

Geotechnical Services

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Geotechnical engineering services play a critical role in building development. Architects and engineers rely on geotechnical information to achieve effective and efficient design solutions for foundations, earth retention systems, and other building elements.

Every building must be supported on soil or rock. Thus, a satisfactory foundation system is one of the first issues to be addressed on any building project. Evaluating the physical properties of the foundation subgrade and determining how best to use those properties is imperative for appropriate substructure design, as well as for a variety of other building-related development issues.

Since architects deal primarily with buildings, the focus of this topic is on geotechnical engineering for design and construction of structures. Bridges, tunnels, dams, major road systems, and other civil structures are excluded.

CLIENT NEEDS

Obtaining geotechnical expertise early in project development makes it possible to address soil and groundwater issues that may impact construction and the long-term performance of a building. A preliminary geotechnical evaluation may reveal that locations proposed for buildings, driveways, parking areas, and other facilities may not be optimum from a geotechnical perspective. Other tangible potential benefits of early geotechnical involvement include possible shortening of the construction schedule through identification of suitable alternate construction methods, which may reduce costs of construction and/or building operation and maintenance.

Types of Geotechnical Services

A/E project teams rely heavily on geotechnical information for designing building foundations and substructure elements. Geotechnical knowledge is also used to resolve issues involving seismic design, protect adjacent structures during construction, and identify potential construction problems. These and other representative services are listed here:

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Summary

GEOTECHNICAL SERVICES

Why a Client May Need This Service

- To evaluate suitability of proposed site and building development
- To develop parameters for foundation and earth retention design
- To identify potential construction problems
- To reduce potential for overdesigning and excessive construction costs
- To determine site seismic class

Knowledge and Skills Required

- General engineering knowledge
- Specialized knowledge of soils
- Familiarity of local soil and groundwater conditions
- Ability to identify and implement appropriate testing methods
- Ability to identify and manage risk

Representative Process Tasks

- Develop proposal
- Engage in field exploration
- Perform laboratory tests
- Analyze test results
- Assess alternatives
- Prepare report
- Provide design assistance
- Provide services during construction

- Preliminary evaluations to assist in site selection and to define the bearing capacities for proposed building locations
- Studies for ground modification/improvement/stabilization to facilitate construction or reduce costs
- Detailed analysis to determine site seismic class
- Evaluations for excavation support and underpinning
- Assessment of corrosive effects of soils on building elements
- Studies to evaluate excessive settlement due to subsoil conditions
- Forensic or expert witness services
- Assessment of foundations in existing buildings that are being renovated with a planned increase in building loads

Geotechnical services are also used in conjunction with other issues that may be directly or indirectly related to a building project. The following services fall within this group:

- Assessment of site environmental conditions
- Analysis of slope stability
- Soil evaluation for pavement design
- Evaluation of subgrade drainage for detention/retention ponds, drainfields, and so on
- Assessment of drainage and seepage problems
- Groundwater monitoring or dewatering
- Special in situ testing (load tests, pressure meter, and so on)
- Geophysical surveys for electrical resistivity, seismic conditions, borehole logging, ground-penetrating radar, and so on
- Design of surcharge and wick drains for compressible soils
- Testing for freezing/thawing, shrink/swell, and wetting/drying conditions

The Need for Quality Services

The importance of having geotechnical information of the highest quality cannot be overstated, and it is prudent for clients to realize the importance of engaging qualified geotechnical engineers. Given the risks associated with using inaccurate or incomplete geotechnical data, basing the selection of a geotechnical firm on its qualifications is critical.

Qualifications-based selection (QBS) approaches encourage innovation, result in facilities that perform more effectively, and can result in facilities that are less costly to

Firms That Provide Geotechnical Services

Geotechnical engineering firms vary in size from several to several thousand professionals. Smaller firms tend to be more specialized or provide only geotechnical consulting services. Larger firms offer a wider variety of services and may employ civil engineers, geologists, chemists, metallurgists, electrical engineers, and mechanical engineers, among others.

The staff makeup of a geotechnical firm depends on its philosophy, mission, market, and locality, among other factors. Firms employing only geotechnical engineers with undergraduate degrees can generally perform geotechnical evaluations on relatively straightforward projects. However, projects of greater complexity often require geotechnical engineers with specialized, advanced training and more extensive practical experience.

