Effective practices for geotechnical and foundation engineering in design-build

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Key Topics

• Pre-bid geotechnical data
• Risks & differing site conditions
• Alternative Technical Concepts (ATC’s)
• Performance based specifications
• Case studies
NCHRP 429 – Geotechnical Information Practices in Design-Build

Describes effective practices in geotechnical procurement, design, and quality management

• Qualifications & experience of D-B geotechnical team is key to quality
• Use over-the-shoulder reviews to expedite schedule
• Weight geotechnical factors appropriately to the importance for project success
• Use ATC’s to allow bidders to reduce risk
Pre-bid geotechnical data

• Forms the basis of the D-B Team’s design, schedule and bid
• May be < 25% of the quantity of information required for final design
• D-B Team must address the limitations in the provided information at bid time
Pre-bid geotechnical data

• Quality and timeliness of basic information is critical
  – Stratigraphy and coverage
  – Emphasis on basic soil and rock material properties
  – Limitations of pre-bid foundation tests
Stratigraphy and Coverage

• Need thorough program of borings or soundings for pre-bid estimating
  – More routine borings with cpt soundings preferred over few borings with sophisticated testing
  – Provide surveyed information for 3D modeling
  – Televiewer data with rock coreholes
  – Provide core samples for examination by bidders
Example: CPT Soundings
Example: ATV Logs of Rock Core Borings

<table>
<thead>
<tr>
<th>Rank</th>
<th>Color</th>
<th>Observation</th>
<th>Flow Rating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Gray</td>
<td>No-Flow Feature (bedding, healed fracture, vein, etc.)</td>
<td>Sealed, No Flow</td>
</tr>
<tr>
<td>1</td>
<td>Cyan</td>
<td>Weak Feature (not continuous around the borehole)</td>
<td>Partial Open Crack</td>
</tr>
<tr>
<td>2</td>
<td>Blue</td>
<td>Clear, Distinct Feature</td>
<td>Continuous Open Crack</td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>Distinct Feature with Apparent Aperture (visible on amplitude and travel-time image)</td>
<td>Wide Open Crack or Cracks</td>
</tr>
<tr>
<td>4</td>
<td>Magenta</td>
<td>Very Distinct, Wide, Possibly Interconnected Fracture (visible on amplitude and travel-time image)</td>
<td>Very Wide Crack or Multiple Interconnected Fractures</td>
</tr>
<tr>
<td>5</td>
<td>Green</td>
<td>Major Fracture Zone or Washed out Zone (visible on amplitude and travel-time image)</td>
<td>Major Fracture with Large Openings or Breakouts</td>
</tr>
</tbody>
</table>
Need basic material properties

- SPT hammer energy measurements
- Groundwater levels
- Pavement section data
- Electronic files for CPTu, or GINT logs
- Borings to sufficient depth
- Lab tests on “Undisturbed” samples
- Follow Agency’s Geotechnical Manual
Limitations of pre-bid load tests

• Expensive for Owner and may be of little value to bidder
• Tied to Owner’s concept
• Subject to low-bidders means and methods
• May yield more ?’s than answers
• May invite claims
Timing of pre-bid geotechnical data

- Late data is of very limited usefulness!
- Causes confusion & inefficient design!
- Estimators throw money into the bid for last minute surprises!
Importance of high-quality pre-bid geotechnical data

Typical Problems:
• No SPT hammer energy measurements
• No groundwater level data
• No pavement section data
• Geotechnical data input into Gint format but electronic files not provided to D-B Teams
• CPTu electronic files not provided
• Investigation does not extend deep enough
Risks & differing site conditions (DSC)

• DSC provisions contribute to a fair and equitable allocation of risk on design-build projects
• Provides a means to address risks and reduce contingency costs
• *Usually* (but not always) included on public works D-B projects
Risks and DSC

Agency should:

• Provide *all* available geotechnical information in a data report

• Describe background geology and known conditions

• Avoid exculpatory language and overly broad descriptions
Risks and DSC

D-B team should:

• Document the basis for design and construction (escrow)

• Evaluate the impact of reasonable variations in ground conditions

• Develop contingency provisions in construction plans and schedule
Risks and DSC: Geotechnical Baseline Reports (GBR)

• Defines basis for bid and allocates risks

  – The Technical Committee on Geotechnical Reports of the Underground Technology Research Council
Differing site conditions and application of baseline geo reports

- Baseline does not eliminate DSC but more clearly defines when DSC occurs
- Example baselines: rock elevations, thickness of soft alluvium, groundwater elevations
- Approach to some high risk items may be prescriptively defined; for example landslide stabilization measures or contaminated soil
Alternative Technical Concept (ATC)

- Fosters innovation from D-B process
- Potential to lower costs/improve schedule
- May represent unfamiliar technology to owner agency
- Potential challenge with performance verification
Alternative Technical Concept (ATC)

Agency should:

• Maintain confidentiality
• Talk early and often. Talk one-on-one
• Require performance testing of concepts; demonstrate effectiveness prior to construction
Alternative Technical Concept (ATC)

D-B team should:

• Consider risks and allocation
• Provide examples and experience
• Plan for performance testing of concepts; demonstrate effectiveness prior to construction
Alternative Technical Concept (ATC)

Examples:

