NORTH CAROLINA'S EXPERIENCE WITH LRFD IMPLEMENTATION

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TRB – WORKSHOP
1/13/08

Two Questions?

- Where have we been?
- Where are we?

OUTLINE

- Local Calibration effort
- ASD & LRFD Comparisons
- Proposed LRFD Design Process
- Planned Future Calibration effort
- Lessons learned, summary & Conclusions

Where have we been?

Concerns with AASHTO LRFD Specs:

- Proposed resistance factors were too low
- Local geology not accounted for
- Current ASD method (Vesic) not included
- Too high factors of safety used in calibration

Geology of North Carolina

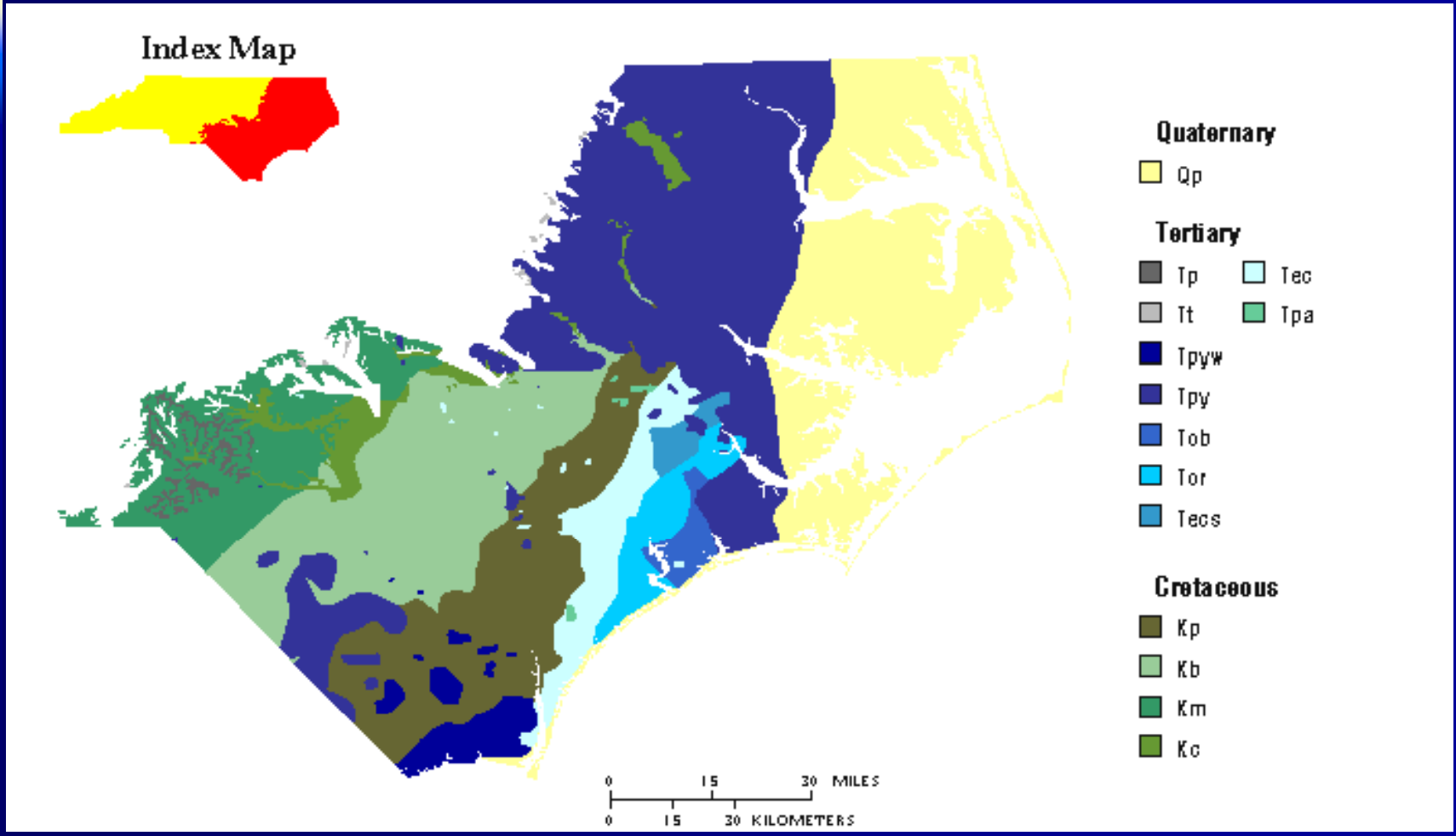
- Coastal Plain- 35%
- Piedmont- 50%
- Blue Ridge Mountains- 15%

Figure 3-1. North Carolina Geologic Map (NCGS, 1985)

Coastal Plain Geology

- Quaternary Deposits: Undifferentiated, some thick organic deposits in some areas.
- Tertiary: Slightly over-consolidated clays, loose to medium dense silts & clays, N-SPT<10bpf. Weak limestone deposits.
- Cretacious: Over-consolidated clays & dense silts & sands. N-SPT>20bpf.

Coastal Plain Geology



Current ASD Practice

Geology vs. Foundation Types:

- P/S Concrete Piles in outer Coastal Plain.
- HP Steel and P/S Concrete Piles in inner Coastal Plain.
- HP Steel piles, steel Pipe piles, Drilled Piers and Spread Footings in Piedmont & Mountains.

Current ASD Practice

Axial Capacity:

- Vesic in C.P. supplemented by Nordlund.
- Both methods use Tomlinson for clays.
- By inspection in Piedmont & Mountains.
- Controlling Factor- Pile installation.
- Use F.S. of 2 .