Geotechnical firms that offer more than geotechnical engineering offer several advantages for some types of projects. For land development or brownfield redevelopment projects, for example, engaging a firm that can provide both geotechnical and environmental services makes it easier for the project team to coordinate and communicate effectively on these subjects.

Market conditions and location normally drive the range of services offered by geotechnical firms. This is why most geotechnical engineering firms are located in major cities or near highly populated areas. In less populated areas where potential projects may be fewer and more varied, traditional civil engineering firms may offer geotechnical services.

Geotechnical Consultant Selection Criteria			
Criteria	Points (0-10)	Weighting Factor	Score
Understanding of the project			
Experience in the immediate vicinity of the site			
Clarity and completeness of proposal			
Past working relationship with the design team, owner, and construction manager			
Experience with similar projects			
Qualifications, experience, and communication skills of the geotechnical project manager			
Reputation of the geotechnical firm			
Suggestions of the geotechnical firm regarding the scope of services and possible alternates			
Quality of services based on references			
Commitment to meeting schedule requirements			
Quality of laboratory and testing equipment and experience of laboratory personnel			
Insurance coverage			
Fee			
Grand Total Score			
<i>Remarks:</i>			

build, operate, and maintain. Selecting a geotechnical engineering firm based on reputation and experience (rather than price alone) is likely to bring greater value to a project. It is therefore generally preferable to use a QBS process in which the firm selection is made before fees are determined or negotiated. If a building owner or client has a tendency to select consultants on the basis of price alone, the architect can advise the owner of the pitfalls of this approach to choosing a geotechnical consultant.

In projects requiring competitive bidding, a modified QBS process can be implemented by applying the selection criteria shown in the accompanying table. Each line item in the chart is scored using a point system from 0 to 10. To refine the scores, the total points for each item can be adjusted using a weighting factor (shown in the third column). For example, if experience is highly valued, a weighting factor of 2, 3, or higher may be applied to the values in that column. The score for each item in the last column (derived by multiplying the points in the second column by the weighting factor) is totaled to arrive at a total score. (*Note:* The last line item on the list is “fee” because, ideally, fees should be the last thing considered when selecting a consultant and thus should be given a lower weighting factor than the other line items.)

SKILLS

Traditionally, geotechnical engineering has been a specialized field within civil engineering. Undergraduate studies generally include coursework in introductory geotechnical engineering and basic geotechnical laboratory testing. Graduate-level studies encompass more advanced coursework in such areas as earth retention systems, marine engineering, slope stability, physiochemical properties of soils, and soil dynamics, among others.

In recent years, many university and college civil engineering departments have merged with environmental departments because of the close interaction among professionals in these areas. Thus, a background in environmental engineering and geology and hydrogeology, along with other civil engineering disciplines (e.g., structural engineering, construction engineering, and fluid mechanics) is highly useful in geotechnical engineering practice. Some universities also have programs that combine civil engineering and architecture courses.

Geotechnical Knowledge and Experience

Geotechnical engineering (once referred to as soil mechanics) involves a sound knowledge of soil-structure interactions under various loading conditions. However, effective geotechnical analysis depends much more on practical experience than any other field of civil engineering. In *Soil Mechanics in Engineering Practice* coauthors Terzaghi and Peck emphasize this point, stating that “in foundation and earthwork engineering, more than in any other field of civil engineering, success depends on practical experience. The design of ordinary soil-supporting or soil-supported structures is necessarily based on simple empirical rules, but these rules can be used safely only by the engineer who has a background of experience.” Thus, teaming with a geotechnical engineer who possesses experience on a wide variety of civil engineering projects and has in-depth knowledge of varying soil and groundwater conditions is a valuable asset to both the design team and the client.

Licensing Requirements

To practice, geotechnical engineers are required by law to be licensed in most jurisdictions. Further, some states require that majority ownership of the firm must be held by licensed engineers. The National Council of Examiners for Engineering and Surveying (NCEES) administers the licensing process for engineers through fifty-five licensing boards representing the United States and its territories. Engineering licensure involves passing examinations and gaining practical experience. For more information, visit the council Web site at www.ncees.org.

