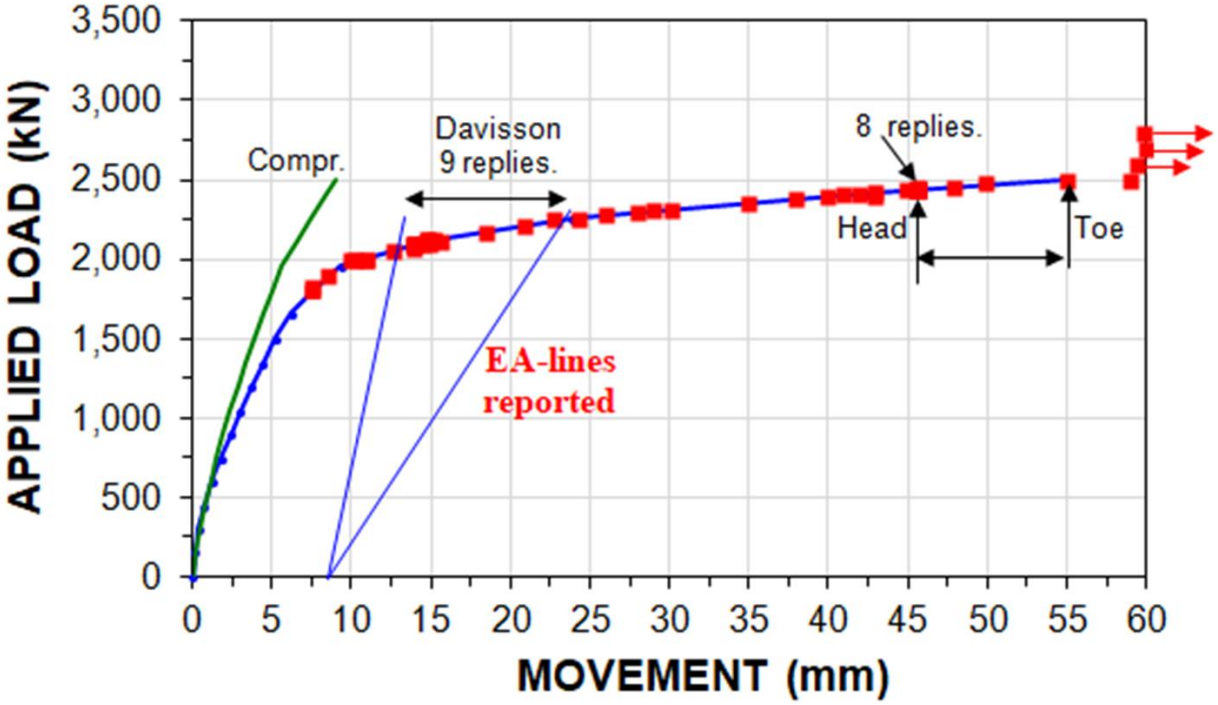


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Forum Paper

Lessons from the 2025 Mobile, AL, Prediction Survey

Bengt H. Fellenius[1*]

Abstract: A prediction survey based on the static loading test on an 18-inch concrete-filled, closed-toe pipe pile in Mobile, Alabama attracted 74 predictions from 92 participants across 26 countries. Participants were asked to submit pile-head loading-movement curves, assess "capacity", and plot force distribution at an applied loading equal to their assessed "capacity". The event proceeded in three phases: initial predictions ("First Go"), revised submissions after receipt of a reference test on a near-by similar pile ("Second Go"), and a final capacity assessment after obtaining the actual test results ("Third Go"). The submissions showed a wide scatter in predicted loading-movement curves also in the Second Go after participants amended their predictions on receiving the results of the reference test. The methods of assessing "capacity" were inconsistent, underscoring the problematic and ambiguous use of "capacity" in practice. The survey revealed that, despite advances in analytical tools, geotechnical predictions are influenced by subjective judgment, disparate definitions, and overreliance on limited data. A reevaluation of how "capacity" is treated in design standards and engineering practice is sorely needed. The survey results showed, in particular, a wide range of the submitted estimate of pile movement for applied loading.

