LRFD - Changes in Geotechnical Exploration

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Louisiana Transportation Conference

February 10, 2009

WHAT IS GEOTECHNICAL EXPLORATION?

- Use of invasive methods to determine the characteristics and properties of the soil beneath a structure to design a foundation to support it.

BORING(s)!

AASHTO LRFD Bridge Design Specifications

- AASHTO … of State Highway … icials
- Issued a… with the goal of incorp… all new bridge d… 2007
- AASHTO … ecifications
  - 4th Edit…

AASHTO LRFD Bridge Design Specifications

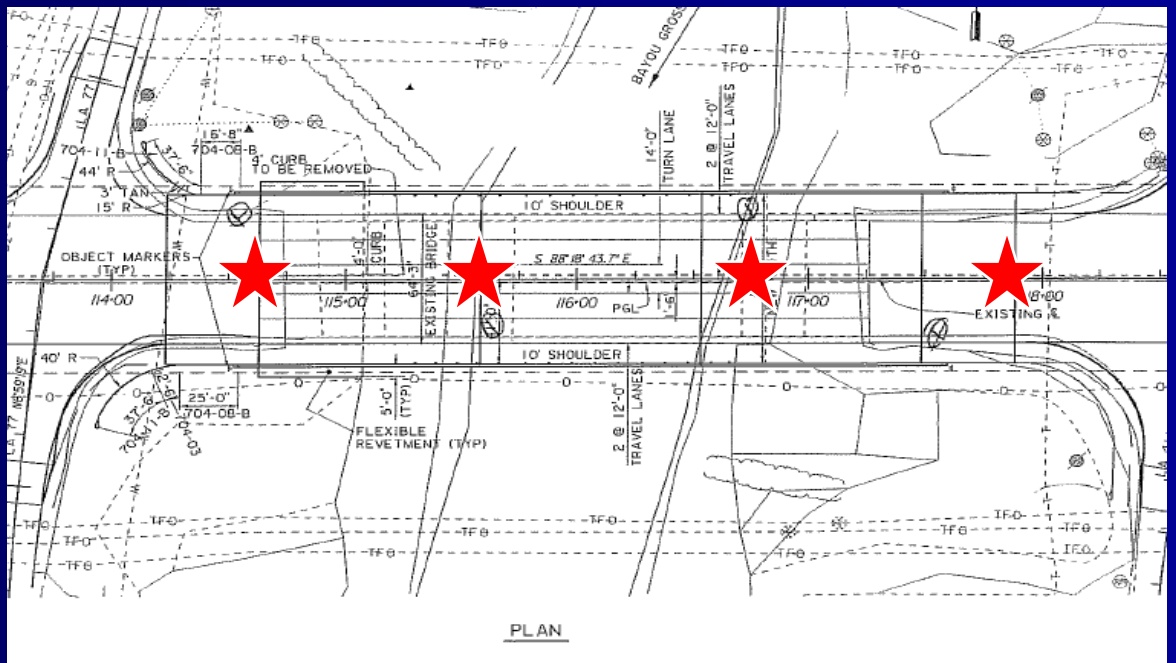
- Section 10 – Foundations covers:
  - Spread Footings
  - Driven Piles
  - Drilled Shafts
  - Micropiles
- 10.4 Soil and Rock Properties
  - Details the procedure for a subsurface exploration program
  - References *Geotechnical Engineering Circular #5, (Sabatini et al., 2002)*
    - ***Highly recommended reading for Geotechnical Engineers***

AASHTO LRFD Bridge Design Specifications Section 10.4

- Provides a *guideline* for a Subsurface Exploration Program
- Program should provide enough data to analyze foundation stability and settlement with respect to:
  - Geological formations present,
  - Location and thickness of soil and rock units,
  - Engineering properties of soil and rock units,
  - Ground water conditions,
  - Ground surface topography, and
  - Local considerations, such as:
    - Liquefiable, expansive or dispersive soil deposits,
    - Underground voids, or
    - Slope instability potential