PROCESS

The geotechnical engineer depends on the architect and the structural engineer to provide architectural and structural information prior to and during the geotechnical evaluation phase. Information from the site civil engineer is also important, especially when mass grading, drainage, and other site issues need to be addressed. If changes are made to the proposed structure or other project features, the structural engineer and architect should inform the geotechnical consultant of these so the field exploration program or scope of services can be adjusted accordingly. In turn, the geotechnical consultant should convey pertinent geotechnical information to the structural engineer and architect, especially if it has the potential to significantly affect the project plan and design.

A geotechnical engineer providing basic geological services in new construction will need to know the proposed location and size of the building, the general type of construction to be used, the number of stories planned, and whether the structure will have a basement. This information will help the engineer develop a scope for the field exploration program (number of soil borings and depths) and determine whether special field or laboratory tests should be recommended.

Developing the Scope of Services

Access to adequate, relevant information is extremely important for developing a scope of services in geotechnical consulting. If information about the site is limited, the geotechnical engineer may have to rely more heavily on experience and professional judgment to develop the scope. Project parameters vary depending on the type of construction proposed, the project size, soil and groundwater conditions, and related factors. Thus, the more information the geotechnical engineer has during the proposal preparation process,

Geotechnical Testing and Analysis

Geotechnical engineers use an array of tools and methods for geotechnical testing and analysis.

Typical Testing Methods

Routine evaluations are generally performed using the testing methods described in this section.

Standard penetration tests. These are performed during routine sampling in soil borings. This involves driving a split-spoon sampler with a 140-pound hammer falling 30 inches. The number of blows (from each drop of the hammer) required to drive the spoon sampler in 6-inch increments is recorded. The sum of the blows from the last two 6-inch drives is known as the Standard Penetration Test resistance or N-value. This is a key parameter for cohesionless soils (gravels, sands, sandy silts, etc.).

Shear tests. Shear strength is a key parameter of cohesive soils (clays, clayey silts, etc.). This property can be estimated by using hand-operated instruments in the field or laboratory (hand penetrometers or Torvane shear devices) or by performing unconfined compressive strength or triaxial shear tests in the laboratory.

Moisture tests. Another property of cohesive soils, moisture content can be used as an initial indicator of plasticity, consolidation (settlement) potential, and other factors.

Particle size distribution tests. This test can be used to determine the distribution of soil grains; it indicates whether the soil is coarse-grained (gravels, sands) or fine-grained (silts or clays). It can also be used to estimate the permeability characteristics of a soil sample based on previous correlations.

Atterberg limits test. Used primarily for evaluating the plasticity characteristics of cohesive soils, this test measures two components: the plastic limit and the liquid limit. These are used together as a basis for classifying cohesive soils.

Other laboratory tests. Tests to measure specific gravity, consolidation, triaxial compression, and other characteristics may be used where settlement or short- or long-term stability is an issue that could impact a project.

Special Testing Methods

More specialized results are achieved using the following tests.

Field vane shear test. Used on sites where lower-strength clays are present, this test provides in situ data, which generally yields more accurate strength data than laboratory tests. Typically, vane shear tests indicate higher shear strength values than laboratory tests (on the order of 25 to 50 percent higher). Soil with higher shear strength can provide higher soil-bearing pressures for foundation design or more favorable characteristics for slope stability analysis, with the view of saving money for the owner.

Pressure meter test. Used to obtain more accurate estimates of in situ soil strength or resistance parameters, this test usually results in soil-bearing capacities that are 1.5 to 3 times (or more depending on soil conditions) greater than the soil resistance measured using conventional soil-boring testing methods. As does field vane shear testing, pressure meter testing can enable more economical foundation design in new construction, as well as permitting the imposition of additional loads on foundations in renovation projects without modification of the foundation size.

Seismic crosshole or seismic cone penetrometer test. These can be used to determine the seismic site class more accurately, potentially lowering costs related to meeting structural code requirements. Although index properties obtained from routine field or laboratory tests have been correlated with shear wave velocity, the correlations tend to be overly conservative, which could result in unnecessary additional expense to a project. The results of these tests potentially make it possible to design structural as well as other building systems (e.g., fire protection and suspended ceiling systems) more economically.

Pile-driving analyzer (PDA) measurement. A PDA is a device that measures the force in pile foundations as the pile is struck with a pile-driving hammer. Much information about the pile can be obtained from this analytical field method, including static load capacity, driving stresses, load distribution transferred energy, hammer performance, and so on. The PDA can obtain this information much more quickly than conventional pile-load-testing methods.