Keywords: prediction, loading-movement, capacity, test simulation, t-z/q-z curves, force distribution

Introduction

The compilation of "true" predictions of pile response under static loading, followed by comparison with the measured test response, has traditionally represented an engaging component of deep foundation conferences. For the purposes of such events, a true prediction is defined as one submitted before the loading test is performed. This distinction is necessary because, as is often humorously observed, the most accurate prediction is typically one prepared after the test results have become available. Back-analysis of measured test data is nevertheless sometimes described as a prediction, thereby reducing the term to a synonym for calculation, despite the fundamentally difference in meaning of "prediction" and "back-analysis".

The first formal pile prediction event was conducted in 1980 and was organized by M. W. O'Neill and several colleagues. A number of similar events were subsequently held. In most cases, participants were requested to predict the pile capacity, whereas only a limited number of events also required prediction of the complete pile-head loading–movement response. For the 2015 Araquari Prediction Event in Brazil, the definition of capacity to be applied to the predicted loading–movement curve was explicitly specified. Neither of these two prediction events was formally documented in a journal publication.

The present paper summarizes the principal results of a prediction survey conducted in conjunction with a static loading test performed on a concrete-filled, closed-toe steel pipe pile installed in Mobile, Alabama. The pile had an outside diameter of 457 mm (18 in.) and was driven to a depth of 17 m. The pipe wall thickness was 9.5 mm, and a 25-mm-thick toe plate, flush with the outside diameter of the pile, was installed at the pile toe.

Invitations to participate were distributed to individuals who had contributed to previous prediction surveys, authors of journal papers addressing piled foundations, and attendees identified from participant lists for selected deep foundation conferences. The recipients were therefore presumed to possess an interest in, and experience with, pile behavior and static loading testing.

Responses were received from 92 individuals representing 26 countries, corresponding to approximately 10% of those invited. A total of 74 independent predictions were submitted. Most participants were located in the United States, Canada, and Brazil, which together accounted for 52 of the respondents.

During the initial invitation, hereafter referred to as the "First Go", participants were requested to submit a predicted pile-head loading–movement curve, report a pile "capacity," and to provide the corresponding axial-force distribution at an applied loading equal to the reported capacity. The definition of capacity was left to the discretion of each participant.

Following receipt of the initial submissions, a Second Go was conducted. Participants were provided with the

[1] Dr. Tech., Consultant, 2475 Rothesay Avenue, BC, Canada, V8L 2B9.
* email: bengt@fellenius.net

