

GeoConstructability

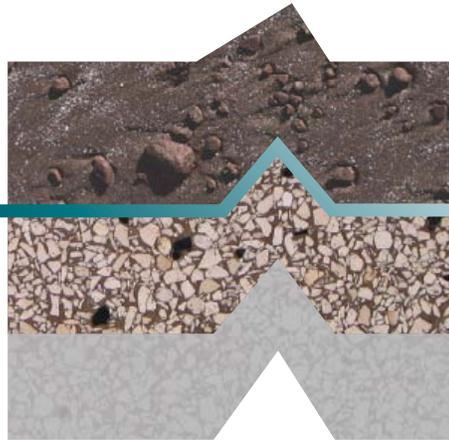
An Owner's Guide to
Obtaining Essential Geotechnical
Information for Construction

- improve project performance
- reduce risk
- encourage innovation
- lower overall project cost



GeoConstructability

An Owner's Guide to Obtaining Essential Geotechnical Information for Construction



- *improve project performance*
- *reduce risk*
- *encourage innovation*
- *lower overall project cost*

Report of the
Geotechnical Constructability Task Force
Geo-Institute of ASCE
August 2011



The Geo-Institute of the American Society of Civil Engineers was founded in 1996 and is an organization of individual scientists, engineers, and technologists who have technical interests in soil, rock, and the fluids they contain. Geo-professionals have the common goals to improve the environment, mitigate natural hazards, and facilitate economical construction of engineered facilities.

Geo-Institute Core Purpose: To advance the geo-professional community.

Geo-Institute Web site: www.geoinstitute.org

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American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4400

www.asce.org

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Introduction

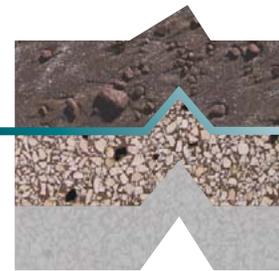
What geotechnical information do project design and construction teams need from owners to better estimate, schedule, design, and construct today's civil engineering projects? This question was identified as a critical issue in geotechnical practice at the 2006 inaugural meeting of the GeoCoalition, an informal association of professional organizations representing key members of the geotechnical design and construction community. The Geo-Institute of ASCE (G-I), a GeoCoalition member, sought to answer this question by creating the GeoConstructability Task Force. To represent their interests, each GeoCoalition member nominated one or two of its own association members who also happened to be G-I members to the task force. This report, which represents the task force's response to its charge, was endorsed by the G-I Board of Governors.

Background

The GeoCoalition is an informal association of professional organizations representing the geotechnical design and construction community. The group comes together once each year to share insights, calendars, and plans for professional activities and to discuss issues of common interest to the constituent organizations. The members of the GeoCoalition (GC) include the International Association of Foundation Drilling (ADSC), the Association of Environmental and Engineering Geologists (AEG), the Geoprofessional Business Association (ASFE), the Deep Foundations Institute (DFI), the Geo-Institute of ASCE (G-I), the Pile Driving Contractors Associations (PDCA), and United States Universities Council on Geotechnical Education and Research (USUCGER). When deemed appropriate, GeoCoalition member organizations may join together to formulate group positions on topics of mutual interest.

The work of this task force represents the first collaborative effort among GeoCoalition member organizations. The task force charge, which is of specific interest to the design and construction community, was to identify what type of information the construction community would like owners to authorize the geotechnical engineer of record to develop prior to preparation of bids on a project. ADSC, AEG, ASFE, DFI, G-I, and PDCA each nominated members of their organizations who also belonged to the G-I to serve on this task force. The task force was funded and managed by the G-I.

The task force's objective was to document the types of geotechnical information that would help contractors develop better estimates and plan



The Geotechnical Constructability Task Force was composed of the following experienced geotechnical consultants and contractors:

Alan Macnab, P. Eng.,
D. GE, Chair
David Albin, P.E.
Allen Cadden, P.E.,
D. GE
David Chapman, P.E.
Don Dolly
Rudolph P. Frizzi, P.E., GE
Christoph Goss, P.E., PhD
Art Hoffmann, P.E.,
D. GE
Bill Laprade, LEG
Jim Melcher
Jim Morrison, P.E.
Dominic Parmantier, P.E.
Gary Rogers, P.E.
Tom Witherspoon, P.E., Ph.D.,
D. GE
Jeremy Zorne, P.E., GE
Edward Kavazanjian, P.E.,
PhD, D. GE, G-I Board of
Governors Liaison