Analytical Tools

Computer software programs have been developed for analyzing various geotechnical issues, including slope stability, groundwater modeling, and soil-structure interaction using finite element and other algorithms. Software tools are also available for developing customized routines to analyze the design of earth retention elements, the time rate of settlement, and other considerations.

the more complete and appropriate the developed scope will be. Following is an outline of information that will enable preparation of a solid geotechnical proposal:

I. Existing Site Conditions

- A. Location
- B. Size
- C. Current/previous use(s)—developed/undeveloped
- D. Previous geotechnical or environmental studies
- E. Existing buildings (if any)
 - 1. Number of stories
 - 2. Slab-on-grade or basement
 - 3. Floor levels/elevations
 - 4. Other pertinent features
- F. Topography (based on available topographical information or site reconnaissance)
- G. Ground cover (grass, weeds, brush, trees, etc.)
- H. Surface drainage
- I. Water courses (lakes, ponds, rivers, creeks, streams, ditches)
- J. Access (affects type of drill rig required)
 - 1. Restricting site conditions
 - 2. Weather conditions
 - 3. Access to interior of existing building(s)
 - a. Overhead height(s)
 - b. Clearing areas or moving equipment/obstructions

II. Proposed Construction

- A. Building(s)—stand-alone(s) or building addition(s)
 - 1. Size
 - 2. Number of stories
 - 3. Slab-on-grade or basement
 - 4. Floor levels/elevations
 - 5. Type of construction (interior framing/exterior facing)
 - a. Structural loads (column, wall, floor, dynamic)
 - b. Machines/equipment housed (special considerations)
 - c. Other pertinent features
 - 6. Pavements
 - a. Existing pavements (type, thickness, age, condition)
 - b. Proposed drainage scheme
 - c. Projected traffic usage and counts
 - 7. Site grading (proposed cut and fill thicknesses)

In addition to the information in the outline, a number of other issues that can affect the level of effort required should be kept in mind when developing a project scope for geotechnical services. A discussion of some of these follows.

In general, the larger the project, the more field exploration is needed. In addition, larger projects may require the use of several field exploration methods, such as soil probing, digging of test pits, and hand augering, along with special field or laboratory testing.

Site soil conditions can determine the field exploration program and laboratory testing needed for a project. A site visit before the scope of services is developed helps the geotechnical firm assess whether test pits, auger probes, or other invasive methods may be required. Field visits are also helpful for evaluating access for a suitable drill rig (truck- or trailer-mounted or on an all-terrain vehicle) and observing ground cover and topography and other features that could affect field exploration and development of the project.

Low-lying areas, such as swamps, creeks, or man-made drainage features, as well as generally undesirable soil and groundwater conditions, frequently require evaluation prior to construction. This investigation gives the project team enough information to reasonably anticipate conditions that may be encountered during construction.

Geotechnical Agreements and Compensation

The building owner is responsible for obtaining geotechnical engineering services under AIA owner-architect agreements. However, in some contracts, the owner may want a single-source arrangement for all project services, including geotechnical services.

Regardless of the contractual arrangement, selection of qualified geotechnical firms should be encouraged—especially given the risks associated with geotechnical engineering services. The process for evaluating and selecting geotechnical consultants is discussed in the Client Needs section of this topic.

To help owners define geotechnical services for their projects, architects can use AIA Document G602, Request for Proposal—Geotechnical Services. This document can serve as a request for proposal and can also be used to develop an agreement between the owner and geotechnical engineer. Architects, however, need to understand the types of geotechnical services relevant to each project—especially with respect to G602 Articles 4, 5, and 6 (Sampling and Testing [field exploration], Reports [field and laboratory tests], and Foundation Engineering Evaluation and Recommendations [items to be covered in the report]). When testing and services beyond what is needed are requested, the scope of services and corresponding fees are unnecessarily increased. It is always prudent to discuss the conditions and parameters of a project with a reputable geotechnical consultant before filling out the G602 document or any other geotechnical service checklist.

Other agreements developed by either the architect or the geotechnical consultant can be used, although some negotiation on the contract language may be required. Two important agreement clauses concerning risk include “limitation of liability” and “indemnification.” Because some clients do not fully understand these concepts, they may become points of contention in contract negotiations. (For an in-depth discussion on managing risk in the delivery of professional services, see “Risk Management Strategies” in Section 12.1 of the 13th edition of the *Architect’s Handbook of Professional Practice*.)

