Welcome to the world of the LA DOTD Geotechnical Design Section.

LA DOTD Geotechnical Section’s “Grab-Bag of Tools” by Steve Meunier, P.E. Geotechnical Engineering Manager
GOAL OF PRESENTATION

• To introduce Consultants to the world of Geotechnical Engineering as practiced within the LA DOTD Geotechnical Section
• To provide an overview of our methodology for geotechnical investigations, driven pile foundations, drilled shafts, cantilevered and anchored sheet pile walls, embankments, slope stability and MSE walls.
• To provide insight into the deliverables expected from Consultants when submitting geotechnical calculation packages to LA DOTD for review
Subsurface Investigations

• First step in the investigation is to collect and analyze all existing geotechnical data to determine whether additional borings need to be taken (Due diligence)

• Borings should be spaced at approximate intervals of 200-ft at bridge locations or as directed by DOTD

• Minimum depth of bridge borings should be 100 feet below existing ground surface

• Minimum depth of retaining wall borings should be to a depth of 1-1/2 times the proposed wall height with concentrated lab testing within the bearing layers
Subsurface Investigations (Cont’d)

- Laboratory visual classification should be performed on all soil samples extracted from borings.
- Cohesive soil samples should be taken using 3-inch Shelby tubes at 5-ft intervals.
- Cohesionless soil samples should be taken using a split spoon at 3 to 5-ft intervals with SPT’s.
- Either Unconfined Compression or U-U Triaxial tests with Atterberg limit tests should be performed on at least 75% of the Shelby tube samples. Pocket Penetrometer or torvane readings will not be accepted in lieu of laboratory compression tests.
- All borings should be submitted in the LA DOTD format with project stations, offsets, measured elevations and Lat/Long coordinates.
Sample LA DOTD Boring Log

<table>
<thead>
<tr>
<th>SOIL TYPE AND COLOR</th>
<th>TEST PILE NO.</th>
<th>LATITUDE OF DRILL SITE</th>
<th>LONGITUDE OF DRILL SITE</th>
<th>DRIVING RESISTANCE (TONS)</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Med.-Stiff. B. Gr. Cl.</td>
<td>125</td>
<td>33</td>
<td>81</td>
<td>57%</td>
<td>33</td>
<td>81</td>
</tr>
<tr>
<td>Very Stiff-Stiff Tann. Gr. C.</td>
<td>133</td>
<td>45</td>
<td>81</td>
<td>M.S.</td>
<td>39</td>
<td>75</td>
</tr>
<tr>
<td>Water Table Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unconfined Compression tests performed on at least 75% of clay samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Measured Elevations

Latitude and Longitude

Project Stationing and Offset Distance
PILE FOUNDATIONS

• Typical pile types used are pre-cast concrete piles from 14-36 inch square, 54 & 66 inch spun-cast, steel pipe piles, H-piles and timber piles.

• Pile sizes should be determined on the basis of the maximum slenderness ratio of $L/d = 20$ and the anticipated design loading.

• The pile unsupported length is measured down below the channel bottom accounting for scour (5-ft minimum), plus a distance to the assumed point of fixity (5-ft minimum). **Point of fixity should be calculated in weak soils.**
MAXIMUM UNSUPPORTED PILE LENGTHS BASED ON
L/d = 20

<table>
<thead>
<tr>
<th>Pile Size</th>
<th>Max. Unsupported Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-inch</td>
<td>23-ft</td>
</tr>
<tr>
<td>16-inch</td>
<td>26-ft</td>
</tr>
<tr>
<td>18-inch</td>
<td>30-ft</td>
</tr>
<tr>
<td>24-inch</td>
<td>40-ft</td>
</tr>
<tr>
<td>30-inch</td>
<td>50-ft</td>
</tr>
</tbody>
</table>
Pile groups require analyses for group capacity, settlement and lateral loads.
PILE ANALYSES

• Static pile capacities are calculated using the FHWA “Driven” Software program.

• The FHWA “Driven” program provides ultimate pile capacity versus depth – this information must be converted to pile tip elevations in your submittal to DOTD. “Driven” allows more flexibility in how you model your soil strength parameters, yet requires more understanding from the user.

• Nordlund’s Method used in Driven tends to over-predict large diameter piles in deep sand conditions. Must apply judgment when using this software in massive sands or in end-bearing cases with varying bearing strata thicknesses.
PILE ANALYSES - SUBMITTALS

• All pile calculation submittals shall include the ultimate pile capacities versus pile tip elevations for each pile bent, indicating the soil boring model with scour, depth of fixity, L/d value and design load.

• These calculations shall indicate the tip elevations required at each bent using the appropriate factors of safety with and without a pile load test, and whether test piles are feasible at this site. Test pile and indicator pile locations should also be stated in your recommendations.

