2) groundwater conditions, (3) classification of soil and rock, and (4) design parameters. Additional information required specifically for constructability is described in Section 2.3.

Stratigraphy is important for design because it often drives considerations of feasibility and because it directly influences the design resistance and performance of drilled shafts, as well as the means and methods of drilled shaft installation. Site characterization programs should therefore identify the types of soil and/or rock present at a site, separate the subsurface into discrete strata, and characterize how these strata vary across the site. Interpretations of stratigraphy are commonly derived from observations and measurements from borings and in situ test soundings. However, geophysical surveys can often be effectively used to improve interpretations of stratigraphy, especially when combined with information from borings and in situ test soundings. Seismic refraction and electrical resistivity methods can be particularly effective for helping to interpret depth to rock, which is often an important consideration for drilled shafts used to support bridges and other transportation structures.

Accurate knowledge of groundwater conditions is needed for drilled shaft design in order to properly assess the state of effective stress. Effective stress methods are used for evaluating side and tip resistance in cohesionless soils for design under axial loading (Chapter 10), for computing *p-y* curves for design under lateral loading (Chapter 9), and for assessing liquefaction of soil deposits under earthquake loading (Chapter 9). Information regarding groundwater conditions is often derived from observing groundwater levels in exploratory borings, especially when groundwater conditions are relatively straightforward (e.g., hydrostatic groundwater conditions) and when water levels in borings respond quickly to conditions in the surrounding ground. However, for more complex conditions or when water levels in borings do not respond quickly, groundwater monitoring wells and piezometers, as well as in situ measurements of pore water pressure (e.g., from piezocone soundings) are necessary to accurately characterize conditions. Groundwater conditions are also commonly time varying, so it is important that measurements made for interpreting groundwater conditions provide some assessment of the expected magnitude of variations over time.

TABLE 2-1 SUMMARY OF INFORMATION NEEDED FOR DRILLED SHAFT DESIGN

Information	Parameter	Subsurface Material		
		Coarse-grained Soils	Fine-grained Soils	Rock
Stratigraphy		✓	✓	✓
Groundwater		✓	✓	✓
Classification	Gradation	✓	✓	
	Atterberg Limits		✓	
	Moisture Content	✓	✓	
	Unit Weight	✓	✓	✓
	RQD and Core Recovery			✓
	Slake Durability Index			✓
Design Parameters	Effective Stress Friction Angle	✓	✓	
	Undrained Shear Strength		✓	
	Preconsolidation Stress	✓	✓	
	Soil Modulus	?	?	
	Uniaxial Compressive Strength			✓
	Intact Rock Modulus			✓
	Rock Mass Modulus			✓
	In situ test parameters	?	?	?

Items indicated as “?” are sometimes used instead of, or in addition to other parameters indicated.

Classification of soil and rock is important for design for several reasons. Soil and rock classifications are often a primary source of information for interpreting stratigraphy, and for evaluating the consistency of conditions from one area of a site to another. Soil and rock classifications also often dictate specific methods that should be used for design, and the associated design parameters that should be characterized. Additionally, soil and rock classification information is often useful for identifying potential concerns that must be considered during design. For example, classification of a soil as high plasticity clay suggests the potential for substantial shrink-swell behavior that should be considered in design.

Finally, site characterization programs should be sufficient to establish reliable values for specific design parameters in each identified stratum. The specific design parameters needed will generally depend on the type of soil/rock present as well as the specific design method adopted for different materials. Design parameters for some materials and methods can be derived from laboratory tests on samples collected by boring and sampling. Design parameters for other methods, particularly those developed for materials that are difficult to sample (e.g., clean sands, highly weathered or fractured rock), are often based on in situ test measurements such as the cone penetration test (CPT) and the standard penetration test (SPT). Additional guidance regarding interpretation of specific design parameters is provided in Section 2.5 and in GEC 5 (Loehr, et al., 2017).

