Session 46

Larry Jones

FDOT

Non-Redundant Drilled Shafts

Topic Description

Presentation of old and new geotechnical and design requirements for non-redundant drilled shaft bridge foundations contained in the FDOT Soils & Foundations Handbook, FDOT Structures Design Guidelines, FDOT Structures Detailing Manual, and FDOT Standard Specifications

Speaker Biography

Larry earned BSCE & MSCE degrees at the University of South Florida in Tampa, where he was a member of Chi Epsilon, Tau Beta Pi, and Phi Kappa Phi honor societies. Before joining FDOT, Larry worked with three different geotechnical engineering consultants: Law Engineering Testing Company in Tampa, Jammal & Assoc./PSI in Winter Park and Geotechnical Consultants International in Winter Park. Larry started with FDOT nearly 11 years ago in the Panhandle's District Three Materials Office, and has been FDOT's State Geotechnical Engineer for almost 5 years.

In 2003 & 2004, Larry participated in the FHWA funded technical working group (TWG) with AASHTO representatives and other engineers from the states using LRFD for bridge design. The TWG was asked to critically evaluate the rewrite of the AASHTO LRFD Bridge Design Specifications Section 10, Foundations which eventually became part of the 2006 AASHTO LRFD Bridge Design Specifications.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

FDOT's Requirements For

Nonredundant Drilled Shaft Bridge Foundations

Larry Jones
FDOT Assistant State Structures Design Engineer
& State Geotechnical Engineer

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Introduction

- National References
  - FHWA Geotechnical Engineering Circular #5: Evaluation of soil and Rock Properties (2002)
  - NCHRP Research Report 507: LRFD For Deep Foundations (late 2004)

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Introduction

- National Design Code
  - AASHTO LRFD Bridge Design Specifications (2006)

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Introduction

- Additional FDOT Requirements
  - FDOT Soils & Foundations Handbook
  - FDOT Structures Design Guidelines
  - FDOT Structures Detailing Manual
  - FDOT Standard Specifications

Introduction

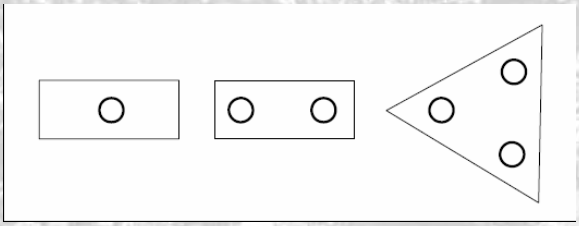
- Define Nonredundant -

Bridge bents or piers containing one column with three or fewer drilled shafts, or two columns with one or more of the columns supported by only one or two drilled shafts, or as those shafts deemed non-redundant per AASHTO LRFD Article 1.3.4.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Introduction

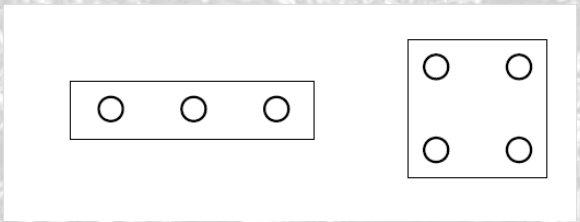
- Nonredundant Examples



FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Introduction

- Redundant Examples



FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

FHWA Geotechnical Engineering Circular #5 Evaluation of Soil and Rock Properties

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

FHWA Geotechnical Engineering Circular #5 Evaluation of soil and Rock Properties

- Soil & Rock Variability
  - Variability in material
  - Variability in sample quality
  - Variability in testing reliability

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

FHWA Geotechnical Engineering Circular #5 Evaluation of soil and Rock Properties

- Estimating Variability
  - Engineers can estimate average values for specific parameters with a relatively high degree of accuracy, if sufficient data is presented.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

FHWA Geotechnical Engineering Circular #5 Evaluation of soil and Rock Properties

- Estimating Variability
  - Unfortunately, it has also been found that engineers typically believe there is less variability in these soil parameters than the data actually supports.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

NCHRP Research Report 507 - LRFD for Deep Foundations

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

NCHRP Research Report 507 - LRFD for Deep Foundations

- Project locations broken into “sites” of similar soil conditions
- Site variability
  - Within the site, not between sites

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

NCHRP Research Report 507 - LRFD for Deep Foundations

- Introduces the concept of a reduced resistance factor for a nonredundant foundation

  (or an increased β value for nonredundant foundations)

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

AASHTO LRFD
Bridge Design Specifications

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

AASHTO LRFD
Bridge Design Specifications

(Interim 2006)

Section 10 Foundations

Art.10.5 Limit States & Res. Factors

Art.10.5.5 Resistance Factors

Art.10.5.5.2 Strength Limit States

- 10.5.5.2.1 General
- 10.5.5.2.4 Drilled Shafts

AASHTO LRFD Bridge Design Specifications

- C10.5.5.2.1 *General*
  - Smaller resistance factors should be used if :
    - Site or material variability is anticipated to be unusually high