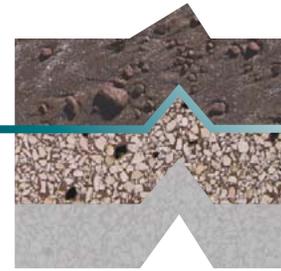
and execute their work with more confidence for the broad range of heavy-civil and building construction projects. The task force focused on how this information would benefit project owners because they commission most geotechnical engineering studies. It is important for owners to realize that contractors do not generally commission their own geotechnical engineering studies because project owners would ultimately pay these costs in the form of higher contractor overhead. As such, contractors depend on owners to furnish them with geotechnical information required for bidding and executing the project. The more comprehensive that information is, the more effective contractors' proposals can be for both the proposed construction procedures and the cost of implementing them. When contractors have limited information, they are forced to deal with increased risk. Building contingencies into their bids and relying on conservative construction procedures are two common techniques contractors use to deal with this risk. Either approach can impose far higher, and wholly avoidable, costs on the owner.

The recommendations in this report can facilitate the collection of more comprehensive and appropriate geotechnical information for cost effective project execution.

While a project's geotechnical engineer may believe that certain additional information would be valuable to contractors and would reduce the owner's risk of unanticipated conditions, only the geotechnical engineer's client (usually the owner or his designated representative) can authorize the study needed to obtain more comprehensive information. Therefore, the task force, composed of experienced geo-professional consultants and contractors, agreed that this report should be concise and be directed to owners. The report does not cover how the desired geotechnical information should be collected. It focuses on the information construction engineers need to properly plan and execute a project.

By improving the understanding of contractors' information needs and the benefits of obtaining this information, we hope that this report can help facilitate the collection of more comprehensive and appropriate geotechnical information for cost-effective project execution. This report was created to help design teams explain to project owners the need and value of an appropriate scope of work in a construction project.

Geotechnical Reports



Types of Geotechnical Reports

Geotechnical reports are prepared for various purposes, including the planning, design, and construction phases of civil works projects. While a report often may accommodate two or more of these purposes, it is rare for a single report and its associated subsurface study program to suffice from project inception to project completion. In fact, due to the owner's financial considerations, geotechnical studies are often limited to the specific objectives of a particular project phase. Hence, on most projects, multiple phases of study are required to take a project from inception to completion.

It is rare for a single report and its associated subsurface study program to suffice from project inception to project completion.

Table 1 identifies several common types of geotechnical reports for which subsurface studies are prepared, including their associated objectives and general characteristics. Please note that this list is not intended to be exhaustive or mutually exclusive. Geotechnical studies are conducted and reports are prepared for a wide variety of purposes, and projects often have multiple phases of study, planning, and design. Furthermore, different phases of investigation may be combined into a single report.

The reports in Table 1 specifically targeted toward construction engineering (report types 5, 6, and 7: the geotechnical constructability memorandum, geotechnical data report, and geotechnical baseline report) are the least common types of reports prepared for construction projects, even though they generally are the only ones that specifically address constructability concerns in a comprehensive manner.

Limitations of Geotechnical Reports

Project constructability considerations are often not taken into account, even in final design geotechnical exploration reports, due to a variety of factors, including the focus of the design team on design issues, financial pressure to minimize costs, lack of information on project components, and rote “rules of thumb” on geotechnical exploration costs.

Project constructability considerations are often not taken into account, even in final design.

The financial pressures that typically restrict geotechnical studies to the specific objectives of a particular development phase often make owners, or their designated representatives, reluctant to authorize additional geotechnical studies for subsequent project phases. For that reason, exploration programs subsequent to final design, including programs in