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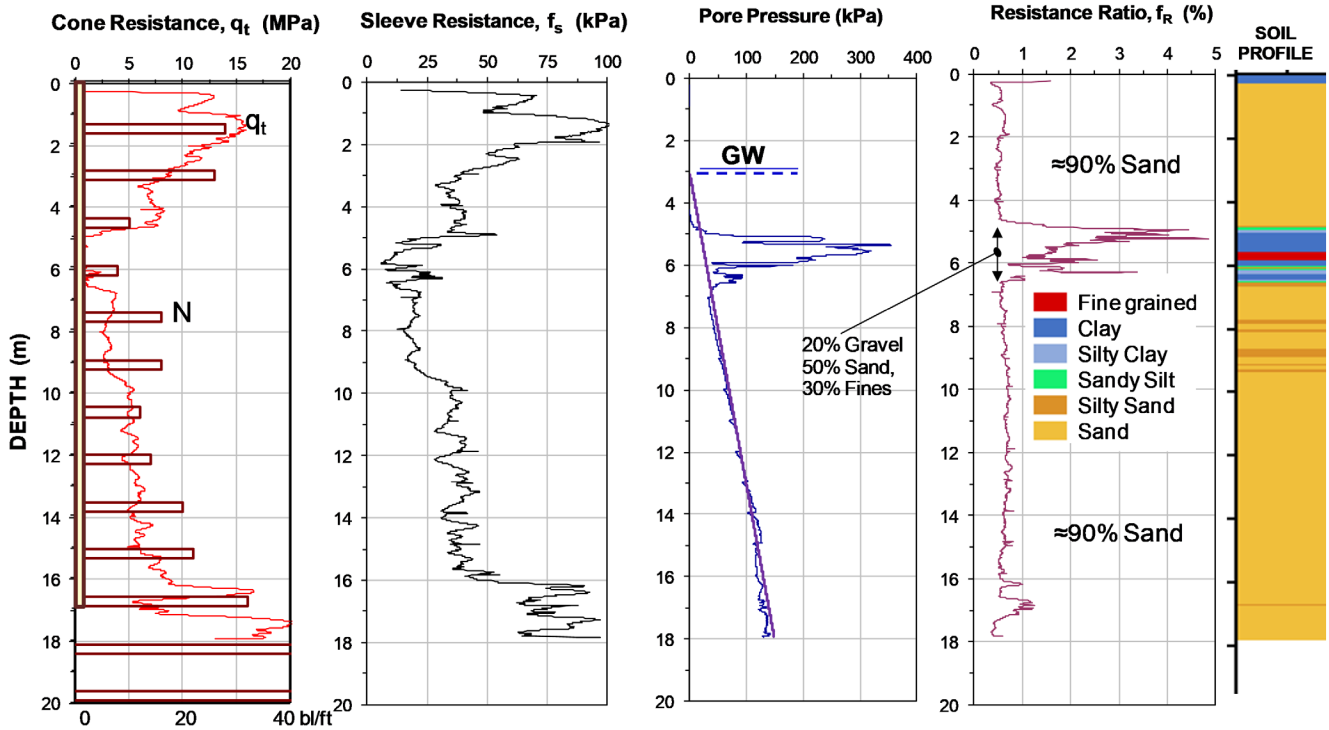


Figure 1. CPT diagrams from the test site with SPT N-indices (pushed March 20, 2012)

results of a static loading test performed at a nearby site on a 457-mm-diameter (18-in.) precast concrete pile. The reference pile had been installed in soil conditions considered similar to those at the prediction site, as indicated by the corresponding CPTU sounding. Participants were asked to evaluate whether the reference test results warranted revision of their initial predictions or whether the original predictions should be retained.

During the Third Go, the measured results from the actual static loading test were distributed to all participants. They were then requested to assess the test response and submit their interpretation of the pile capacity.

In addition to the formal predictions, numerous expressions of interest were received from individuals who requested access to the eventual results but declined to participate because the requested analyses were beyond their available capabilities. These respondents commonly indicated that, although pile capacity could be calculated from the information provided, the complete pile-head loading–movement response could not be determined.

One or two participants stated that their available software could generate a pile-head loading–movement curve and allow a capacity value to be inferred from that curve, but could not provide the axial-force distribution at a specified applied loading. Instead, the software provided only the distribution corresponding to the assumed ultimate resistance, with ultimate resistance mobilized at every point along the pile. Such a distribution is generally not representative of the response at an applied loading equal to an assessed capacity. The ultimate soil resistance at each pile element would contribute its full proportion of the assessed capacity only if plastic failure were simultaneously mobilized along the entire pile–soil interface and at the pile toe. Such a condition does not normally occur during a static loading test, because resistance is mobilized progressively and nonuniformly along the pile.

The site information provided to the participants included a soil profile supplemented by SPT and CPTU data, as presented in Figure 1. The subsurface conditions were divided into four principal layers. With the exception of an approximately 2-m-thick zone of gravelly sand containing about 30% fines between depths of 4.5 and 6.5 m, approximately 90% of the soil particles were within the sand-size range.

The sand was characterized as compact from the ground surface to a depth of approximately 4.5 m, loose between depths of approximately 4.5 and 16 m, and dense below 16 m. A pronounced increase in density was observed at a depth of approximately 16 m. Within the interval from 4.6 to 6.6 m, the total mass density was approximately 1,850 kg/m³, whereas a value of approximately 2,050 kg/m³ was reported for the soils above and below this interval. The groundwater table was located at a depth of approximately 3 m.

