ALDOT Implementation of LRFD Design and Construction Procedures for Driven Piles

Matt Revell, P.E.
Assistant Geotechnical Engineer
ALDOT Bureau of Materials & Tests
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• Initial implementation
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• 1st (only) revision January 15, 2016

• Developed to conform to requirements in AASHTO LRFD Bridge Design Specifications, 7th Ed., 2014
LRFD for Driven Piles

1) Generalized concept of LRFD for driven piles

2) Important changes to current procedures

3) Where is LRFD taking us??
The Dilemma...
How do we account for variability between foundation units?
# ASD vs. LRFD

<table>
<thead>
<tr>
<th>ASD</th>
<th>LRFD</th>
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<tbody>
<tr>
<td>• Is the driving criteria developed from Pile “A” valid for Pile “B”??</td>
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<tr>
<td>• Simple True or False argument</td>
<td>• To what extent is the driving criteria developed from Pile “A” valid for Pile “B”??</td>
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</tbody>
</table>
Is the driving criteria produced from Pile “A” valid for Pile “B”?
LRFD:

Is the driving criteria produced from Pile “A” valid for Pile “B”?

If so, how valid is it?
To what extent...

Φ Geotechnical Resistance Factor

- LRFD gives us the tools to quantify our confidence in the geotechnical investigation, analysis, and design of a project
- Represents the level of confidence we have in our design to maintain its validity across inevitable site variability
- Based on reliability of method used to predict nominal capacity
Geotechnical Resistance Factor

- Ranges from 0.0 – 1.0; typical value between 0.5-0.8
- Dependent on quantity \textit{and} quality of pile capacity verification performed during construction
- Percentage of nominal resistance derived from production driving criteria allowed to be relied upon in final design (setting final tip elevation during const.)
- $\Phi(R_N) > \text{Factored Load}$
- Static Load Test @ Pile “A”
- Wave Equation for production driving criteria (bearing curve)
- Dynamic Load Tests @ Piles “A₁” & “A₂”
- Φ = 0.80
- Required Nominal Resistance (R_{N,Req}) @ Pile “B” = Factored Load/ Φ

- Factored Load = 100 tons, R_{N,Req} = 125 tons
LRFD “Site” Delineation

• Geotechnical designer is tasked with dividing the project into “Sites” with similar driving conditions

• “Sites” are dependent on geology, subsurface stratigraphy, groundwater conditions, & engineering properties of soil and/or rock

• Automatic triggers: Changes in pile type/size/factored load

• Described in body of foundation report and shown graphically on boring location map

• “Sites” can be as large as the entire project or limited to a single substructure unit, and in extreme cases even a single pile
LRFD “Site” Delineation (cont’d)

• The single most important step in the LRFD design process for driven piles

• Unlike other LRFD design procedures (structural) in that this step is governed at least in part by engineering judgment (not the only step involving human element)

• First entry point in the process for over-conservatism
Selection of NRVP for individual “Sites”

- NRVP: Nominal Resistance Verification Program

- Selection of NRVP for a particular “Site” governs value of Resistance Factor, $\Phi$

- Geotechnical designer tasked with selecting the most appropriate NRVP for each LRFD “Site” previously identified
  - 2\textsuperscript{nd} entry point for over-conservatism
• Static Load Test @ Pile “A”
• Wave Equation for production driving criteria
• Dynamic Load Tests @ Piles “A_1” & “A_2”
• $\Phi = 0.80$

• Required Nominal Resistance ($R_{N,\text{Req}}$) @ Pile “B” = \frac{\text{Factored Load}}{\Phi}

• Factored Load = 100 tons, $R_{N,\text{Req}} = 125$ tons
Selection of NRVP for individual “Sites”

- NRVP: Nominal Resistance Verification Program

- Selection of NRVP for a particular “Site” governs value of Resistance Factor, $\Phi$

- Geotechnical designer tasked with selecting the most appropriate NRVP for each LRFD “Site” previously identified
  - 2nd point of entry for over-conservatism

- Several recommended by AASHTO; ALDOT has identified 4 that we will use going forward
  - Ones that matched closely with current practice in Alabama

- NRVP A
- NRVP B
- NRVP C
- NRVP D
  - (Not terminology you will find in AASHTO)
Quality and Quantity of field testing

NRVP A
NRVP B
NRVP C
NRVP D

* - Resistance factor for NRVP D based on static analysis method used during design
NRVP A

- Static load test of at least 1 pile per site condition
- Dynamic testing with signal matching of at least 2 piles per site condition
  - No less than 2% of production piles
- $\Phi = 0.80$

- Applicable to “Sites” where no obvious bearing stratum identified during investigation
- Piles will develop capacity through some combination of side and base resistance
- Most comprehensive field verification of nominal resistance
NRVP B

• Static load test of at least 1 pile per site condition (without dynamic testing)
• $\Phi = 0.75$

• Applicable to “Sites” where the additional time and cost of performing comprehensive verification testing may outweigh the cost of simply driving the piles deeper based on a lower resistance factor
• May be thought of as a “proof testing” program, where piles are driven to estimated tip elevations and static load tested to verify capacity
• Will likely be most appropriate to small projects (example: 2-lane single span bridges, similar to many ATRIP projects)
NRVP C

- Driving criteria established by Dynamic Test Pile with signal matching
- Dynamic testing with signal matching of at least 2 piles per site condition
  - No less than 2% of production piles
- $\Phi = 0.65$

- Essentially the same as NRVP A minus the Static Load Test
- Anticipated backup to NRVP A if Static Load Test proves to be impossible during construction
NRVP D

- Only static analysis or engineering judgment used to establish driving criteria
- No field verification of nominal resistance
- $\Phi = \Phi_{\text{Static}}$

- Used where piles are expected to be driven to refusal into hard rock, weathered rock, or some other obvious bearing stratum
- Geotechnical capacity of the pile approaches the structural capacity of the pile section
LRFD Moving Forward

• LRFD designed and constructed projects will give us the data we need to calibrate resistance factors specific to conditions encountered in Alabama

• Starting with 4 NRVP’s, predict reducing to 2-3 that work well in our organization

• LRFD gives us the tools that we need to develop new NRVP’s and corresponding resistance factors based on data captured from existing procedures...we just have to get started
• Initial up-tick in cost
• After further refinement of resistance factors, expect cost to decline
Questions?
Thank You

Matt Revell, P.E.
Ph: 334-206-2257
Email: revells@dot.state.al.us
LINC: 1*99*516