Table 1. Common Types of Geotechnical Reports

Report Type	Project Phase	Study Objective	Typical Characteristics
1. Geotechnical Site Assessment Summary	Initial Evaluation	Due diligence for property transfer	Limited subsurface study to identify geological hazards, problem soils
2. Geotechnical Feasibility Report	Project Feasibility Study	Identification of potential site uses/ constraints on use	Widely-spaced borings, soundings for site profiling, in situ and laboratory testing for soil classification, geologic reconnaissance
3. Geotechnical Design Memorandum	Preliminary Design	Identify and evaluate design alternatives	Borings, soundings within project footprint, in situ and laboratory tests for soil property characterization, detailed geologic mapping
4. Geotechnical Design Summary Report	Final Design	Detailed design of project elements	Borings, soundings at anticipated structure locations, additional in situ and laboratory tests for property characterization as warranted
5. Geotechnical Constructability Memorandum	Constructability Assessment	Value engineering	Additional exploration at alternative locations, special purpose testing (e.g., to evaluate soil improvement options)
6. Geotechnical Data Report (GDR)	Contract Documents	Contract geotechnical information for construction	Summary of available factual geotechnical information for use by bidders
7. Geotechnical Baseline Report (GBR)	Contract Documents	Contract geotechnical information for construction	Summary of contractual interpretation of geotechnical information for the purpose of establishing the basis of contract

support of value engineering and constructability reviews, are often not performed, despite the fact that the value they can provide may far exceed the costs typically involved. Accordingly, owners should seek guidance from their geotechnical engineer, from other design team members, and from construction managers about the true cost/benefit involved in a supplemental subsurface study program subsequent to completion of the design phase.

Even if a comprehensive multi-objective study and report are authorized at some point during project design, additional study may subsequently be required due to changes in project scope and/or the inability to anticipate future requirements of subsequent phases. Many projects have wound up in litigation because the locations of project elements changed between the time the design study was conducted and the design was completed, but an additional site study was not conducted at the new locations. Soil properties and profiles were merely projected to the new locations from existing borings.

The common rules of thumb on the cost of geotechnical study and design can also result in inadequate geotechnical study. These rules of thumb (e.g., that the cost of a geotechnical study should be no more than a fixed percentage of the estimated total construction cost) can also have a chilling effect on innovation and value engineering. These rules of thumb suggest that “less is more,” i.e., that studies that reduce the cost of construction by facilitating innovative design should actually be less expensive than conventional study programs. Experience shows that, in fact, the opposite is generally true: spending more money up front in the study and design phases of a project will generally save money over the project life span, either through support of innovative design or avoidance of claims. Owners should recognize that rote geotechnical study and testing protocols are unlikely to provide the information needed for innovative design or for comprehensive evaluation of project alternatives.

As a result of these factors, geotechnical information available to project constructors is often inadequate to support effective bid preparation, thus putting significant risk on the contractors, stifling innovation, and increasing costs to owners, as discussed below.

Impact of Insufficient Geotechnical Information

The geotechnical information developed during the design phases of a project can often be insufficient for the project’s bidding or construction phase. Insufficient geotechnical information typically results in a cumulative shifting of risk and an increase in cost over the project’s life. Insufficient geotechnical information in support of construction engineering simply transfers the risk (and cost) associated with insufficient information to the constructor. The lack of sufficient geotechnical

Many projects have wound up in litigation because an additional site study was not conducted.

Spending more money up front, in the study and design phases of a project, will generally save money over the project life span, either through support of innovative design or avoidance of claims.

information and transfer of risk to the contractor reduces the potential for savings in total (lifecycle) project cost that might be realized with additional geotechnical information. Insufficient geotechnical information almost inevitably results in a higher bid cost for a project and is one of the most common causes of delays and/or claims on civil construction projects.

A phased approach to project execution, while minimizing capital outlays during the early phases of a project, essentially necessitates a phased approach to the geotechnical study. Even if a comprehensive geotechnical study is authorized early in the project, owners must understand that it is difficult, if not impossible, for a geotechnical engineer to anticipate all data needs for construction during the preliminary design phase or even at the start of final design. Resolving the geotechnical uncertainties that arise during design is often deferred to the construction phase. Furthermore, disconnects between designers, their geotechnical specialists, and contractors may result in failure to collect the appropriate information required to support an accurate estimate and to plan and execute the project.

Importance of Addressing Constructability

Because of the issues discussed above, this task force recommends that owners always consider authorizing specific geotechnical studies that address the needs of the construction team (such as report types 5, 6, and 7 from Table 1). These reports, created specifically for the construction team, should be bound into the construction documents or placed in a convenient spot for construction team to review during the bidding period. A document that only addresses design requirements may cause confusion, delay, and excessive and unnecessary claims.