Results of First Go

The invitation requested prediction of the pile-head loading–movement response but did not require participants to describe the analytical methods employed. Nevertheless, several participants provided information regarding the procedures used to derive the loading–movement response from the mobilized shaft resistance. The reported approaches included effective-stress-based (ß) methods, or

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stress-independent (α) soil response, or correlations with SPT N-values, and CPTu-based methods. Many submissions appeared to assume fully mobilized plastic shaft resistance. Only two participants explicitly reported the use of load-transfer functions, including *t–z* and *q–z* relationships.

In contrast, the pile-toe response was likely modeled in most submissions using a movement-dependent toe resistance represented by a *q–z* relationship.

Figure 2 compiles the 74 submitted pile-head loading–movement predictions together with the corresponding assessed axial capacities, indicated by points on the individual curves. Approximately 15 submissions may be identified as outliers relative to the majority of predictions.

The reported "capacities" were not predictions in themselves, but rather assessments derived from the respective predicted loading–movement curves. Some values were selected subjectively, whereas others were determined using a specific capacity criterion. These criteria ranged from the Davisson offset limit (Davisson, 1972) to definitions based on the loading corresponding to a pile movement equal to 5%, 10%, or 20% of the pile diameter.

Among the participants who defined capacity as the loading producing a movement equal to 10% of the pile diameter, approximately equal numbers applied the criterion to pile-head movement and pile-toe movement. Several participants defined capacity as the loading corresponding to the point of maximum curvature on the predicted loading–movement curve. Others selected the loading at which the predicted curve became approximately linear. Considering that many codes and standards relate permissible foundation loadings to pile capacity, the wide variation in the definitions and assessment procedures is, at the very least, a matter of concern.

The ratios of the largest to the smallest reported capacity values and of the corresponding movements were both approximately 10. This range is approximately five times greater than a commonly applied factor of safety.

Figure 3 presents the submitted axial-force distributions at an applied loading equal to the reported capacity. The results

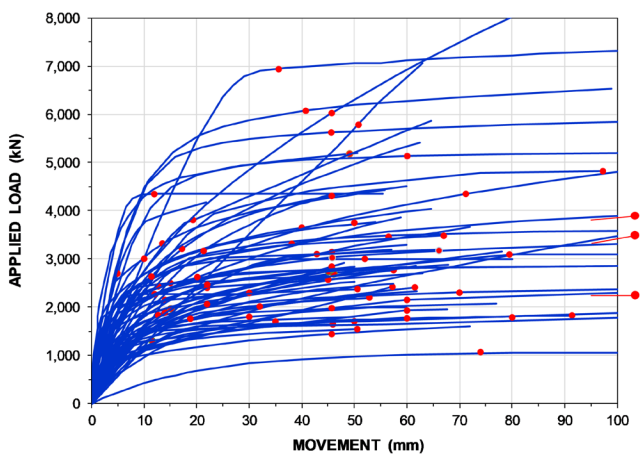


Figure 2. Loading-movement curves and associated "capacities" submitted by 92 participants (74 separate with a few overlapping)

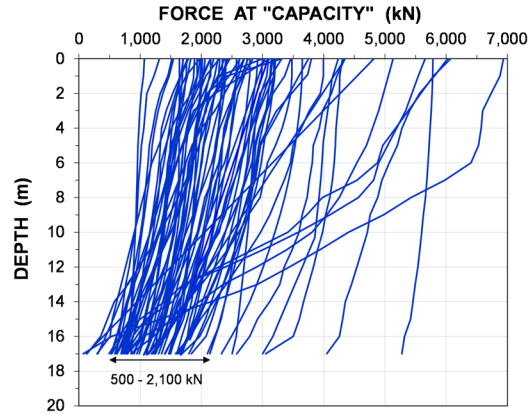


Figure 3. Submitted force distributions at an applied loading equal to "capacity"