An important consideration for site characterization activities for drilled shafts is that many drilled shaft design methods are empirical methods that relate drilled shaft performance to some specific form of measurement (e.g. undrained shear strength, CPT tip resistance, etc.). Because the methods are empirical, it is important that design parameters be established using measurements that are consistent with the empirical design relations. Use of site characterization methods that are inconsistent with the empirical methods can have unintended and undesirable consequences. For example, commonly used methods for predicting unit side resistance in clays relate unit side resistance to undrained shear strength, which is known to be subject to varying degrees of bias as a result of sample disturbance. Many common empirical methods are developed using "typical" boring and sampling techniques (often from unconsolidated-undrained triaxial tests on 3-inch diameter Shelby tube samples). These empirical methods therefore inherently incorporate effects of "typical" sample disturbance. If alternative methods are used to characterize undrained shear strength for design (e.g., using the SHANSEP approach that greatly reduces effects of disturbance), one might remove an inherent bias in the empirical design method and actually produce designs that are less reliable than desired despite the fact that more accurate interpretations of undrained shear strength will be produced. The converse outcome also applies if inferior methods are used to characterize undrained shear strength, in which case designs will tend to have reliability that is greater than desired. It is therefore important that site characterization be performed to produce measurements that are consistent with those used to develop the empirical methods that will be used for design.

2.3 INFORMATION REQUIRED FOR CONSTRUCTION OF DRILLED SHAFTS

Additional information beyond that needed for design is usually required by both contractors and engineers for the purpose of establishing appropriate construction methods, selecting proper tools and equipment, making cost estimates, preparing bid documents, and planning for construction. This aspect of site characterization cannot be overemphasized, considering that: (1) the most frequently cited cause of drilled shaft failure is improper construction; and (2) subsurface conditions represent a significant source of construction claims, change orders, and cost overruns (Boeckmann and Loehr, 2016). It follows that careful attention to acquisition and communication of all pertinent information about subsurface conditions can reduce risks of poor performance and the potential for claims, change orders, and cost overruns. Examples of information required specifically for construction are given in Table 2-2.

Drilled shafts bearing on or socketed into rock pose special challenges for construction (Turner, 2006). Many designers assume the tip of the shaft will bear on relatively sound or intact rock and that measures will be taken during construction to verify that assumption. It is critical for both the designer and contractor to have a common understanding of what constitutes adequate bearing conditions in rock and what measures will be taken to locate the shaft tip at the proper elevation. Exploratory drilling conducted at the shaft location prior to construction should include rock coring to a depth that is sufficient to determine that the rock is not a cobble or boulder ("floater"), to evaluate rock quality, and to evaluate the potential for solution cavities or zones of decomposed rock. Boring logs should include clear indication of the depth to acceptable bedrock. If coring into rock is not done prior to construction, it may be necessary to core the rock within and below the rock socket for each drilled shaft during construction to confirm rock quality. For both cases, it is advisable to establish agreement on two issues prior to construction. First, there must be clearly defined criteria for what constitutes adequate rock quality. The criteria could be based on factors such as core recovery, RQD, rock strength, degree of weathering, or other parameters that can be objectively determined. Second, there must be a clear understanding regarding how to proceed when coring reveals conditions that do not meet the established criteria. This might involve excavation to greater depth. It then becomes necessary to define the method of payment for additional excavation beyond the anticipated depth.