Two brief examples of how the geotechnical design information could be inadequate for construction purposes are given below.

Example 1: Drilled Shafts in Rock

Rock exists at some depth below the ground surface at all sites and often the upper regions of the rock are weathered and fractured. If the rock is close enough to the ground surface and/or the foundation loads are high enough, the preferred foundation system for a building or other structure may be a rock-socketed drilled shaft. To design a rock-socketed drilled shaft foundation, the design engineer needs to know where the top of competent (read unweathered) rock occurs. This information is usually detailed in a geotechnical design report (Type 4). However to construct the rock socket, the contractor may need to excavate tens of feet of rock of various competencies to reach the top of what the engineer considers to be competent rock. Most construction contracts pay for rock excavation based on the difficulty to remove it and the payment limits have little to

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do with whether or not it is “competent rock.” Therefore, if only the top of competent rock is defined in the geotechnical design report, the amount of excavated rock the contractor should be paid for might be seriously underestimated before the work is performed, with the result being a large overrun in costs when actual conditions are exposed.

Example 2: Depth to Groundwater

The engineer designing a building’s basement may need to know the highest predicted level of groundwater beneath the structure to define the buoyant forces acting on the structure’s bottom slab (e.g., structural strength, need for tiedowns) as well as to design waterproofing for the basement. However, the contractor needs to know what to expect at the time of construction. A geotechnical design report that only identifies the current (i.e., at the time of exploration) and/or highest anticipated groundwater levels without additional discussion on when and how likely it is to occur might cause construction engineers to select a far more expensive foundation excavation system (e.g., sheet piling as opposed to soil nailing) than would be required if they could phase the work so that basement construction could occur during periods of low groundwater table levels. Omissions of this type (i.e., a lack of specific information about groundwater and its behavior) can lead to unnecessary expenditures for the owners.

Owners who authorize their geotechnical engineer to provide the contractor with the type of construction engineering information contained in reports type 5, 6, and 7 (see Table 1) are more likely to get on-time projects that are at or close to budget.

Construction Engineering Imperative

The preparation of a geotechnical report that addresses the contractors’ needs is likely to result in more on-time and on- (or close to) budget completion of projects. Owners who authorize their geotechnical engineers to provide the contractor with the type of construction engineering information contained in reports type 5, 6, and 7 (see Table 1) are more likely to get on-time projects that are at or close to budget. The essential types of constructability information that should be included in a project’s geotechnical engineering reports depend on the type of project. The appendices attached to this report provide detailed guidance on the types of information required by the construction engineer for specific types of projects.

Guidance on Geotechnical Information Needed for Construction

This report’s objective is to identify the types of geotechnical information that could help constructors to reduce risks and encourage innovation when preparing bids for, planning, and executing geo-construction projects or project elements (e.g., earthworks, foundation construction). Appendix 1 provides guidance on the types of information that should generally be included in geotechnical reports prepared for construction purposes (e.g.,

geotechnical constructability memoranda, geotechnical data reports, and geotechnical baseline reports) for all types of heavy civil and building construction. Appendices 2 through 10 provide additional guidance of the following specific types of construction projects:

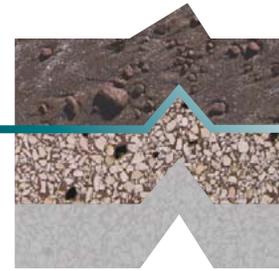
- Appendix 2 Dewatering
- Appendix 3 Deep Foundations
- Appendix 4 Shallow Foundations
- Appendix 5 Mass Excavation and Grading
- Appendix 6 Marine Construction
- Appendix 7 Ground Improvement
- Appendix 8 Slope Stability
- Appendix 9 Anchored Earth Retention
- Appendix 10 Tunneling

The information provided in these appendices is based upon “commonly encountered” project considerations. No project is common. All projects involve a unique set of variations, conditions, requirements, and constraints based on the local geology, site conditions, and project-specific requirements. Owners should encourage open dialog between civil and structural designers, their geotechnical engineers, and constructors during the project’s design and bid phases to identify specific project needs and to facilitate cost-effective project implementation.

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Appendix 1

Common Report Elements



Geotechnical engineering reports that support construction projects such as those listed in Appendices 2 through 10 could improve the construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects, and there may be other information not listed that may be important for specific projects.