AASHTO LRFD Bridge Design Specifications Section 10.4

- Table 10.4.2-1 – Minimum number of Exploration Points and Depth of Exploration
- Should be the starting point for any project



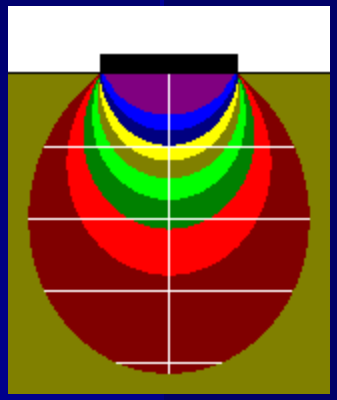
PLAN

AASHTO LRFD Guidelines for minimum subsurface exploration plan (Table 10.4.2-1)

- Retaining walls
  - Length <= 100’
    - One exploration point (EP) for each wall
  - L > 100’
    - EP spaced every 100~200’
    - Locations alternated in front of and behind wall
  - Anchored walls
    - EP placed in the anchorage zone, spaced apart at 100~200’ along the wall
  - Soil-nailed Walls
    - Additional EP at a distance of 1.0-1.5 times the wall height behind the wall spaced apart at 100~200’ along the wall

AASHTO LRFD Guidelines for minimum subsurface exploration plan (Table 10.4.2-1)

- Retaining walls (cont'd)
  - Depth of EP should



    - be below the point where the stress increase due to the estimated foundation load is less than 10% of the existing overburden stress at that depth,
    - Between 1~2 times the wall height, and
    - Fully penetrate soft, highly compressible soils into competent material of suitable bearing capacity

AASHTO LRFD Guidelines for minimum subsurface exploration plan (Table 10.4.2-1)

- Shallow Foundations
  - Substructure with widths <= 100’
    - One EP per substructure
  - Substructure with widths < 100’
    - Minimum of two EP per substructure, with additional points provided if erratic subsurface conditions are encountered
- Shallow Foundations
  - Depth of EP should:
    - Fully penetrate unsuitable foundation soils into competent material
    - be below the point where the stress increase due to the estimated foundation load is less than 10% of the existing overburden stress at that depth,
    - 10’ into bedrock if encountered before the second condition is met

AASHTO LRFD Guidelines for minimum subsurface exploration plan (Table 10.4.2-1)

- Deep Foundations
  - Substructure with widths <= 100’
    - One EP per substructure
  - Substructure with widths < 100’
    - Minimum of two EP per substructure, with additional points provided if erratic subsurface conditions are encountered, especially for the case of shafts socketed into bedrock

AASHTO LRFD Guidelines for minimum subsurface exploration plan (Table 10.4.2-1)

- Deep Foundations
  - Depth of EP should extend:
    - A minimum of 20’ below the anticipated pile or shaft tip elevation or a minimum of 2X the maximum pile group dimension, whichever is greater;
    - Through unsuitable strata to reach hard or dense materials;
  - EP for foundations supported on or extending into rock should include a rock core below the anticipated tip elevation equal to:
    - PILES - A rock core of at least 10’
    - SHAFTS - A rock core of at least
      - 10’, or
      - 3X shaft diameter for isolated shafts, or
      - 2X the maximum shaft group dimension, whichever is greater

AASHTO LRFD Bridge Design Specifications Section 10.4

- Objective: "Establishing a reliable longitudinal and transverse substrata profile"
  - Reducing the risk of construction problems to an acceptable minimum

  or
  - Engineer-speak for "We don't want any surprises"

AASHTO LRFD Bridge Design Specifications Section 10.4

- Encourages adjustment due to:
  - Anticipated/Observed site variability
    - Increase exploration points
  - Prior Site Knowledge
    - Decrease exploration points
  - DOTD has been developing a GIS database for geotechnical data.
    - Details to be presented by Gavin Gautreau, P.E.
    - Session 50 – Tues 3:15 p.m. – Meeting Room 4
    - Any consultants with DOTD geotechnical data from work not handled by my office please contact me to include this data