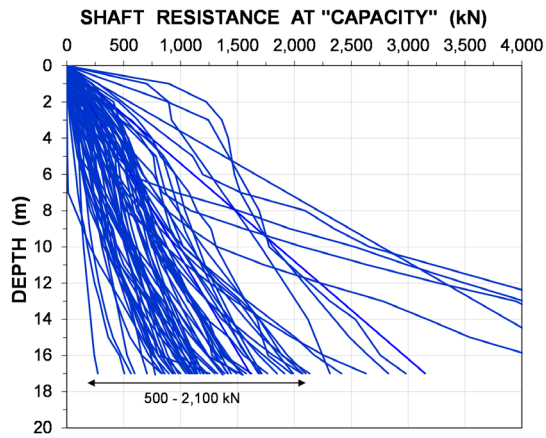


Figure 4. Distributions of shaft resistance at "capacity" extracted from the records

initially appear to indicate general agreement regarding shaft resistance, with the observed scatter arising primarily from differences in the calculated toe resistance, which ranged from approximately 500 to 2,100 kN.

However, as shown in Figure 4, the shaft-resistance distributions exhibited a comparable degree of scatter when they were extracted from the submitted data and evaluated separately from the toe-resistance values.

Results of Second Go

To bring the event a bit closer to reality, after having received the responses, I sent all participants the results of a reference test, a static loading test on a square 18-inch square precast concrete pile (PC) driven to 22.4 m depth, close to the subject site and tested 14 days after the driving. The soil profiles and CPTU sounding results for the two sites were similar. The idea was that the reference test would provide some 'insight and experience' to reassess the first analysis and, if found warranted, enable the participants to revise their calculations and submit an amended prediction. The amended prediction would then be closer to the results of a design for an actual project, where the design engineer applies insight and experience in designing the pile to be used for foundation

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support. Whether or not the designer's next step would be a full-scale test would depend on the confidence in the calculated response, that the 'prediction' would be correct and applicable to the case considered, and, of course, it depends on many additional factors not available to participants in a survey.

Figure 5 compiles the CPT sounding from the original invitation (Figure 1) to that of the reference test (green curves). The two are very similar, suggesting that a back-analysis of the results of the reference test could be used to support a representative simulation of the prediction pile. The result would then be closer to that applied to a pile considered for use in an actual project.

Figure 6 shows the measured pile-head loading-movement curve from the reference pile and pile "capacities" determined by 3 methods applied to the loading-movement curve and 7 CPT-methods employing the UniPile6 software (www.unisoftGS.com). The CPT-methods provide no information about pile movement, only report "capacity". To avoid clutter, only one of the various "diameter rules" mentioned by the responses is included, the 10% of the diameter rule (on the linear extrapolation of the curve). The "capacities" determined from the CPT sounding methods, shown and named in the graph, resulted in a low of about 2,400 kN and a high of about 4,200 kN. For convenience, they are here plotted at about 40 mm movement (plus signs). The labels identify the individual methods used for the prediction. "UAW" is abbreviated for Univ. of Western Australia (Randolph and Wroth, 1978), Doan and Lehane 2021, and Lehane et al. 2022. "EF" represents the Eslami and Fellenius (1997) method, "LCPC" stands for the method develop by the Laboratories des Ponts et Chausses (Bustamente and Gianeselli, 1982), "SN" is Schmertmann-Nottingham (Nottingham (1975) and Schmertmann (1978), "TF" is Tumay and Fakhroo (1982), and "Dutch" is short for the deRuiter and Beringen (1979) method. Note that the CPT-methods were originally derived from reference to "capacities" determined from results of full-scale static loading tests by an array of "capacity" definitions with disparate reference to pile movement.

Figure 7 shows the measured pile-head loading-movement curve from the reference pile together with a simulated curve termed "Head", fitting effective stress calculations to the given soil layers and densities by back-calculating and employing various β-coefficients and t-z / q-z functions until achieving the fit. The back-calculation and simulation fitting was made using the UniPile6 software. The curves marked "Shaft", "Toe", and "Compression" represent the calculated shaft and toe resistances and pile compression. Note, though, that the fit involves a good deal of "best judgment".