Background

- Geotechnical reports prepared for previous projects
- References for existing aerials surveys, geologic maps, and natural resources survey maps
- Site description
- Site history, i.e., past/present uses (undeveloped, agricultural, mining, rural, urban, and industrial)
- Existing onsite/adjacent features (e.g., fills, structures, existing foundations, utilities, vegetation, surface features, outcrops, water courses/bodies, seeps/springs, drainage patterns, slopes, landslide features, erosion features, and irrigation)
- Experience with similar sites
- Proposed improvements (e.g., size, configuration, loading, and elevations)
- Location and capacity of nearby wells

Subsurface Exploration

- Borings to at least a depth sufficient to evaluate the stress regime imposed by the structure or construction scheme proposed
- Water depths, recorded over time, to ensure water-level stabilization
- Other test methods, such as cone-penetrometer test (CPT), pressuremeters, geophysical, test pits, and field permeability, provided that an observable calibration can be obtained (i.e., borings, test pits, etc.)
- Soil/rock classification system used

It is also recommended to provide bidders/constructors a location where they can examine soil and rock samples retrieved in the field soil investigations.

Field Study Methods

- Date(s)/time(s) of exploration
- Locations/elevations of exploration (e.g., borings, trenches, test pits, in-situ test soundings, and geophysical methods)
 - Plotted relative to proposed and existing features/topography
 - GPS coordinates, where possible
- Equipment
 - Drilling rig (type, size, drilling method, auger/bit type, casing, and fluid)
 - Sampler type(s) (e.g. SPT, Shelby tube, and California modified)
 - Hammer type (e.g., automatic, cat-head, wireline, and downhole)
 - Hammer weight and drop
 - Rod type/size
 - Coring equipment (e.g., sonic or conventional, type, size, and run length)
 - Excavation equipment (e.g., type, size, weight, bucket size/type, and ripper)
 - In-situ testing (CPT, DMT, SPT, pocket penetrometer, torvane, and pressuremeter)
 - Geophysical methods (surface seismic refraction, and downhole methods)

Laboratory Testing

- Coarse grained soils
 - Sieves
 - Hydrometer
 - Unit weights
- Fine grained soils
 - Sieves with wash
 - Unit weights
 - Atterberg limits
 - Water content
 - Unconfined compression tests
- Organic soils
 - Loss on ignition
 - Moisture content
- Rock
 - Type
 - UCS
 - RQD
 - Jointing

- All soils and rock
 - Aggression potential, pH, and corrosion potential

Subsurface Condition Discussion/ Recommendations

- Regional geology/hydrogeology
 - Formation(s)/structure/bedding/faulting
 - Hydrogeology/hydrology (regional groundwater, past/present groundwater elevations, drainage courses/bodies, and surface seeps/springs)
 - Unusual/exceptional local meteorological conditions at the time of exploration
- Site geology
 - Onsite formation(s) – described in top down order, thickness of units, and layering
 - Geologic cross-sections
 - Annotated photographs of geologic units (if exposed)
 - Rock core photos

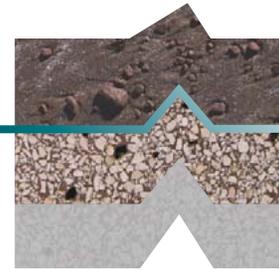
Other Relevant Information

The geotechnical engineer often is not responsible for providing certain types of information that is of great importance and must be transmitted to the construction team. In addition, the documents communicated to the construction team that detail these items must reflect a clear understanding and acknowledgement of the information contained in them.

- All utilities, including those privately owned
- Drawings of existing structures likely to be impacted by the work
- Accurate and scale appropriate topography mapping with datum information
- Inverts of pipes
- Easements, rights of way, etc.
- Preexisting/abandoned foundations or other structures
- Contamination
 - Type
 - Extent
 - Concentration
- Environmental constraints

Appendix 2

Dewatering



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include dewatering, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Background

- FEMA / historic flood information
- Summary description of the dewatering means and methods typically utilized in the project area
- Likely effect of dewatering on adjacent structures and construction