Geotechnical Engineering Circular #5

- Chapter 3 – Planning a Subsurface Investigation and Laboratory Testing Program
  - Identify data needs
  - Gather and analyze existing information
  - Conduct site visit
  - Develop preliminary site model
  - Develop the site investigation program
  - Develop the lab testing program
  - Lather, Rinse, Repeat
- Much of this has been implemented by DOTD

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- Section 10.4 also covers:
  - Laboratory Testing
  - In-Situ Testing
  - Geophysical Testing

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- Laboratory Testing
  - Should be performed in accordance to established standards
    - AASHTO
    - ASTM
    - Owner-supplied procedures (DOTD TR)
  - Classified into two general classes:
    - Classification or index tests
      - Performed on undisturbed or disturbed samples
    - Quantitative or performance tests
      - e.g. permeability, compressibility, or shear tests
      - Performed on undisturbed samples except in cases of fill materials or materials with an unstable soil-structure

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- In-Situ Testing (SPT, CPT, DMT, PMT, VST)
  - Performed according to ASTM and AASHTO standards
  - When used to estimate design properties through correlations, such correlations should be well-established through:
    - Long-term widespread use, or
    - Detailed measurements that illustrate the accuracy of the correlation
  - Correlations that are specific to one geological formation should be evaluated before applying it to other geologic formations

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- Geophysical Testing
  - Performed according to ASTM and AASHTO standards, or other widely accepted guidelines
  - Examples include:
    - Ground Penetrating Radar
    - Seismic Refraction
    - Neutron Moisture Content
  - Used only in combination with the other two direct methods

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- Section 10.4.6 specifically addresses Soil Strength (10.4.6.2.2)
  - Consolidated-Undrained (CU) and Unconsolidated-Undrained (UU) testing should be used where possible
  - Field Vane testing when undisturbed sampling is very difficult
  - Other In-Situ methods to estimate the undrained shear strength (CPT, etc...)

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- Soil Strength Comments (C10.4.6.2.2)
  - "Strength measurements from hand torvanes, pocket penetrometers, or unconfined compression tests should not be solely used to evaluate undrained shear strength for design analyses. Consolidated undrained (CU) triaxial and in-situ tests should be used."
  - For relatively deep deposits of cohesive soil (e.g. >20') all undrained strength data should be plotted with depth with the type of test used to evaluate the strength clearly identified.
  - Correlations for S_u based on in-situ test measurements should not be used for final design unless they have been calibrated to the specific soil profile under consideration. Correlations for S_u based on SPT tests should be avoided.

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- Section 10.4.6 also addresses N-values
- SPT N-value should be corrected for overburden effects if specified by the design method or correlation (10.4.6.2.4-1)

$$N1 = C_N N$$

where;

N1 = SPT blow count corrected for overburden pressure, sigma prime sub v (blows/foot)

C_N = [0.77log$_{10}$(40/(sigma prime sub v)], and $C_N < 2$

sigma prime sub v = vertical effective stress (ksf)

N = Uncorrected blow count (blows/foot)

AASHTO LRFD Guidelines for minimum subsurface exploration plan

- SPT N-value should also be corrected for hammer efficiency if applicable to the design method or correlation (10.4.6.2.4-2)

$$N_{60} = (ER/60\%)N$$

where;

N_{60} = SPT blow count corrected for hammer efficiency (blows/ft.)

ER = Hammer efficiency expressed as percent of theoretical free fall energy delivered by the hammer system actually used

N = Uncorrected SPT blow count (blows/ft.)

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What has DOTD done to implement LRFD in regards to Geotechnical Exploration?

