Alaska Department of Transportation & Public Facilities

CAPWAP-Based Correlations for Estimating the Static Axial Capacity of Open-Ended Steel Pipe Piles in Alaska

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December 2012

Prepared For:

Alaska Department of Transportation & Public Facilities
Research, Development, and Technology Transfer
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FHWA-AK-RD-12-07

REPORT DOCUMENTATION PAGE	Form approved OMB No.

Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
FHWA-AK-RD-12-07	December 2012	FINAL REPORT 8/12/2009 – 12/26/2012

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
CAPWAP-Based Correlations for Estimating the Static Axial Capacity of Open-Ended Steel Pipe Piles in Alaska	AKSAS #60616/T2-08-01 Federal # HPR-4000(69)
6. AUTHOR(S) Stephen E. Dickenson, Ph.D., P.E.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) New Albion Geotechnical, Inc. 1625 O'Farrell Street, Reno, NV 89503	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) State of Alaska, Alaska Dept. of Transportation and Public Facilities Research, Development and Technology Transfer 2301 Peger Rd Fairbanks, AK 99709-5399	10. SPONSORING/MONITORING AGENCY REPORT NUMBER FHWA-AK-RD-12-07

11. SUPPLEMENTARY NOTES

Performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

CAPWAP analyses of open-ended steel pipe piles at 32 bridge sites in Alaska have been compiled with geotechnical and construction information for 12- to 48-inch diameter piles embedded in predominantly cohesionless soils to maximum depths of 161-feet. This database includes 68 piles, 33 of which tested at End of Initial Driving and Beginning of Restrike demonstrating time-effects on pile resistance. The CAPWAP analyses were used to develop empirical relationships for unit shaft and toe resistances at BOR. The CAPWAP-based unit shaft resistance demonstrates a depth-dependent trend, with values 1 to 3 days after EOID that are considerably less than estimates made using common static analyses. The toe resistance was found to be highly variable and dependent on both the prevalence of gravel and cobbles at the toe and pile diameter.

Class A Prediction involving 29 piles driven into deltaic deposits demonstrated very good agreement with CAPWAP results for 1 to 6 day BOR. The proposed method provided much more reliable estimates of pile resistance than widely-adopted static analyses and modifications for set-up are proposed. The method can be refined with new data; reducing uncertainties in computed pile resistance, pile lengths, and construction costs associated with field modifications of piles.

14. KEYWORDS :	15. NUMBER OF PAGES
Pile foundations (Pbpbfs), Axial loads (Smimb), Monitoring (Dmbm), Dynamic tests (Gbsd), Pile driving (Fcat)	92
	16. PRICE CODE N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	N/A

EXECUTIVE SUMMARY

High strain dynamic testing of 68 piles performed at 32 project sites in Alaska has provided the basis for modifying existing procedures for estimating the static axial capacity of open-ended steel pipe piles in predominantly cohesionless soils. Holocene deposits of glacial outwash, stream alluvium, deltaic lobes, and intertidal soils have been found on numerous projects to be problematic due to the interlayered nature of the deposits and for the low axial capacities that are often exhibited with open-ended pipe piles. Dynamic load testing and analysis are commonly required by the Alaska Department of Transportation & Public Facilities (ADOT&PF) during construction to confirm the axial capacity of piles in the sensitive and difficult soils found in the geologic environments previously listed. Dynamic driving analyses performed at the End of Initial Driving (EOID) are often supplemented with additional testing performed, in general, one to five days later (Beginning of Restrike, BOR) in order to assess time-dependent aspects of pile resistance and confirm axial capacity.

A dynamic load test database has been compiled for 68 cases provided by the ADOT&PF. Trends in the statewide data have been evaluated to enhance existing practice-oriented methods for estimating the static axial capacity of open-ended steel pipe piles in deposits common along streams and in coastal regions of Alaska. The following site- and project-specific data have been compiled and tabulated in the database: site location, geologic conditions, pile characteristics, hammer and driving system, driving resistance, Pile Driving Analyzer (PDA) data, results of analysis from the Case Pile Wave Analysis Program (CAPWAP) and Case Method, and correlations between the CAPWAP-derived capacity and the results of four common dynamic formulae (Engineering News, Janbu Method, Gates equation, and the Washington State Department of Transportation equation).