Site Exploration

- Relevant subsurface strata/aquifer(s) and groundwater conditions, such as aquifer(s) and aquitard(s), including both soil and rock strata
- Relevant field tests, e.g., permeability tests (rising head, falling head, constant head, packer, etc.) in boreholes, test excavations, and test pumping
- Groundwater level and sampling observations, e.g., static level, artesian conditions (differing water levels in separate strata), turbidity, and suspect visual/olfactory observations
- Strata permeability characteristics based on field testing
- Interconnection between aquifers

Laboratory Testing

- Permeability testing
- Chemical analysis/results
- Analysis results (e.g., MODFLOW computer modeling) of dewatering types assumed in the analysis, such as well points, deep wells, and sump pumping

Subsurface Condition Discussion/ Recommendations

- Anticipated pumping flow rates

Identification of Future Studies

- Anticipated drawdown
- Need for groundwater cut-off

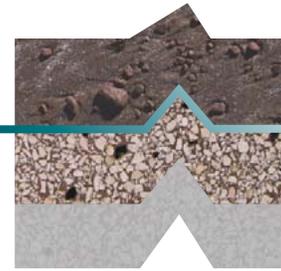
Other Relevant Information

The geotechnical engineer often is not responsible for providing certain types of information that is of great importance and must be transmitted to the construction team. In addition, the documents detailing these items communicated to the construction team must reflect a clear understanding and acknowledgement of the information contained in them.

- Need for effluent containment, treatment, handling due to environmental, or other site logistical conditions
- Permitted discharge locations
- Local permit and regulatory requirements

Appendix 3

Deep Foundations



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include deep foundations, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Subsurface Condition Discussion/ Recommendations

Drilled Shafts/Continuous Flight Auger Piles (CFA)

- Soil
 - Incidence of cemented or very hard layers
 - Bearing strata
- Rock
 - Strike/dip
 - Stratification
 - Slope of surface
- Incidence of oversize (boulders and cobbles)
- Soil rock interface delineation
- Propensity for caving
- Delineation of artesian water tables/ water problems
- Potential for gassy environment

Driven Piles

- Bearing strata identity
- Rock
 - Slope of surface
 - Need for shoes
 - WEAP analysis

Micropiles

- Bearing strata identity
- Rock
 - Slope of surface

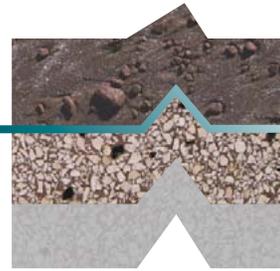
Other Relevant Information

The report should discuss whether a test pile program is warranted and suggest program elements. This would include the number of test piles, the number of load tests (lateral, compression, or tension), dynamic testing, and restrikes and acceptability of using pseudostatic methods.

The report also should discuss the advantages and disadvantages of various types of foundation choices.

Appendix 4

Shallow Foundations



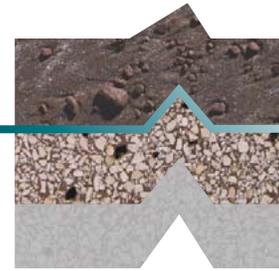
In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include shallow foundations, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Subsurface Condition Discussion/ Recommendations

- Appropriate foundation types
- Site preparation requirements
- Bearing capacity
- Drainage
- Site soil treatment or replacement requirements
- Preloading
- Slab-on-grade/structural slab recommendations
- OSHA trenching and shoring parameters, and classification
- Rock rippability
- Need for mud mats/subgrade stabilization
- Backfill and compaction
- Vegetation requirements (removal or location)
- Soil treatment
- Is the native material suitable for backfill and, if not, can it be used elsewhere on site or does it need to be removed?

Appendix 5

Mass Excavation and Grading



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include mass excavation and grading, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Background

- Proposed grading/excavation (lateral extent, cut depths, fill depths, and slope inclinations)

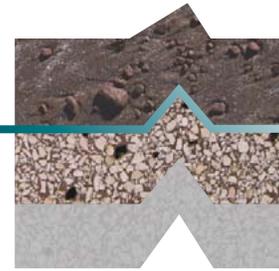
Subsurface Condition Discussion/ Recommendations