• Should unusual lateral loads be applied to a foundation, then appropriate analyses should be performed using “L-Pile” or “Florida Pier” methods.
## PILE SAFETY FACTORS

### Pile Design and Construction Control Safety Factors

<table>
<thead>
<tr>
<th>Construction Control Method</th>
<th>Static Design Safety Factor $S_{Design}$</th>
<th>Construction Control Safety Factor $S_{EOD}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Pile with Static Load Test</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Indicator Pile with Dynamic Monitoring</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>No Field Testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-System: Permanent Pile with Wave Equation</td>
<td>2.75</td>
<td>2.75</td>
</tr>
<tr>
<td>On-System: Permanent Pile with Gates Dynamic Formula</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Off-System: Permanent Pile with Wave Equation</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Off-System: Permanent Pile with Gates Dynamic Formula</td>
<td>3.00</td>
<td>3.00</td>
</tr>
</tbody>
</table>
“DRIVEN” SOFTWARE - INPUT
These depths will need to be converted to pile tip elevations on the output table.
LRFD Considerations

• DOTD is in the process of calibrating resistance factors for our local conditions
• Extremely important to properly characterize the project site into design reaches based upon geology and site variability
• Resistance factors will be ultimately based upon site variability, number of static load tests per site and judgment…..yes, we will still apply engineering judgment to our designs
• We currently have several LRFD projects on the drawing board and a few in construction at this time
LRFD Lessons Learned to Date

- Dynamic monitoring and load test methods become extremely important tools to enhance pile designs.
- QA/QC role becomes very important on LRFD projects.
- Not all Pile Load Test Methods are equal in the world of LRFD.
  - Statnamic Tests in clays may possess different resistance factors than other Load Test methods.
  - For Example: We are in process of evaluating these issues on the Twin Spans Project.
- Not all sampling and testing methods are equal in the world of LRFD.
- Not all calculation and modeling methods are equal in LRFD.
DRILLED SHAFTS – DESIGN CRITERIA

- The drilled shafts will be designed both with and without test shafts at each site, taking the appropriate safety factors into consideration.
- A safety factor between 2.5 and 3.0 will be used without a test shaft.
- A safety factor of 2.0 will be used with a test shaft.
- Short-term shaft deformations due to load transfer will be limited to ¾-inch to 1-inch at twice the design load and less than or equal to ¼-inch at 1.5 times the design load.
- The shafts will be designed in accordance with DOTD guidelines for CSL tubes, clearances, minimum reinforcement, spacing requirements, etc. as specified in our specifications and design guides.
- Post-grouted shafts will be considered on a project-by-project basis based upon site characteristics and loading requirements.
DRILLED SHAFTS – EXAMPLE

Deformation Criteria:
- 3/4-1 inch at twice design load
- 1/4 inch at 1.5 times design load

O’Neill’s Trend-Line Curves
SLOPE STABILITY ANALYSES - CRITERIA

• All slopes will be analyzed for global stability for design and construction loads using both short-term and long-term soil parameters.

• The minimum factors of safety against failure are 1.3 to 1.5 for normal conditions and 1.1 for seismic or rapid drawdown cases in accordance with AASHTO.

• LA DOTD recognizes that there will be some slopes that will not be stable in the event of a meandering scour situation. These sites will be taken on a case-by-case basis.

• All submittals will consist of the input/output tables with graphics indicating the critical failure surfaces along with the soil borings used in the models. All design and construction loads will be taken into consideration in these analyses.
STABILITY ANALYSIS - EXAMPLE
SHEET PILE WALLS

• Sheet pile walls shall be analyzed using classical geotechnical engineering methods for both short-term and long-term soil parameters taking into consideration all design and construction loads in accordance with DOTD’s Preliminary Sheet Pile Design Guidelines.

• Minimum factor of safety of 1.5 is applied only to the passive side for stability against rotation.

• The design shall include the recommended sheet pile type and section, minimum section modulus, minimum depth of penetration, moment of inertia criteria with estimated deflections and anchor loads.
The working stress design method will be used to design the structural section of the sheet pile. The analysis package will consist of the soil model and all input/output information for the shear, moment and deflection of the sheet pile. The design shall include all details of the sheet piling, backfill and drainage requirements, corrosion protection measures and connection details.
**TYPICAL SHEET PILE ANALYSIS RUNS**

![Diagram of sheet pile analysis runs with input data indicating an anchored retaining wall in granular soil, design for FS=1 on both active and passive conditions.](image)
TYPICAL SHEET PILE ANALYSIS RUNS

ANCHORED WALL RESULTS BY FREE EARTH METHOD

ANCHORED RETAINING WALL IN GRANULAR SOIL
DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

NET SOIL PRESSURE (PSF)
FOR ANCHORED WALL DESIGN BY FREE EARTH METHOD
TYPICAL SHEET PILE ANALYSIS RUNS

ANCHORED WALL RESULTS BY FREE EARTH METHOD

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

ELEV. (FT)

2.00E+10

30.00

26.00

22.00

0.00

-9.01

SCALED DEFLECTION (LB-IN^3)
FOR ANCHORED WALL DESIGN BY FREE EARTH METHOD

0 6.00E+09
M.S.E. WALLS

• LA DOTD has currently approved two MSE wall systems, the Keystone steel-reinforcement wall and the Mesa geogrid-reinforcement wall. Both wall systems have undergone HITEC approval and have gone through the LA DOTD approval process.