TABLE 2-2 INFORMATION USED FOR DRILLED SHAFT CONSTRUCTABILITY

Application	Information
Selection of appropriate drilling equipment and tools for excavation	• Presence, size, distribution, and hardness of cobbles and boulders • Obstructions such as old foundations, pipes, construction rubble, trees, etc. • Rate of advancement of exploratory boreholes • Torque and crowd of the drilling machine used for exploration • Tools and methods used for sampling • Characteristics of rock mass (depth, strength, hardness, fracturing, RQD, weathering, etc.)
Selection of appropriate methods and materials for excavation support (dry, casing, slurry, combined)	• Cohesionless soils below water table; grain size distribution for coarse-grained soils, including percentage of fines (to assess suitability of polymer slurry use) • Location of free water or seeps, rate of groundwater inflow, and piezometric levels; proximity of surface water infiltration sources (river, lake, ocean) • Presence of artesian groundwater conditions in confined aquifers • Methods of support used for exploratory borings (drilling mud, casing, other); observations of caving (stand-up time); observations of fluid loss • Hardness, pH, and chloride content of groundwater (for slurry construction) • Environmental restrictions on use and disposal of slurry
Match field inspection (quality assurance) procedures with construction procedures	• Anticipated base conditions and requirements for base cleanout • Anticipated Integrity Testing methods • Potential use of specialized inspection tools (borehole calipers, Shaft Inspection Device (SID), downhole cameras, etc.) • Need for supplemental borings/rock cores during construction

In some regions, the depth to bedrock and weathering of rock can be extremely variable. For example, in some karstic environments the rock surface may be pinnacled and highly variable both laterally and vertically as illustrated in Figure 2-1. When such conditions are encountered, it may not be practical to confidently establish tip elevations for individual drilled shafts prior to construction. In such cases, site characterization activities should strive to clearly identify that highly variable conditions are present, to characterize the anticipated variability to the extent possible, and to clearly communicate that highly variable conditions are present so that designers and constructors are aware of the conditions and can take appropriate measures for design and construction. Additional site characterization, which may include completion of pilot holes prior to excavation of individual drilled shafts, coring and probing beneath the tips of drilled shafts, and visual inspection of shaft excavations prior to placing concrete, should then be required during construction to establish final bearing depths.

It is important to recognize that establishing the suitability of rock for meeting design requirements is not equivalent to defining rock for purposes of excavation and payment. A contractor has a right to be paid for rock excavation regardless of its quality as a bearing material, and pay quantities should not be based on suitability of the rock for an engineering design function.

Inadequate characterization of groundwater conditions is one of the most common and costly sources of construction claims, change orders, and cost overruns (Boeckmann and Loehr, 2016). Careful attention should therefore be paid to characterizing groundwater conditions, especially when conditions involve artesian conditions or high rates of seepage. Artesian conditions and zones of high seepage should be clearly indicated on boring logs and described in geotechnical reporting documents. In rock formations, water inflow to a bored hole is controlled by seepage along discontinuities. This type of flow can vary significantly over short distances and can be a critical factor in drilled shaft construction. It is also not uncommon to observe high seepage rates in one borehole or drilled shaft excavation and little or no seepage in an adjacent hole just a short distance away. It is, therefore, important to observe and record rates of water inflow to exploratory boreholes in rock, and to communicate those observations to potential contractors for estimating the potential for water inflow during drilled shaft construction. Loss of drilling fluids within exploratory borings, and the depths at which such loss occurs, should also be recorded since such conditions may be indicative of cavities or voids that may lead to loss of slurry or concrete during drilled shaft construction.

Figure 2-1 Example of extremely variable rock formation in karstic region.

Where subsurface contamination is detected or anticipated, special measures may be required to ensure worker safety and safe disposal of contaminated cuttings and drilling fluid. When these factors are known beforehand and made clear to all parties, proper measures can be incorporated into construction plans and appropriate payment provisions can be included. When contamination problems are discovered during construction, costs for addressing safety and disposal issues can be significantly greater, involving schedule impacts as well as increased drilling and disposal costs.