• Base grouting of drilled shafts to enhance capacity
• Reliance on long term pile setup
• Use of equipment that is not covered in specifications
• Innovative ground improvement techniques
Performance based specifications

Owner describes the expected outcome without prescribing a specific approach or design

• Fosters innovation
  – Allow the Contractor to select means and methods

• Reduces potential claims

• Requires performance verification
Performance based specifications

• Geotechnical Investigations
  – Set the minimum requirements for extent of exploration
  – All the D-B Team to determine the type of investigation (borings, in situ tests, laboratory study)
  – Reference the State Manual of Instruction
Performance based specifications

• Foundation load testing – verification of both design and construction methods
  – O-cell or Statnamic on drilled shafts
  – Static and/or Dynamic testing on driven piles

• QC/QA and integrity testing for production
  – Crosshole sonic or other
  – Dynamic monitoring
Performance based specifications

• Embankment settlements
  – UDOT example: 4 inches allowable settlement in 5 years (after project completion) w/ < ¼ inch differential within 12 ft horizontal distance

• Liquefaction mitigation

• Vibration monitoring
Performance based specifications

Agency should:

• Set realistic expectations; overly stringent performance requirements cost time and money that will be reflected in the bid cost

• Clearly define performance measurement requirements

• Use best value selection for optional items
Performance based specifications

D-B team should:

• Plan to achieve performance requirements with robust contingency plans
• Budget adequately to satisfy performance measurement requirements with qualified subconsultants
• Approach best value selection for optional items strategically
Selected Case Histories

• Honolulu Transit, Hawaii
• Biloxi Bay Bridge, Mississippi
• Hastings Bridge, Minnesota
Honolulu Transit Project
Complex Geology – GBR Provided
Anticipated Geologic Materials

- Basalt Formation
- Saprolite (Partially Weathered Basalt)
- Volcanic Tuff (“Mudrock”)
- Coralline Detritus & Coral Formation
- Alluvium (Stiff/Dense Silty Clays & Silty Sands with Variable Amounts of Cobbles & Boulders)
- Recent Alluvium & Lagoonal Deposits (Soft Silty Clays & Loose Silty Sands)
Basalt Characteristics
Cobbles & Boulders in Alluvium
GBR for Honolulu Transit

• Owner’s defined purpose “to help define the contractual ground rules of the bidding process in regards to allocation and definition of geotechnical risks”

• “baselines are developed which will serve as a contractual basis for comparison with actual conditions encountered during foundation construction”

• “The Contractor may rely on these baselines in preparing his Price Proposal”
Farrington guideway case Honolulu, HI

- Key components to the baseline report
  - Geologic setting
  - Site and subsurface conditions
  - Previous construction experience
  - Baselines for stratigraphy and ground characterization
  - Design considerations
  - Construction considerations
Farrington guideway case Honolulu, HI

- Baselines developed for:
  - Application of baselines to the contract price
  - Geologic profile (fill, recent alluvium, coraline deposits, older alluvium, basalt, cobbles and boulders, clinker zones and voids)
  - Groundwater
  - Ground characterization
  - Contamination
Farrington guideway case Honolulu, HI

• Construction considerations:
  – Anticipated ground behavior
  – Groundwater control and management
  – Ground support (casing) requirements
  – Obstructions
  – Rock excavation
Performance Verification

- Base grouting ATC used in gravel zone within alluvium – load tests verify performance
- Load tests with different geologic conditions, construction methodology
- Testing for Basalt with clinker zones below tip
- Testing for Tuff with alluvium below tip
Base Grouting Operations

Oscillator Drilling Equipment
Keys for Honolulu Transit

• Robust pre-bid design to accommodate wide range of conditions
• GBR to limit risks to bidders
• ATC approach to mitigate deep soft alluvium
• Extensive performance verification with method shafts O-cell tests prior to production shafts
Case History – Biloxi Bay Bridge

• US 90 Bridge over Biloxi Bay destroyed by Hurricane Katrina on August 29, 2005.
• Design-Build contract awarded June 7, 2006
• Project cost: $338.6 million
• Schedule date open to traffic: March 28, 2008
Biloxi After Katrina
Test Pile Program

• 21 test and indicator piles, 19 on main bridge
• Verify drivability, hammer, cushions, etc.
• Multiple restrikes w/ PDA/CAPWAP
• Static, statnamic, lateral load tests
Keys for Biloxi

• Established long term setup with test piles
  – Avoid restrikes, reduce schedule risk
• Axial resistance w/ limited reliance on end bearing
  – Avoid variable pile lengths
• Hammer sufficient to drive to tip w/ minimal risk of refusal or damage
• Owner buy-in on approach to testing
October 26, 2007
Biloxi Bay Bridge Opens Two Weeks Ahead of Schedule
Example: Hastings Bridge, MN

• Best value selection process
  – price / technical score

• Key Issues:
  – Verification of high capacity pipe piles
  – North abutment settlement issue
Hastings, MN Steel Pipe Piles

• 42” dia x 1” x 150’
• PDA used to monitor driving stress so pile can be driven hard
• Statnamic axial for verification
Pile Supported Embankment

Pile raft thru soft clay at north embankment
Photo from the Star-Tribune
Summary

• Need high quality, timely pre-bid geotechnical data
• Risks & differing site conditions should be addressed appropriately
• Use ATC’s to obtain value from D-B
• Use performance based specifications with accountability