DOTD Implementation of LRFD Bridge Design Standards

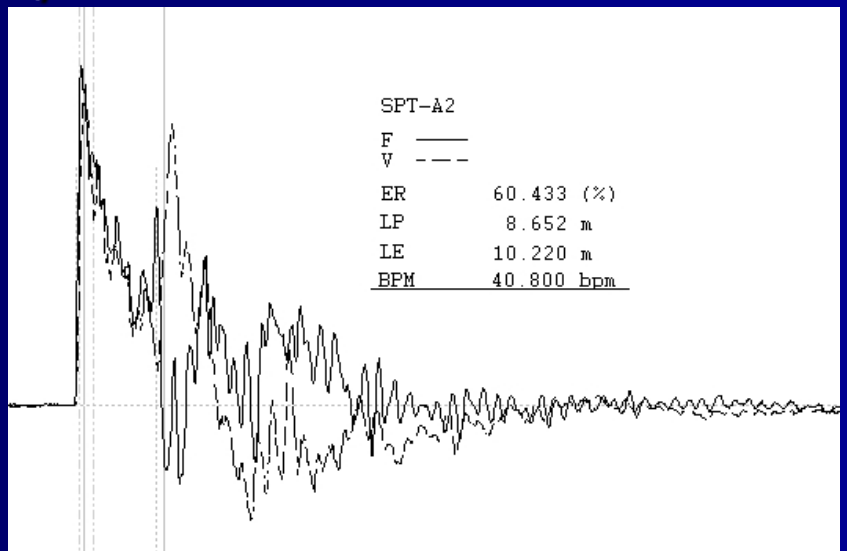
- Changes have been made to DOTD exploration programs gradually
- These affect both field and lab programs
- Several more changes yet to be implemented

DOTD Implementation of LRFD Bridge Design Standards

- Field Exploration Changes
  - EP locations follow the guidelines
    - EPs are spaced no more than 100’ apart
    - Borings and CPTs in combination, when applicable
  - Field extrusion of tube samples is forbidden
    - Transport should adhere to ASTM D4220

DOTD Implementation of LRFD Bridge Design Standards

- Field Exploration Changes (cont'd)
  - SPT N-value correction for hammer efficiency
    - DOTD has obtained an instrumented NWJ rod
    - Used with existing PDA equipment as per ASTM D4633 - 05 Standard Test Method for Energy Measurement for Dynamic Penetrometers



DOTD Implementation of LRFD Bridge Design Standards

- Field Exploration Changes (cont'd)
  - BRAND-SPANKING NEW DRILL RIG!

DOTD Implementation of LRFD Bridge Design Standards

- Laboratory Testing changes
  - Require UU strength testing on at least 75% of extruded samples per boring
  - Samples should be extruded just prior to being prepared for testing
  - Unconfined tests may be run on remaining samples
  - This change equals a 100% increase in cost per sample (Retainer Contract Rates)
    - Unconfined=$34/test
    - UU=$55/test + Lab Extrusion@$13/tube=$68/sample

DOTD Implementation of LRFD Bridge Design Standards

- GIS integration
  - Geotechnical Information Layer for ArcGIS
    - Borings
    - CPT
    - Test Piles
    - Instrumentation, etc…
  - In-house only at this point
  - Will allow for rapid retrieval of data

DOTD Implementation of LRFD Bridge Design Standards

- LTRC N_k Correlation Study (al-Shibli, Okeil)
  - Recently completed by LSU/LTRC
  - Attempted to collect enough data to assign a range of N_k factors to regions of the state
  - Not enough CPT data points were available with boring data, so the entire state was evaluated
  - Intend to continue evaluating the correlations as more CPT data is collected
  - Unit Weight Correlation

DOTD Implementation of LRFD Bridge Design Standards

- Redesign of Geotechnical Deliverables
  - Boring Log
  - Grain Size
  - Consolidation
  - Etc..
- New formats will include more detailed information
- DOTD utilizes gINT
- Once gINT templates are developed, we will distribute these openly
- Completed gINT file to be a deliverable
  - Upload to GIS Database

DOTD Implementation of LRFD Bridge Design Standards

AND FINALLY:

- Development of a DOTD Geotechnical Manual
  - Preliminary work being done now
  - Once a working draft is available, we will ask for ‘volunteers’ in the Geotech community for a peer review

Any Questions?