An effective way to obtain essential information on drilled shaft constructability is to install one or more full-sized test excavations, referred to as a “technique shaft” (also as a “method shaft” or “trial shaft”) during the design phase or at the start of construction. A technique shaft should be of sufficient depth and diameter to reveal problems and difficulties likely to be encountered by a contractor installing production shafts at the same site. Examples of information that may not be obtained easily from exploratory borings but will be obvious during technique shaft construction include: (a) caving or squeezing soil, especially if wash-boring techniques or rotary drilling with casing are used for site investigation, (b) presence of cobbles or boulders that could easily be missed by a small-diameter boring or be mistaken for a layer of rock, (c) elevation at which water will flow into the excavation and the rate of water inflow, and (d) conditions at the shaft tip and effectiveness of base cleanout methods. If there are questions pertaining to placement of reinforcing cages or concrete, a technique shaft can be carried through these stages of construction as well. Technique shafts can also provide important data for design, for example, the degree of sidewall roughness for shafts in rock. It may also be possible to conduct in-situ tests, take downhole photographs or videos, and verify assumptions about tip conditions, all of which can be important for evaluating design parameters. A technique shaft can also be combined with a design-phase load test, providing a wide range of design and constructability information and reducing uncertainty during final design. During construction, however, it is typical to complete the technique shaft prior to installing the test shaft so any modifications to means and methods derived from construction of the technique shaft can be applied to the test shaft and reflected in load test results.

The information described above and collected specifically for constructability must be made available to bidders to provide them with a basis for making improved cost estimates, and to avoid potential claims related to the withholding of project information. The same information is also needed by the engineer to forecast potential construction methods and construction problems in order to develop specifications for the project, make cost estimates, and perform risk analysis.

2.4 RECOMMENDED MINIMUM SCOPE FOR GEOTECHNICAL INVESTIGATIONS

The scope of a site characterization program should be determined by the complexity of ground conditions, foundation loading characteristics, size and structural performance criteria for the bridge or other structure, acceptable levels of risk, experience of the agency, constructability considerations, and other factors. The primary source of information concerning loading characteristics and the structure will be the Bridge and Structures Office of the state or local transportation agency. Any preliminary plans developed by the structural engineer should be studied and the geotechnical engineer should coordinate directly with the structural engineer and other project staff, preferably through periodic meetings with the design team.

Some information needed to appropriately scope site characterization activities may only be known following a preliminary study of the site. For this reason, site characterization for drilled shaft projects may be carried out through a phased characterization program as described in GEC 5 (Loehr, et al., 2017). Such phased investigations typically include collection of existing site data and geologic information, preliminary investigations intended to identify and characterize soil/rock type and general stratigraphy, followed by one or more detailed investigations intended to refine preliminary interpretations and establish values for design parameters. When properly planned, phased investigations can provide sufficient and timely subsurface information for each stage of project development while limiting the risk and cost of unnecessary explorations. Phased investigations are also fundamental to design-build projects wherein initial investigations are conducted prior to bidding to sufficiently define conditions for preliminary design, and additional investigations are performed by the design-builder after contract award for final design and construction. In the overall design process for drilled shafts presented in Chapter 8 (see Figure 8-1), collection of existing data and preliminary investigations comprise Step 2: Define Preliminary Project Geotechnical Site Conditions. More detailed site characterization constitutes Step 4: Develop and Execute Subsurface Exploration and Laboratory Testing Program for Feasible Foundation Systems. Additional site exploration could be required during construction in some cases.

Article 10.4 of the AASHTO LRFD Bridge Design Specifications (AASHTO, 2017a) includes provisions for site characterization and establishing soil and rock properties for foundation design. Article 10.4 recommends a minimum of one boring per substructure (pier or abutment) at bridge sites where the width of the substructure is 100 ft or less and at least two borings for substructures over 100 ft wide for bridge foundations in general. For drilled shafts, it is often desirable to locate a boring at every drilled shaft, especially when the shafts will be founded on or socketed into rock. In practice, this is not always feasible and factors such as experience, site access, subsurface variability, geology, and the importance of the structure will be considered. For multi-shaft foundations composed of smaller diameter shafts (say 6 feet or less) supporting routine bridges in relatively consistent ground conditions, the minimum requirements provided in the AASHTO specifications are likely sufficient. However, similar multi-shaft foundations with larger diameter shafts or more variable subsurface conditions likely justify greater numbers of borings to characterize the volume of ground that will encompass the multi-shaft foundation. For example, for groups of four or more drilled shafts, one should consider placing borings at the locations of the four corner shafts in each group. Additional borings within interior of the group should also be considered for larger groups unless ground conditions are known to be particularly uniform. For foundations where a single column is supported on a single shaft, borings should be made at the location of every shaft. Borings should also be made at each shaft location when subsurface conditions exhibit extreme variations over short distances, such as can be encountered in karstic limestone or degradable rock formations.