- Rippability/excavatability/excavation characteristics
- Shrinkage/bulking estimates
- Fill material recommendations (e.g., material selection, maximum/minimum particle size, upper/lower plasticity index, and expansion index)
- Onsite soil suitability for engineered/structural fill (methods to improve unsuitable soils, e.g., chemical treatment, blending, and mixing)
- Slope stability analyses, permissible slope inclinations (cut and fill), and stability fills/structures
- OSHA trenching and shoring parameters, and classification
- Adverse bedding conditions
- Anticipation of unstable/unsuitable soils (estimate locations/elevations)
- Clearing/grubbing and vegetation removal/stripping depths
- Remedial grading (fill removal, unsuitable soil removal, debris removal, and undercut in rock areas)
- Import soil recommendations
- Unstable soil mitigation recommendations

- Fill/development area preparation
 - Scarification depth
 - Moisture conditioning requirements— aerating/drying, pre-soaking/irrigation, and anticipated conditions/difficulties
 - Weather and time of year limitations for earthwork
- Stability fills/buttresses
- Overexcavation recommendations
- Subdrainage provisions and anticipated locations
- Blasting considerations (e.g., overburden “blanket”)
- Trenching considerations (e.g., sidewall/bottom stability and need for geotextile fabric wrap)
- Compaction equipment recommendations (e.g., type, size, weight, static, and dynamic)
- Maximum lift thickness
- Moisture content requirement (relative to optimum)
- Relative compaction requirement (minimum/maximum)
- Rock placement relative to rock size (to avoid nesting)
- Fill placement schedule to maintain stability
- Conditions requiring special consideration
 - Soil stabilization/improvement (chemical treatment, geosynthetics, and reinforcement)
 - Wet weather grading considerations
 - Soil drying (chemical treatment, mixing, and blending)
 - Estimated percentages
 - Site winterization/erosion control
 - Applicable treatment types

Appendix 6

Marine Construction



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include marine construction, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Background

- Water Body Information
 - Tide charts
 - Bathymetry
 - Seasonal variations in water elevations
 - Flood elevations
 - Water elevation variances due to downstream dam or sluice gate operations
 - Rate of water flow (in GPM or CFS) with corresponding current velocities

Field Study Methods

- GPS locations of investigative borings/soundings

Subsurface Condition Discussion/ Recommendations

- Incidence of oversize (boulders)

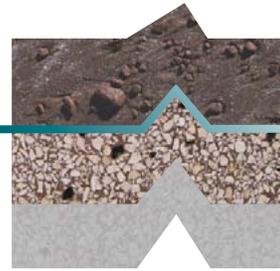
Other Relevant Information

The geotechnical engineer often is not responsible for providing certain types of important information that must be transmitted to the construction team. In addition, the documents detailing these items communicated to the construction team must reflect a clear understanding and acknowledgement of the information contained in them.

- Navigation restrictions
- Ecological restrictions
- Anchoring restrictions (e.g., cables, navigation, etc.)

Appendix 7

Ground Improvement



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include ground improvement, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Subsurface Exploration

- Soil/Rock
 - Permeability
 - Water pressure tests in rock
 - Presence of organics
 - Fibrous or not
- Presence of shells
- Groundwater
 - pH
 - Hardness
- Karst and other anticipated local geologic issues

Field Study Methods

- Seismic cone
- CPT or energy measure SPT

Laboratory Testing

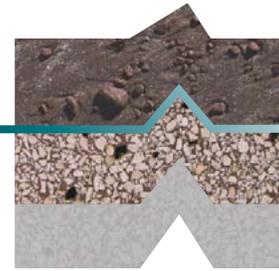
- Organics
 - Ability of cement to setup with bench testing

Subsurface Condition Discussion/ Recommendations

- Anticipated soil and rock reaction to construction activities (e.g., deterioration of surface soils under construction traffic or weather)
- Presence of moisture sensitive soils or rock
- Suitability of on-site materials for use in construction
- Loading history of site—preconsolidation pressure

Appendix 8

Slope Stability



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include slope stability, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Background

- Define existing paved areas or storage areas near the crest of slopes
- Maps showing evidence of past or ongoing movement, such as scarps, bulges, cracks, leaning trees and fractures or bedding planes in rock outcrops
- Preconstruction monitoring baseline survey of existing nearby structures
- Description of existing structure loads
- Existing cross sections