The back-analysis of the measured response of the PC pile was performed using the t–z and q–z functions presented in Figures 8 and 9, respectively (Fellenius, 2026). A hyperbolic t–z function based on the Chin–Kondner formulation (Chin, 1970) was adopted. The selected function exhibited only a moderate strain-hardening trend and therefore approximated an elastic–plastic response. The same normalized function, expressed as percentage of mobilized resistance versus movement, was applied to all four soil layers.

Figure 8 indicates the target β_{rtg} coefficients used in the analysis. These coefficients were combined with a target movement of 5 mm and applied in the back-analysis of the shaft resistance mobilized within the four soil layers. The same function coefficients, (C_1 = 0.0088) and (C_2 = 0.0060), were used for all layers.

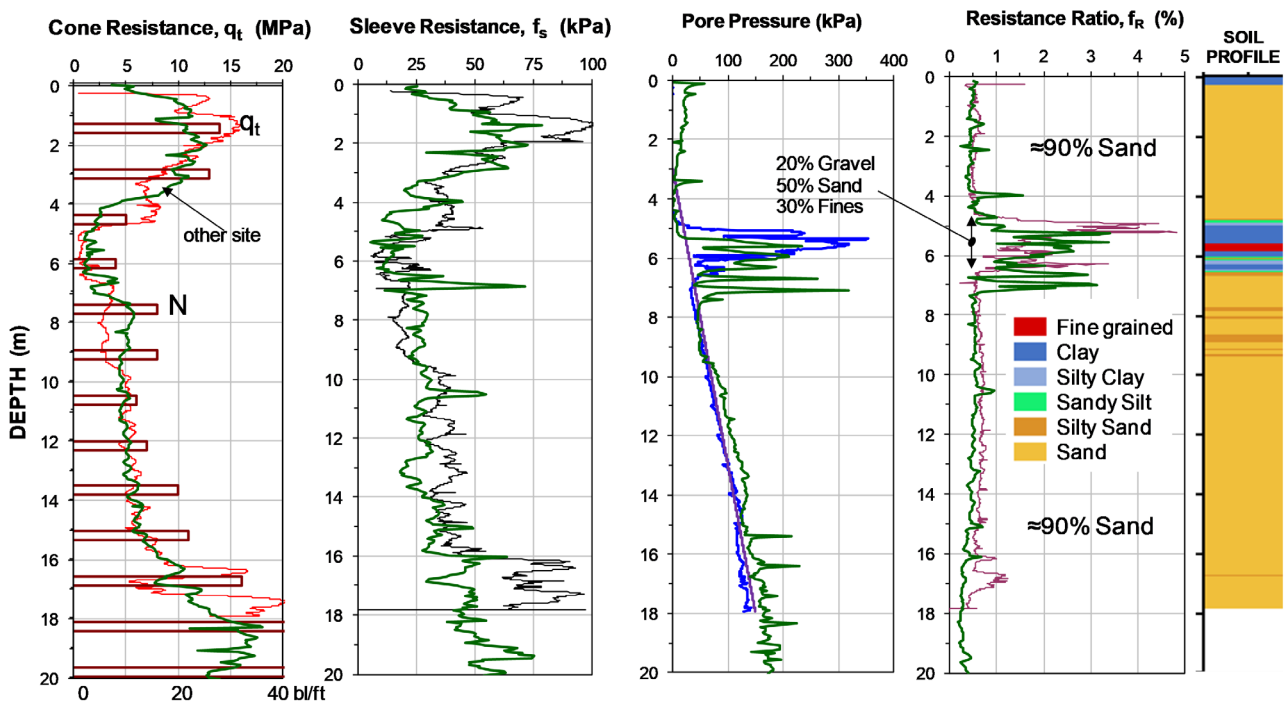


Figure 5. CPT diagrams from the test site with the q_c-diagram from the reference site