The scope of design phase investigations may also depend on plans for QA/QC during construction. For example, at sites where depth to rock or the condition of rock is highly variable, it may be prudent to require sufficient design-phase borings to capture the potential variability that will be encountered during construction but to complete additional borings as "probe holes" during construction. In such cases, the final shaft depth can be established during construction based on information obtained from the probe holes, and the number of borings required prior to design may be accordingly reduced. In extreme cases, the Florida Department of Transportation has sometimes even required multiple probe holes within a single, large diameter shaft founded in highly variable rock. Figure 2-2 shows illustrations of extreme variability in hard pinnacled limestone that might warrant multiple probe holes during construction for large diameter shafts.

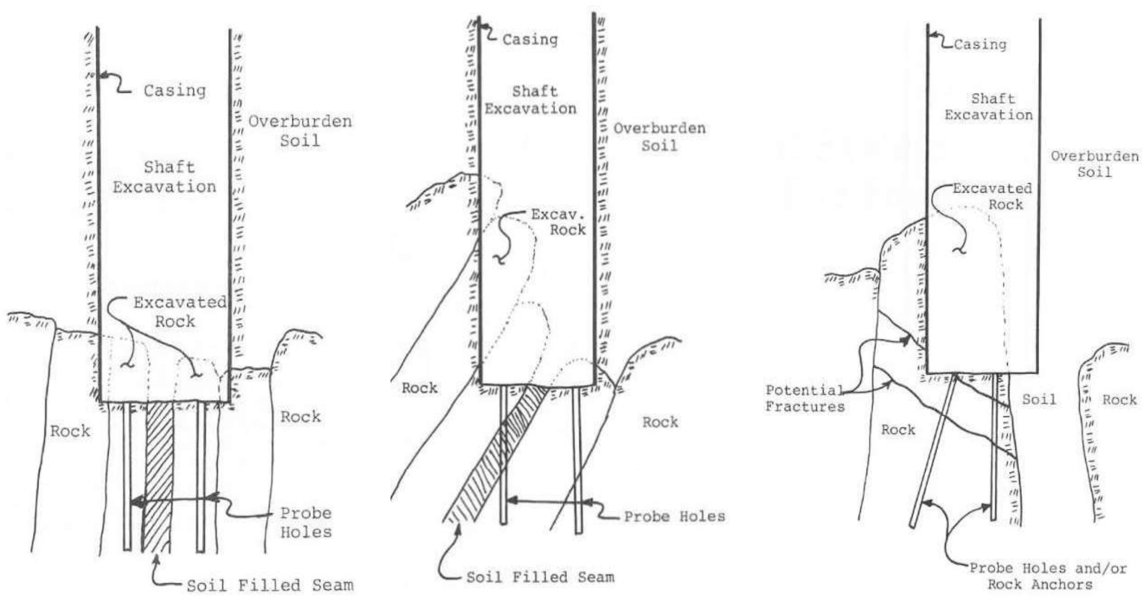

Figure 2-2 Extreme conditions at tip of drilled shafts in hard pinnacled limestone (Brown, 1990).