Subsurface Exploration

- Piezometric levels and evidence of seepage
- Rock and soil outcrop mapping

Laboratory Testing

- Coarse grained soils
 - Triaxial or direct shear test—where sites have a history of movement, large cuts, or embankments are planned
- Fine grained soils
 - Triaxial testing (unconsolidated undrained with pore pressure measurements) where the failure plane is not expected to be horizontal within the soil layer being tested.
 - Direct shear testing— where the failure plane may be essentially horizontal through the soil layer being tested.
 - Consolidation assessment
 - Soil anisotropy and variations in shear strength and permeability
- Rock
 - Bedding and fracture roughness or strength

Subsurface Condition Discussion/ Recommendations

For Temporary Slopes

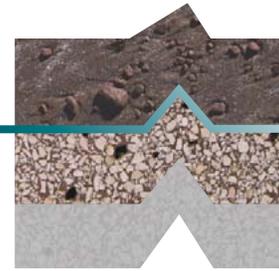
- Anticipated loads from adjacent structures, paved or storage areas, phased construction conditions, construction equipment loading near the crest of the slope, etc.
- Slickensides or sensitive soil conditions not obvious from the test data.
- Known or common local geologic conditions sensitive to slope issues
- Steepest slope recommended unless controlled by governing agencies such as OSHA
- Commentary on temporary slope face protection.
- Stable area for laydown, material storage and wasted soil
- Allowable length of open , unretained cut, or trench
- Recommendations for surface erosion protection and maintenance

For Permanent Slopes or Owner-Provided Temporary Slope Conditions

- Significant design strength limitations or excavation difficulties such as slickensides, sensitive soil conditions, adverse rock fracturing or bedding, and boulders that may affect the uniform excavation of slopes
- Known residual or fully softened strength limitations of geologic strata
- Possibility of weakening or piping of exposed soils
- Slope design and limitations of future loading allowed near the crest of the slope including the dimension to the crest of the slope where loading is not permitted
- Final geometry cross sections including soil stratification, strength and groundwater information used in design, and critical failure circles or blocks representative of the analysis completed
- Recommendations for maximum slopes to be used by designers completing final site plans and developing temporary condition plans
- Recommendations for temporary and final surface erosion protection and maintenance
- Recommendations for monitoring and instrumentation during construction and after completion

Appendix 9

Anchored Earth Retention



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include anchored earth retention, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Background

- Preconstruction wall and foundation monitoring baseline survey, if appropriate

Subsurface Exploration

- Preconstruction vibration survey, if appropriate
- Borings/or explorations
 - Ensure there are sufficient borings in the anchor zone, as well as along the wall line

Laboratory Testing

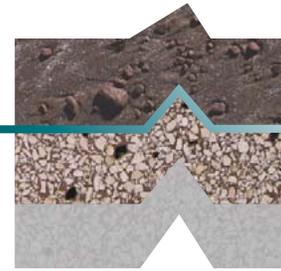
- Coarse grained—triaxial or direct shear test—where movement cannot be tolerated

Subsurface Condition Discussion/ Recommendations

- Anticipated loads from adjacent foundations, phased construction, crane areas, etc.
- Anticipated settlement and lateral movement criteria and commentary on need for underpinning
- If soil nailing is considered, ability of soil to stand
- If Soldier Pile and Lagging is considered, arching considerations
- Any limitation on installation or removal, such as limits on the use of vibratory hammers

Appendix 10

Tunneling



In addition to those elements outlined in Appendix 1, geotechnical engineering reports that support projects, which include tunneling, could enhance construction processes by relating the information indicated below. The types of information indicated may not be applicable to all projects and other information not listed may be important for specific projects.

Background

- Regional precipitation trends

Subsurface Exploration

- Potential for boulders
- Rock outcrop mapping
- Potential for gassy environment

Laboratory Testing

- Soil
 - Mass and intergranular strength
 - Shear strength
 - Cementation
- Rock
 - Mass and intergranular strength
 - Unconfined compression
 - Metamorphism
 - Massivity
 - Fracture/shear spacing
 - Weathering profile
 - Expansivity
 - Structural deficiencies
 - Faults
 - Landslides
 - Shears
 - Voids
 - Abrasivity
 - Linear cutter tests

Subsurface Conditions Discussion/ Recommendations

- Aquifer characterization
 - Confined/unconfined
 - Aquifer/aquitard
 - Field permeability
 - Anticipated inflow
- Anticipated loads from adjacent facilities
- Tolerable settlements
- Suggested tunneling methods
- Performance prediction
- Allowable quantity of dewatering