LRFD for Analysis/Design of Piles Axial capacity

- Conducted by N.C. State Univ.

  Researchers:

  M.S. Rahman, PhD, P.E., Professor

  M.A. Gabr, PhD, P.E., Professor

  K.J. Kim, PhD, P.E., NCDOT

  R.Z. Sarica, Graduate Assistant

  M.S. Hossain, Graduate Assistant

Data Available For Calibration (C.P.)

Pile Type	PDA (EOD)	PDA (BOR)	PDA (Both)	Static Load Test
P/S Conc.	85	26	20	22
HP Steel	17	3	2	2
Steel Pipe	7	15	10	0
Conc. Cylinder	3	0	0	5

Limits On Available Data

- Had sufficient data for P/S concrete piles.
- Majority of HP steel pile data was PDA EOD.
- Majority of Steel Pipe pile data was from 1 project.
- Insufficient data for concrete cylinder piles.

Recommended Φ for C.P. HP Piles

Target Reliability Index	Vesic	Nordlund	Meyerhof
2.0	0.75	0.80	0.65
2.5	0.65	0.70	0.55

Recommended Φ for C.P. P/S concrete piles

β	Vesic	Vesic	Nord lund	Nord lund	M-hof	M-hof
	NToe ≤ 40	NToe > 40	NToe ≤ 40	NToe > 40	NToe ≤ 40	NToe > 40
2.0	0.60	0.50	0.55	0.40	0.90	0.80
2.5	0.50	0.40	0.45	0.35	0.70	0.60

Comparison between AASHTO and NCDOT Φ's

- Nordlund: Φ for NCDOT P/S Concrete piles approximately same as AASHTO.
- Meyerhof: Φ for NCDOT P/S Concrete piles significantly higher than AASHTO.
- Φ from all 3 methods significantly higher than AASHTO for HP Steel piles.

Where are we?

- Plan to use Nordlund method and AASHTO Φ for P/S concrete piles.
- Plan to use Nordlund method and Φ of 0.70 for HP steel piles & 0.60 for Steel Pipe piles in the interim.
- Plan to collect more PDA BOR data for HP Steel piles & re-calibrate HP steel piles.
- Completed 3 comparative examples.
- Established LRFD process for end bents.

Where are we?

- Working on interior bents design process.
- 4 Geotechnical Engineers attended the 3-days LRFD NHI class.
- Planning to have an internal training for rest of Geotech.'s in Feb. or march 2008.

Planned Calibration Efforts

- HP Steel piles.
- PDA with a minimum of 96 hours re-strike.
- Minimum of 20 tests.
- Develop Resistance Factors.
- Steel Pipe piles will follow.

ASD & LRFD Comparisons

- Comparisons for end bents only.
- B-3467 Halifax Co. Cretacious formation.
- B-3692 Robeson Co. Tertiary over Cretacious formations.
- B-3871 Martin Co. tertiary soil formation.
- HP Steel piles in all cases.

Case Studies-HP piles AASHTO Φ (Estimated Pile lengths ft.)

project	ASD	LRFD with PDA	LRFD no PDA
B-3467 Halifax	840 (8)	840 (4)	725 (5)
B-3692 Robeson	960 (8)	825 (5)	840 (6)
B-3871 Martin	1395 (9)	1100 (5)	1225 (7)

Case Studies - Observations

- ASD pile lengths based on current policy of using an allowable load of 50 tons for HP 12x53 Steel piles.
- LRFD pile lengths based on AASHTO specs that allows loads up to structural capacity of a pile.
- Adopting LRFD and AASHTO specs may result in shorter pile lengths.

Case Studies- Observations

- Influence of geology on pile lengths is evident.

Proposed LRFD Design Process End Bents

- Structures Design Unit(SDU) provides Nominal Compressive Structural Resistance.
- Geotechnical Engineering Unit(GEU) Computes Factored Compressive Resistance, Nominal and Factored Static & Dynamic Resistance.
- GEU Provides Preliminary Foundation recommendations to SDU.

Proposed LRFD Design End Bents

- GEU requests factored structure loads, with & without PDA, # of piles needed per bent for each case.
- GEU completes analysis & provides final recommendations using maximum factored structural load as maximum factored geotechnical resistance.

Summary & Conclusions P/S Concrete piles

- Had sufficient data for calibration.
- Good match- Nordlund & PDA BOR.
- Vesic slightly over-predicted PDA BOR.
- Meyerhof under-predicted PDA BOR.
- Good match- Nordlund & static load test but COV was high.
- Vesic over-predicted Static L. T. but COV was reasonable.

Summary & Conclusions P/S Concrete

- Computed R.F. almost equal to AASHTO for Nordlund.

Summary & Conclusions HP Piles

- Computed Φ higher than p/s concrete for Nordlund & Vesic.
- Computed Φ almost equal to p/s concrete for Meyerhof.
- Computed Φ based on PDA EOD < recommended, but those computed based on PDA > recommended. Recommended is close to ASD FS= 2

Summary & Conclusions General:

- Reliability not constant for the same F.S. depended on static analysis method, field test and pile type.
- Computed Resistance Factors(R.F.) were almost equal for Vesic and Nordlund for HP steel & p/s conc. piles.
- Significant difference between computed Φ and AASHTO's for M-hof.

Summary & Conclusions General

- Need separate R.F.'s for low & high displacement piles.
- Based on 3 case studies, Adopting LRFD & AASHTO Specs may result in pile length estimates lower than NCDOT's current ASD procedure.

ANY QUESTIONS?