ADDRESSING RISK THROUGH IMPROVED SITE CHARACTERIZATION PROGRAMS

PRESENTED AT GEO-OMAHA OMAHA NE, 02/21/2020

PREPARING FOR SUBSURFACE EXPLORATION

“If you do not know what you should be looking for in a site investigation, you are not likely to find much of value”

Glossop (1968) Eighth Rankine Lecture

BENEFITS OF SITE CHARACTERIZATION

- More reliable estimates for geotechnical design parameters allow designers to design more efficient and cost-effective transportation features.
- Early identification of geotechnical hazards allow project risks to be identified early in the project cycle, when it is often easier and less costly to address the risk.
- Accurate characterization of stratigraphy, groundwater conditions, and the types of soil and/or rock present can substantially influence project costs, both directly and indirectly (both higher and lower).
BENEFITS OF SITE CHARACTERIZATION

- Failure
- Over-Design

BENEFIT OF UPFRONT INVESTMENT IN SITE INVESTIGATION

Source: NCHRP Synthesis 484 - Influence of Geotechnical Investigation and Subsurface Conditions on Claims, Change Orders, and Overruns (After Figure 1)

GENERAL OBJECTIVES FOR SITE CHARACTERIZATION

- Investigation represents a systematic study conducted to identify the ground conditions present at a site and to accurately characterize the engineering behavior of the soil and/or rock.
GENERAL OBJECTIVES FOR SITE CHARACTERIZATION

- Stratigraphy
- Groundwater Conditions
- Suitability
- Hazard Identification
- Location and Alignment
- Design Parameters
- Constructability
- Condition Assessment

PERFORMANCE REQUIREMENTS FOR SITE CHARACTERIZATION

- Characterize the stratigraphy and general characteristics of soil and rock units, including how these characteristics vary across the site.
- Establish appropriate and reliable values for required design and construction geo-material parameters and characterize groundwater conditions.
- Identify and characterize geotechnical hazards that may impact design, construction, and performance.

Note: These are technical requirements and not legally binding

CLASSES OF SITE CHARACTERIZATION INVESTIGATIONS

- Office Studies
- Preliminary Investigations
- Design Investigations
- Borrow Site Investigations
- Investigations for Performance Monitoring and Condition Assessment
- Forensic Investigations
- Investigations for Projects using Alternative Contracting Methods
CLASSES OF SITE CHARACTERIZATION

Office Study:
- A **critical first step** for practically all site characterization programs.
- Often completed prior to conducting field or laboratory activities.
- Significantly contribute to location and alignment decisions prior to conducting field or laboratory investigations.
- Often contribute to early identification of geotechnical hazards.

COLLECTION AND INTERPRETATION OF EXISTING INFORMATION

**Minimum Subsurface Needs**
- Design and Construction Requirements
- Performance Requirements
- Geologic Concerns (variability)
- Extreme Events (scour, seismic)
- Construction Sequences and Phases
- Types of Analysis
- Engineering Properties and Parameters
- Location, Numbers and Types of Tests

AASHTO LRFD BDS Specifications Section 10.4.1

**Minimum Subsurface Exploration Needs**
- Geological Formations
- Location and Thickness of Soil and Rock Units
- Engineering Properties (unit weight, strength and compressibility)
- Ground Water Conditions
- Ground Surface Topography
- Local Conditions (voids, swelling, liquefaction)

AASHTO LRFD BDS Specifications Section 10.4.3
### INFORMATION AND TESTING NEEDS (FHWA-IF-02-034)

#### Gotechnical Issues

<table>
<thead>
<tr>
<th>Engineering Evaluation</th>
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<th>Field Testing</th>
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00 Lesson - Introduction

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COLLECTION AND INTERPRETATION OF EXISTING INFORMATION

Historical Data:
- Agencies and companies generally maintain records of geotechnical investigations performed for prior projects.
- Historical data can provide an efficient and effective basis for preliminary interpretation of a site.
- Historical data should be carefully considered because historical measurements may or may not reflect current practices or conditions.

COLLECTION AND INTERPRETATION OF EXISTING INFORMATION

Office Study:
- Preliminary information about sites can be derived from a number of sources, many of which are publicly available.
- Limitations are associated with using maps and mapping information.
- USDA soil survey maps and data
- USGS topographic maps
  [https://ngmdb.usgs.gov/](https://ngmdb.usgs.gov/)
The availability of open-source and commercial remote sensing products has increased dramatically in recent years.
- Google Earth™
- Google Maps™
- LiDAR: Light Detection and Ranging
- UAS: Unmanned Aerial Systems
- Photogrammetry
DEVELOPMENT OF SCOPE FOR FIELD INVESTIGATIONS

- Field investigations for site characterization may involve
- Completion of test borings and in situ test soundings
- Collection of soil and/or rock samples for laboratory testing
- Cone Penetrometer Testing (CPT) and Measurement While Drilling (MWD)
- Geophysical measurements
- Geologic mapping of rock outcrops
- Activities to characterize groundwater conditions
DEVELOPMENT OF SCOPE FOR FIELD INVESTIGATIONS

Developing Preliminary Scopes

Important factors to determine the scope of work:

- Importance of the infrastructure (Bridge foundations vs. highway pavement) and purpose of the investigation (ex. forensic study)
- Anticipated stratigraphic variability at the specific site
- Availability of historical borings and other preliminary information

MINIMUM INVESTIGATION GUIDELINES (FHWA-NHI-16-072)

Note: These are non-binding guidelines

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<th>Application</th>
<th>Minimum Number of Exploration Points and Location of Exploration Points</th>
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| Mobile & Fixed Bridge Foundations | For evaluation purposes (e.g., geotechnical conditions), a minimum of one exploration point per structure. | Depth of exploration should be:
| | | (1) greater than the shallower foundation unit (e.g., soft, fine-grained soils) into competent material of sufficient bearing capacity (e.g., stiff clays, silts), or (2) to a depth that is determined based on stability criteria and site conditions. |
| | For stabilization purposes (e.g., installation of rock sockets): | For installation of rock sockets, the wall depth should be determined using the following criteria:
| | | (1) For installations in rock soils, the wall depth should be determined using:
| | | a. A minimum of one exploration point per wall segment, or
| | | b. A minimum of five exploration points per wall segment, or
| | | c. A minimum of three exploration points per wall segment. | Depth of exploration should be:
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When do you need more than the minimum?

### INFLUENCE OF NUMBER OF MEASUREMENTS

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<th>Quantity of measurements</th>
<th>Type of measurements</th>
<th>Quality of measurements</th>
<th>Reliability of geotechnical design/construction parameters</th>
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Statistical Sampling

- **Standard deviation (σ)** is a measure that is used to quantify the amount of variation or dispersion of a set of data values.
INFLUENCE OF NUMBER OF MEASUREMENTS
Statistical Sampling

\[ n = 20 \]

INFLUENCE OF NUMBER OF MEASUREMENTS
Estimates for Geotechnical Parameters

INFLUENCE OF NUMBER OF MEASUREMENTS
Estimates of Variability and Uncertainty

Coefficient of variation (COV) shows the extent of variability in relation to the mean of the population.
INFLUENCE OF NUMBER OF MEASUREMENTS
Judgment for Establishing Appropriate Number of Measurements

Assumptions for the Variability of a Given Site
Additional Investigation if Unreasonable Assumptions
Develop a Scope for Investigations
Conduct Measurements
Evaluate the Reasonableness of the Assumptions

INFLUENCE OF TYPE OF MEASUREMENT

Direct Measurements
- Uniaxial compression tests
- Direct shear tests or triaxial compression tests
- One-dimensional consolidation tests

Indirect Measurements
- Atterberg limits to estimate compressibility for soils
- Atterberg limits to estimate peak or residual values of $\phi'$ for soils
- CPT tip resistance to estimate $s_u$ or $\phi'$ for soils
- SPT $N$-values to estimate $s_u$ or $\phi'$ for soils

INFLUENCE OF BORING, SAMPLING AND TESTING METHODS

Sources of Bias - Sample Disturbance
- Drilling techniques
- Handling and transportation
- Sealing of samples
- Specimen preparation
### INFLUENCE OF BORING, SAMPLING AND TESTING METHODS

**Sources of Bias – Loading Method**
- Direct or direct simple shear
- Compression or tension
- Stress or strain controlled
- Dynamic or static

### INFLUENCE OF BORING, SAMPLING AND TESTING METHODS

**Sources of Bias – Loading Rate**
- Slow rate of strain
- Rapid rate of strain
- Stress controlled

### CONSIDERATIONS FOR TIME VARYING CONDITIONS

The predominant mechanism causing changes in soil properties with time is **changing groundwater and moisture conditions**.
- Precipitation
- Surface water runoff
- Tidal fluctuations
- Pumping
- Irrigation

Result is changes in effective stress, and physical or chemical properties.
DEVELOPMENT OF SCOPE FOR FIELD INVESTIGATIONS

During preliminary scope development, scoping can be improved by:
- Having additional tools available
- Evaluation of existing information
- Having a well-qualified engineer on site
- Planning for a phased investigation approach

OBJECTIVES FOR INTERPRETATION OF GEO-MATERIAL PARAMETERS

- Establish an appropriate, rational, and defensible site model that can be used for analysis, design and construction of features.
- Design models may include cross-sections, profiles, or complete three-dimensional models of a site.
- Models should include characterization of the variability and uncertainty associated with the geo-material parameters.

EDC-5 INNOVATION

ADVANCED GEOTECHNICAL METHODS IN EXPLORATION (A-GAME)

TOOLS FOR ENHANCED, EFFECTIVE SITE CHARACTERIZATION
WHAT ARE THE ADVANCED GEOTECHNICAL METHODS IN EXPLORATION?

- The A-GME is a toolbox of underutilized subsurface exploration tools that will assist with:
  - Assessing risk and variability in site characterization
  - Optimizing subsurface exploration programs
  - Maximizing return on investment in project delivery

SITE CHARACTERIZATION – CURRENT PRACTICE

- Total Volume Tested or Sampled < 0.01% (typically)
- Boring/CPT Locations
  - Boring Type: SPT every 5 feet; 18 inch of Sampling
- To Scale

SITE CHARACTERIZATION – CURRENT PRACTICE

- Total Volume Tested or Sampled < 0.01% (typically)
IMPLICATIONS OF A-GAME

QUESTIONS

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