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

AASHTO LRFD Bridge Design Specifications

- C10.5.5.2.1 *General*
  - Reduce resistance factors if :
    - Design assumptions increase design uncertainty and;
    - Design assumptions have not been mitigated by conservative selection of design parameters.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

AASHTO LRFD Bridge Design Specifications

- 10.5.5.2.4 *Drilled Shafts*

  Reduce resistance factors by 20% for nonredundant foundations such as a single shaft supporting a bridge pier,

  to reflect a higher target β value of 3.5 (1 in 5,000) to be consistent with the superstructure design requirements

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

AASHTO LRFD Bridge Design Specifications

- 10.5.5.2.4 *Drilled Shafts*

  Where the resistance factor is reduced in this manner, the ηR factor provided in Article 1.3.4 should not be increased to address the lack of foundation redundancy.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation
  - For bridges (including pedestrian bridges) to be supported by non-redundant drilled shaft foundations perform at least one SPT boring at each drilled shaft location during the design phase.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation
  - The number of borings required to be evenly spaced at each non-redundant drilled shaft location will be dependant on the shaft size as follows:

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation

Shaft Diameter, feet	Borings/shaft
<= 7	1
7* – 9	2
9* – 10	3

* Highly Variable Sites

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation
  - Contact the State Geotechnical Engineer for exploration requirements for drilled shaft diameters larger than 10 feet (if allowed).

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation
  - Extend borings at least 3 shaft diameters below the proposed/final shaft tip elevation.
  - Core the limestone load bearing strata and test core samples.
  - Pilot holes during construction when the original boring depth is insufficient, shafts are lengthened or shaft locations are changed.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation
  - Borings shall be located by survey within 1' (one foot) of the shaft location.
  - If access during design prevents this accuracy, plan notes will require the pilot holes during construction.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Investigation
  - However, every effort shall be made to perform these borings and test the cores during design.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Design

  Appendix A updated from the original 1998 Design Conference Presentation to clarify the most misinterpreted contents and include a design example.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Design

  All nonredundant shafts shall be minimum of 4’ diameter.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Design

  Consider the combined effects of axial loads and moments to properly evaluate the geotechnical bearing resistance of the shaft and the effect on the distribution of the stresses across the shaft bottom.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Design

  There is often sufficient horizontal reaction to resist moments in shafts embedded at least seven (7) shaft diameters below the design ground surface.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Soils & Foundations Handbook 2006

- Design
  - Plans note:
  - Inspect each drilled shaft using a Shaft Inspection Device (SID) to ensure shaft cleanliness at the time of concrete placement.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Structures Design Guidelines

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Structures Design Guidelines

- Design
  - All nonredundant shafts shall be minimum of 4' diameter.
  - Add a note to Foundation Layout Sheet requiring that all nonredundant drilled shaft locations be inspected using SID.
  - Add a note to the Foundation Layout Sheet requiring all nonredundant drilled shafts to be integrity-tested using cross-hole-sonic logging (CSL.)

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Structures Design Guidelines

- Design
  - Add a note to Foundation Layout Sheet requiring additional pilot holes when needed.
  - Require the pilot holes two weeks prior to shaft excavation.

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Structures Design Guidelines

- Exemptions
  - Shafts for bridge widening when the substructure is attached to the original structure
  - Shafts up 60-inches in diameter installed to support miscellaneous structures (i.e. sign structures, mast arms, high-mast light poles, noise walls)

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Structures Detailing Manual

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Structures Detailing Manual

- Drilled Shaft Data Table (See Ex 7a)

DRILLED SHAFT DATA TABLE

INSTALLATION CRITERIA					DESIGN CRITERIA					TESTING
Pier or Bent No.	Shaft Size (in.)	Tip Elev. (ft.)	* Min. Tip Elev. (ft.)	Min. Rock Socket Length (ft.)	Factored Design Load (tons)	Down Drag (tons)	Long Term Scour Elev. (ft.)	100-Year Scour Elev. (ft.)	[illegible]	** Consider Nonredundant
1	--	--	--	--	--	--	--	--	.5[illegible]	No
2	48	--	--	--	--	N/A	--	--	.4[illegible]	Yes
3	48	--	--	--	--	N/A	--	--	.4[illegible]	Yes
4	--	--	--	--	--	--	--	--	.55	No

Tip Elevation: The elevation to which the shaft shall be constructed unless test load data, rock cores, or other geotechnical test data obtained during construction allows the Engineer to authorize a different tip elevation.

* Min. Tip Elevation: The highest elevation that the shaft tip may be constructed if adjustments are made to the tip elevation

** Inspect all nonredundant drilled shafts using SID or approved alternate down-hole camera to verify shaft bottom cleanliness at the time of concreting. Test all nonredundant drilled shafts using cross-hole-sonic logging (CSL).

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Specification 455

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Specification 455

- Pilot Holes when boring locations were not accessible during design
- CSL required for all non-redundant bridge shafts
- CSL testing and acceptance criteria provided clearly in Specification 455-17.6.1

FICE/FDOT Design Conference 2006
Designing For More Than Bridges & Roads

Questions?

Larry.Jones
@DOT.STATE.FL.US