For secant/tangent pile retaining walls and retaining walls supported on drilled shafts, a minimum of one boring is required for walls up to 100 ft long, and a minimum of two borings is required for walls with lengths of 100 to 200 ft.. For walls greater than 200 ft length, the spacing between borings should be no greater than 200 ft. Additional borings should be considered in front and behind the wall line to define conditions at the toe of the wall and in the zone behind the wall to estimate lateral loads and anchorage capacities, and for global stability analyses. The same considerations identified above for bridge foundations at highly variable sites also apply to drilled shafts for retaining walls.

AASHTO (2017a) recommends the following for depth of borings, for both bridge foundations and retaining walls:

> 'In soil, depth of exploration should extend below the anticipated pile or shaft tip elevation a minimum of 20 ft, or a minimum of two times the maximum pile group dimension, whichever is

deeper. All borings should extend through unsuitable strata such as unconsolidated fill, peat, highly organic materials, soft fine-grained soils, and loose coarse grained soils to reach hard or dense materials'.

'For shafts supported on or extending into rock, a minimum of 10 ft of rock core, or a length of rock core equal to at least three times the shaft diameter for isolated shafts or two times the maximum shaft group dimension, whichever is greater, shall be extended below the anticipated shaft tip elevation to determine the physical characteristics of rock within the zone of foundation influence. Note that for highly variable bedrock conditions, or in areas where very large boulders are likely, more than 10 ft. of rock core may be required to verify that adequate quality bedrock is present.'

The scope for geotechnical investigations should also consider the need to acquire sufficient numbers of test measurements to reliably establish geotechnical design parameters and assess the variability and uncertainty of those parameters. Guidance regarding interpretation of geotechnical design parameters and the reliability of those parameters is provided in GEC 5.

The above recommendations for borings in soil and rock to be made to two times the maximum group dimension may not be practical or necessary in all cases. For example, if a group of shafts is designed so that tip elevations correspond to the top of rock and the rock mass is known to be competent material, there is no need to extend borings beyond three shaft diameters into the rock. In rock, geologic knowledge based on experience should always take precedence over general guidelines such as those provided here. In rock mass that is known to be uniform and free of cavities, voids, weathered zones, etc., it may not be necessary to drill more than one diameter (10-ft minimum) below the design tip elevation. On the other hand, in highly variable rock mass containing solution cavities, weak zones, boulders in a soil matrix, or other potentially adverse features, borings may need to extend as deep as necessary to verify competent bearing layers. All of the recommendations cited above, for both frequency and depth of borings, are subject to modification based on the level of geologic knowledge of the site and subsurface variability. In general, the more uniform the subsurface conditions and the more experience the geotechnical engineer has with those conditions, the fewer borings are required. For sites with highly varying geologic conditions, where there is little prior experience, a greater number of borings and/or deeper borings may be warranted.

2.5 INTERPRETATION OF GEOTECHNICAL DESIGN PARAMETERS AND REPORTING

Values for geotechnical design parameters should generally be determined according to guidance provided in GEC 5 (Loehr, et al., 2017). When used with AASHTO LRFD methods (or other similarly established design methods), design parameters should generally be selected to represent the mean value of the parameter within a stratigraphic unit. Additionally, the uncertainty in design parameters should be evaluated to ensure that design parameters have appropriate reliability for use with the LRFD methods. In situations where insufficient measurements are available to produce reliable estimates of the mean value for the parameter, a conservative estimate for the parameter should instead be used, as described in GEC 5.

When selecting values for design parameters derived from in situ test measurements, care should be taken to establish whether the in situ measurements are being used as “direct” or “indirect” measurements as described in GEC 5. If the in situ test measurements are used to infer values for common engineering properties (e.g., strength parameters, stiffness, etc.) that serve as the basic inputs for the design method, the in situ measurements should be interpreted as being indirect measurements. Conversely, when in situ test measurements serve as the primary inputs to the design method (e.g., a method that directly relates unit side resistance to CPT tip resistance), the in situ test measurements should be interpreted as direct measurements as described in GEC 5.