• All MSE walls will be designed in accordance with the LA DOTD Geotechnical Engineering Design Guide No. 8.
MSE WALLS – cont’d

- External and global stability of the MSE walls will be the responsibility of LA DOTD or the designated design Consultant in accordance with AASHTO guidelines.
- Internal stability will be the responsibility of the MSE wall manufacturer in accordance with AASHTO guidelines. LA DOTD or the designated design Consultant will perform a review of the internal stability calculations and shop drawings.
- The FHWA software entitled “MSEW” will be utilized to check both external and internal stability of the MSE walls, along with other pre-approved spreadsheets and software.
“MSEW” SOFTWARE FOR MSE WALLS
“MSEW” SOFTWARE FOR MSE WALLS

**Geometry / Surcharge**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, H [ft]</td>
<td>26.5</td>
</tr>
<tr>
<td>Backslope, $\beta$ [deg.]</td>
<td>18.3</td>
</tr>
<tr>
<td>Batter, $\omega$ [deg.]</td>
<td>1.7899</td>
</tr>
<tr>
<td>Backslope rise, S [ft]</td>
<td>1</td>
</tr>
</tbody>
</table>

**Wall embedment**

Click to change wall embedment from its adjoining finished grade to top of excavated foundation soil. $E = 1.50$ ft.

**NOTE:** The DESIGN height, $H_d$, of the wall is equal to the height of wall, $H$ (measured from top to the finished bottom grade of the wall) + embedment depth, $E$. Consequently, $E$ may effect significantly the final layout of reinforcement and should carefully be selected.

$H_d = \text{Design height} = H + E$

**Uniformly Distributed**

- Dead load surcharge: 0 [lb/ft²]
- Live load surcharge: 250 [lb/ft²]

**Concentrated**

- Strip Load, $P_v$
- Isolated Load, $P_v'$
- Point Load, $P_v''$
- Horizontal Load, $P_h$

**Input Values**

1234567
“MSEW” SOFTWARE FOR MSE WALLS

Stress distributions

Meyerhof equivalent stress distribution

\[ \sigma_V = 4203.9 \text{ [lb/ft}^2] \]
\[ e = 1.95 \text{ [ft]} \]

Trapezoidal stress distribution assuming rigid footing:

\[ 5238.3 \quad 1800.8 \]
\[ 24.00 \]

Results

<table>
<thead>
<tr>
<th></th>
<th>STATIC</th>
<th>SEISMIC</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate bearing capacity, ( q_{ult} )</td>
<td>25882.93</td>
<td>N/A</td>
<td>[lb/ft]</td>
</tr>
<tr>
<td>Meyerhof stress, ( \sigma_V )</td>
<td>4203.87</td>
<td>N/A</td>
<td>[lb/ft]</td>
</tr>
<tr>
<td>Eccentricity, ( e )</td>
<td>1.95</td>
<td>N/A</td>
<td>[ft]</td>
</tr>
<tr>
<td>( e / L )</td>
<td>0.081</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Fs calculated</td>
<td>6.16</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Base length</td>
<td>24.00</td>
<td>N/A</td>
<td>[ft]</td>
</tr>
</tbody>
</table>

Display results of external loads

For Help, press F1
"MSEW" SOFTWARE FOR MSE WALLS
“MSEW” SOFTWARE FOR MSE WALLS
EMBANKMENT SETTLEMENT

• Embankment settlements shall be calculated for design cases with and without surcharge and wicks versus the time required for at least 90% of the primary consolidation to occur.

• Presentation of these calculations shall include in graphical form each of the options considered in the analyses along with the soil borings utilized in the settlement models.

• Surcharge and wick drain design sheets, along with any recommended monitoring program shall be clearly indicated on the plans and specifications.
EMBANKMENT SETTLEMENT - EXAMPLE

Predicted Settlement

- 100% Settlement: 4.94 inches
- Embankment Only
- 4" surcharge: 41" wicks @ 5" spacing
- 4" surcharge

S.P. No. 454-02-0035
2/13/2004
Boring 1

LaDOTD Pavement Geotechnical Design
Juban Interchange
South Approach
“You can’t wish into the ground what you failed to solve on paper.”

(Karl Terzaghi, Father of Soil Mechanics)

QUESTIONS???