The extensive collection of dynamic load test data from ADOT&PF projects has facilitated the development of CAPWAP-based correlations for static axial capacity. It would be advantageous to establish empirical relationships for axial pile capacity on the basis of static load test data; however, the lack of static data from ADOT&PF projects necessitates a reliance on the dynamic load test database. Two practice-oriented methods making use of the database are provided in this report: (i) the "CAPWAP-Based Method" wherein unit shaft resistance (f_s) and toe resistance (q_t) are estimated from average trends of the CAPWAP results for the 68 piles in the database, and (ii) the Effective Stress Method (Fellenius, 1996, Hannigan et al, 1997, 2006) with recommendations for selecting the input soil parameters (φ', β, N_t), and limiting values for f_s and q_t for the soil conditions that prevail in the database. This investigation highlights the uncertainty inherent in pile capacity estimation procedures applied to cohesionless soils in Alaska. Procedures are proposed for refining capacity estimates computed during initial analysis using static methods and during construction using dynamic formulas. The proposed methods have been developed for predominantly cohesionless soil deposits in Alaska and provide correlation to the static axial capacity of open-ended steel pipe piles derived from dynamic analysis performed, therefore, inherently reflect the same limitations that may be associated with CAPWAP estimates of resistance for the pipe piles making up the database (diameters of 12 to 48 inches, embedment lengths of 23 to 161 feet, median time between EIOD to BOR of 46 hours).

CAPWAP results at BOR are used to confirm the design capacity for the pile (ultimate bearing resistance · LRFD soil resistance factor) has been achieved. In the “problem” soils commonly encountered in Alaska, the results of the CAPWAP analyses at BOR for open-ended pipe piles are often considerably less than estimates made using static analysis procedures. Therefore, a primary goal of the investigation was the development of a static analysis procedure that would yield soil resistances (shaft and toe) that are equivalent to the CAPWAP results at BOR. The empirical CAPWAP-Based procedure developed in this investigation provides estimates of shaft and toe resistance for the conditions and construction sequence that existed for the projects making up the database. As previously noted, the time constraints associated with the construction sequence on most projects, many at remote sites, limits the length of time between EOID and BOR; therefore, full set-up may not have been achieved. This situation can result in computed shaft resistance that is systematically lower than the static, long-term resistance. Guidelines are provided for adjusting the soil resistance estimates to account for soil set-up.

The proposed procedure has been applied in a step-by-step manner for a Class A prediction in order to demonstrate the application of the method, and to highlight the strengths and limitations of the CAPWAP-based correlations on a project-specific basis. The Hyder Causeway Trestle project in the southern coastal region of Alaska provided a very timely and worthwhile application for the proposed procedures. The geotechnical site investigation and preliminary pile bearing resistance estimates were made in 2008, with construction commencing after the first draft of this project report was completed and the pile resistance estimate was presented. The Hyder Causeway project, presented in Chapter 5 of this report, provided the most comprehensive collection of CAPWAP results obtained to date on a ADOT&PF project. The project involved 24-inch diameter closed-ended steel pipe piles driven in deltaic deposits of sand with gravel and silt to depths ranging from roughly 90 feet to 160 feet. PDA monitoring was carried out on 29 piles providing BOR data for all piles, with 12 piles evaluated during a second BOR test 1 to 4 weeks after the first BOR test. The time between EOID and BOR was as much as 48 days. Overall, the CAPWAP-based correlations provided very good agreement with the project-specific CAPWAP results at the Hyder Causeway project for BOR tests performed 1 to 5 days after EOID, which is consistent with the data from which the empirical relationship was based. The extensive pile testing program at Hyder highlighted the inherent variability of pile resistance at a single project site, provided a thorough case study for possible refinements to axial capacity estimation in coastal Alaska, and facilitated the development of a soil set-up factor for the sandy deposits at the site.