Geotechnical reports developed for sites where drilled shafts will be used should generally be prepared according to guidance in GEC 5 and Federal Highway Administration GEC 14 (Sheahan, et al., 2016). These reports should document the available subsurface information and the interpretation of these data for design purposes. In addition, as described previously in this chapter, the content of reports addressing constructability can have a dramatic impact on bid prices and the potential for claims, change orders, and cost overruns. Careful attention should therefore be paid to making sure that constructability is addressed in geotechnical reporting documents and that those documents are made available to potential bidders.

2.6 DIFFERING SITE CONDITIONS

A common source of contractor claims on drilled shaft construction projects is "differing site conditions" (DSC). Federal law requires that a DSC clause be incorporated into all Federal-Aid Highway Projects. Drilled shaft construction involves inherent risk of encountering conditions differing from those anticipated due to the complexity and variability of natural earth and rock formations and materials. The purpose of the DSC clause is to provide contractors with legal grounds for recovering costs to which they are rightfully entitled when conditions are encountered that differ materially from what a contractor could reasonably anticipate based on the documents available at the time of bidding. Inclusion of a DSC clause is also intended to induce contractors to limit contingencies in their bids, thus promoting lower initial pricing. The best approach for reducing DSC claims is to conduct a thorough site investigation and to disclose all relevant information to contractors bidding on the project.

Geotechnical Engineering Notebook Issuance GT-15 (FHWA, 1996) was prepared to provide guidance to design and construction engineers on the topic of geotechnical differing site conditions. This guideline provides information on adequate site investigation, disclosure and presentation of subsurface information by highway agencies, and the use of such information in mitigating or resolving contractor claims of differing site conditions. Recommendations are provided for disclosure of factual, qualified, and interpretive geotechnical information. A major point made in GT-15 is that the best way to reduce the risk of geotechnical construction problems is early recognition of geotechnical problems during the design stage and designing accordingly. This normally requires conducting an adequate subsurface investigation in advance of final design.

Complete disclosure of all available subsurface information in contract documents is an important factor in both preventing contractor claims and obtaining fair bids for the work to be performed. Subsurface information may be presented in detail in either the contract documents or made available at a central location for bidder inspection. The amount of subsurface information actually presented and the method of presentation in the contract documents can vary depending on the complexity of the project.

2.7 GEOMATERIALS REQUIRING SPECIAL CONSIDERATION

Some geologic environments pose unique challenges for determining material properties for design of drilled shafts or for drilled shaft construction. Examples include:

- Argillaceous sedimentary rock
- Limestone and other carbonate rocks
- Glacial till

- Piedmont residual soils
- Cemented soils

Experience has demonstrated that the geomaterials listed above may require methods adapted to the specific geologic environment. Suggestions on how to approach characterization of engineering properties for drilled shaft design or construction in these materials are presented in Appendix B. Appendix B also provides detailed descriptions of approaches used successfully by state transportation agencies to design drilled shafts in these challenging geomaterials. Application of the term 'special' does not imply that the materials listed above are encountered infrequently. In some locations, these are the predominant geomaterials in which drilled shafts are used, and can provide excellent support. Rather, the term "special" suggests that procedures for establishing engineering properties may require techniques adapted to the unique material characteristics.

2.8 SUMMARY

This chapter provides guidance for developing and executing site characterization programs for projects that include drilled shaft foundations. The guidance provided in this chapter is intended to be used in conjunction with guidance provided in the AASHTO Subsurface Investigations Manual (AASHTO, 1988), Geotechnical Engineering Circular No. 5 (Loehr, et al., 2017), and Geotechnical Engineering Circular No. 14 (Sheahan, et al., 2016). In the chapter, information requirements for design and construction of drilled shaft foundations are described along with guidance for developing appropriate scopes for site characterization investigations. The importance of differing site conditions (DSC) clauses is also discussed. Finally, several geomaterials that require special consideration for site characterization and design are identified and discussed.