Compensation for geotechnical services is usually based on a lump-sum fee when the scope of services does not include assumptions. However, if assumptions are included and deviations from them occur, modifications to the fee can result. Keep in mind that it is more difficult to fully define the scope of services on projects involving complex geotechnical conditions or when special services are required (e.g., where vibration measurements are needed or when soil dynamics and other special issues must be addressed). In such cases, compensation based on time and materials may be appropriate.

If available, previous geotechnical or environmental information for a site can be beneficial. Often, however, the project team may not know of or have access to soil borings or other field exploration previously performed in areas that have been developed before.

If a geotechnical consultant is familiar with local soil and groundwater conditions or has experience on adjacent sites, this can significantly benefit a project. The consultant’s site-specific knowledge can be effectively used to develop an appropriate scope of services and anticipate the potential risks from the proposed construction.

Steps in Basic Geotechnical Services

Activities involved in performing basic geotechnical services for a typical project involving design and construction of a new building are summarized in the table on page 122. Major activities are shown in bold, and the geotechnical professionals and associated project team members involved with each activity are identified. Routine geotechnical evaluations can normally be completed in three to four weeks after authorization to proceed has been received. More complex projects require a longer timeline.

PROVIDING SOUND FOUNDATION RECOMMENDATIONS

Accurate and reliable geotechnical analysis enables architects and engineers to design structures with a greater degree of efficiency and cost-effectiveness. While the geotechnical

Basic Activities in the Provision of Geotechnical Services

Activity	Consultant Personnel	Timeline
Develop proposal	PE/PM ¹	Varies ²
Obtain available project information	PE/PM	
Develop scope of services	PE/PM	
Negotiate a fee for the service	PM	
Coordinate tasks with project team	PM	1 day
Register project	Admin. asst. or PE	
Schedule field exploration	PE	
Obtain utility clearances	PE	Varies ³
Prepare instructions for driller	PE	
Perform field exploration	Drillers	Varies ⁴
Conduct appropriate laboratory tests	Lab technician	1–2 days
Analyze field and laboratory results	PE/PM	1 day
Prepare report	PE/PM	3–7 days
Draft location diagram(s)	Drafting staff	1 day
Prepare soil boring logs	Drafting staff/admin. asst.	1 day
Draft report	PE	2 days
Review report	PM	1 day
Design building components	PE/PM	
Services during construction	Field technician/field engineer	
¹ PE = project engineer; PM = project manager. ² Proposal development can vary from less than one day to several weeks, depending on client needs and the complexity of the project. ³ The time required to obtain utility clearances varies from state to state, but is normally about three business days. ⁴ The time required for field exploration varies, based on the amount of drilling, type of sampling for field tests, site conditions, etc.		

aspect of building design and construction is often overshadowed by other, more visible project activities and tasks, geotechnical services are nevertheless indispensable in providing a basis for the creation of structurally safe and sound buildings.

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The AIA provides a contract document designed especially for geotechnical services, G602-1993.

Another option is to specify the services in AIA Document B102-2007, which is designed for alternative services.

G602–1993, Request for Proposal—Geotechnical Services

AIA Document G602™–1993 can form the agreement between the owner and the geotechnical engineer. It allows the owner to tailor the proposal request to address the specific needs of the project. In consultation with the architect, the owner establishes the parameters of service required and evaluates submissions based on criteria such as time, cost, and overall responsiveness to the terms set forth in the request for proposal. When an acceptable submission is selected, the owner signs the document in triplicate, returning one copy to the engineer and one to the architect, thus forming the agreement between owner and geotechnical engineer.

B102–2007, Standard Form of Agreement Between Owner and Architect without a Predefined Scope of Architect’s Services.

AIA Document B102–2007 is a standard form of agreement between owner and architect that contains terms and conditions and compensation details. B102–2007 does not include a scope of architect’s services, which must be inserted in Article 1 or attached as an exhibit. Special terms and conditions that modify the agreement may be included in Article 8. The separation of the scope of services from the owner/architect agreement allows users the freedom to append alternative scopes of services. AIA Document B102–2007 replaces and serves the same purpose as AIA Document B141–1997 Part 1.

For more information about AIA Contract Documents, visit www.aia.org/contractdocs/about

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