RESEARCH PROJECT CAPSULE [14-1GT]

February 2014

TECHNOLOGY TRANSFER PROGRAM

Calibration of Region-Specific Gates Equation for LRFD

PROBLEM

The original 1957 Gates pile driving formula is an empirically derived dynamic formula that is used to predict pile capacity in the field during pile installation. The original Gates formula tends to over-predict pile capacity for low driving resistances and under-predict pile capacity for high driving resistances. Thus, the Federal Highway Administration (FHWA) proposed a modified version of the Gates formula that addressed this limitation. The FHWA-modified Gates equation is $R_n = 1.75\sqrt{E}\log(10N) - 100$, where R_n is the nominal pile resistance (i.e., ultimate pile capacity (kips)), E is the developed hammer energy (ft.-lb.), and N is the number of hammer blows for 1 in. of permanent set (blows/in.). The Louisiana Department of Transportation and Development (DOTD) uses a variation of the FHWA-modified Gates equation, hereinafter referred to as the DOTD dynamic formula, to verify the nominal pile bearing resistance in units of tons as per the 2006 Louisiana Standard Specifications for Roads and Bridges, Section 804.10. The DOTD dynamic formula is typically used on smaller projects where static load tests and dynamic monitoring are not practical.

The resistance factor (ϕ) for load and resistance factor design (LRFD) specified by the current AASHTO design guide for the Gates equation is 0.40. However, the worst-case resistance factor used in DOTD's static pile capacity design methodologies is 0.50 for designs using static equilibrium methods with no field verification. This discrepancy penalizes the target pile capacity needed during field observation if the DOTD dynamic formula equation is used, which is unreasonable, and has created confusion among designers, consultants, district personnel, and inspectors in Louisiana.

OBJECTIVE

The objectives of this research are to recalibrate the FHWA-modified Gates equation and update the associated LRFD resistance factor for pile types and local soil conditions encountered in Louisiana. This research is consistent with FHWA recommendations that "Highway agencies should establish long-term correlations between pile capacity predictions from dynamic formulas and static load test results to failure." Improved consistency relative to the current design approaches will be achieved if the updated resistance factor matches or exceeds the worst-case resistance factor used by the DOTD, which will reduce confusion among users. Updating the resistance factor will also serve to increase confidence in the FHWA-modified Gates equation, refine the state-of-practice in LRFD, optimize the efficiency of the piles, and reduce project costs. It may also identify the need for an alternate pile verification approach for small projects.

JUST THE FACTS:

Start Date:
January 2, 2014

Duration:
14 months

End Date:
March 1, 2015

Funding:
SPR: TT-Fed/TT-Reg

Principal Investigator:
Eduardo Tavera, P.E.,
President
GeoStellar Engineering, LLC

Administrative Contact:
Mark Morvant, P.E.
Associate Director, Research
225-767-9124

Technical Contact:
Zhongjie "Doc" Zhang, Ph.D., P.E.
Pavement & Geotech
Research Administrator
225-767-9162

Louisiana Transportation Research Center
4101 Gourrier Ave
Baton Rouge, LA 70808

Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

POINTS OF INTEREST:

Problem Addressed / Objective of Research / Methodology Used Implementation Potential

Another important goal of this research will be to enhance the DOTD's geotechnical information database by linking the historical records to a geographic information system (GIS) platform that visually correlates test results with soil types across the state. In this way, DOTD and its consultants will be provided a tool for design, as well as a platform for easily adding new information from future projects. The database and GIS platform will be readily accessible to a wide group of users and provide significant technical and economic advantages for the geotechnical community in Louisiana.

METHODOLOGY

The methodology adopted in this project consists of several steps: compile and interpret relevant pile driving and load test data from sites in Louisiana, create a spatial database of the pile-related data that can be imported into DOTD's geotechnical information database, compare the nominal (i.e., predicted) resistance from the FHWA-modified Gates equation (or DOTD dynamic formula) to observed resistances from static load tests and dynamic analyses (e.g., CAPWAP) to assess bias statics, use multivariate regression methods to recalibrate the FHWA-modified Gates equation so as to reduce the mean and standard deviation of the bias values, use reliability-based methods to determine updated values of the LRFD resistance factor for the revised equation, and assess potential benefits and provide guidelines related to the implementation of the results of this study.

IMPLEMENTATION POTENTIAL

The implementation of this research will impact the method of pile capacity verification for small bridge projects by replacing the current DOTD dynamic formula with a Louisiana-calibrated dynamic formula that will have a known level of reliability and associated risk. The results of this research will be implemented by updating the Louisiana Standard Specifications for Roads and Bridges to include the Louisiana-calibrated dynamic formula(s) and will include specifications on how to properly apply the Louisiana-calibrated dynamic formula(s). Geotechnical design reference documents will need to be updated to include the limitations and appropriate use of the Louisiana-calibrated dynamic formula(s) along with the appropriate resistance factors that should be used in LRFD design procedures based on the dynamic formula(s). The project team will provide implementation language for a future revision of Section 804.10 of the Louisiana Standard Specifications for Roads and Bridges. The implementation of a Louisiana-calibrated dynamic formula will affect geotechnical designers (in-house engineers and consultants), construction field personnel, and the construction headquarters division. The responsibility for the successful implementation of the results of this research will rely on the Pavement and Geotechnical Design (Section 67) and the Construction Division (Sections 53 and 40).