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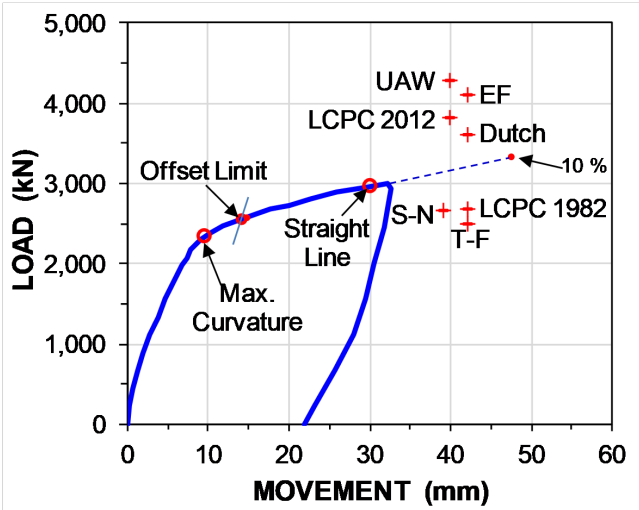


Figure 6. Reference precast concrete pile: Measured pile-head loading-movement and "capacities" defined by different methods

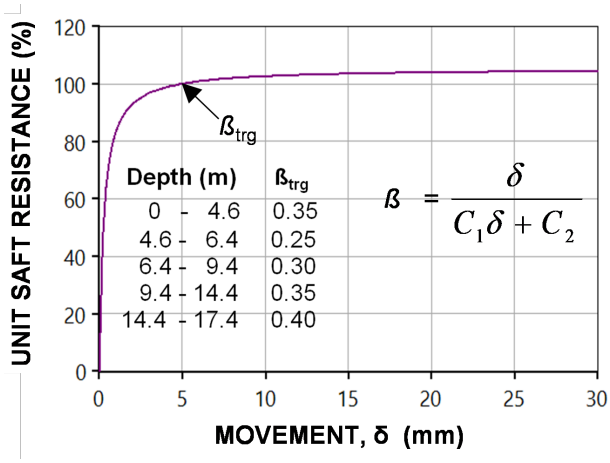


Figure 8. The *t-z* function and target coefficients used to obtain the fit

The target resistance and target movement values should not be interpreted as defining pile capacity. Rather, they represent a resistance–movement pair about which the function curve pivots, with the curve shape governed by the selected function coefficients. An identical curve may therefore be represented using a different target resistance–movement pair together with appropriately adjusted function coefficients.

The toe response was modeled with a Gwizdala *t-z* function, a power function per Gwizdala and Tejchman (1997) with the function coefficient, θ of 0.30 and a target unit toe stress, r_{trg} of 3,500 kPa for 5 mm movement. The θ value of 0.30 is lower than the more common value of 0.5 and suggests that the pile has a significant residual toe force (Fellenius, 2026).

The shaft and toe resistances assumed to obtain a satisfactory fit are interdependent, and the shape of the response is more important than the selected target value. Ideally, the reference test would have been performed on an instrumented pile, allowing the toe resistance to be fitted independently of the shaft response. For example, if the back-analysis had used the same target value but a toe-function coefficient, (θ), of 0.5, which is more commonly adopted than 0.3, an acceptable fit to the measured test curve could still have been achieved by adjusting the *t–z* function to represent strain-softening behavior.

Figure 10 presents the simulated loading–movement response of the prediction pile obtained using UniPile. The analysis applied the parameters derived from the fit to the reference test, including the same $ß_{rtg}$, r_{rtg}, values, a target movement of 5 mm, and the corresponding soil-layer input.

The UniPile software also provides a series of axial-force distributions, as shown in Figure 11. Depending on the capacity criterion applied to the loading–movement curve, one of the eight distributions may be selected as the requested force distribution. Alternatively, the software may be used to calculate the force distribution corresponding directly to an applied loading equal to the selected capacity.

Of the 92 participants who responded to the initial invitation, 48 also responded to the second invitation. Revised predictions were submitted by 22 participants, whereas 21 participants indicated that no revision to their original predictions was

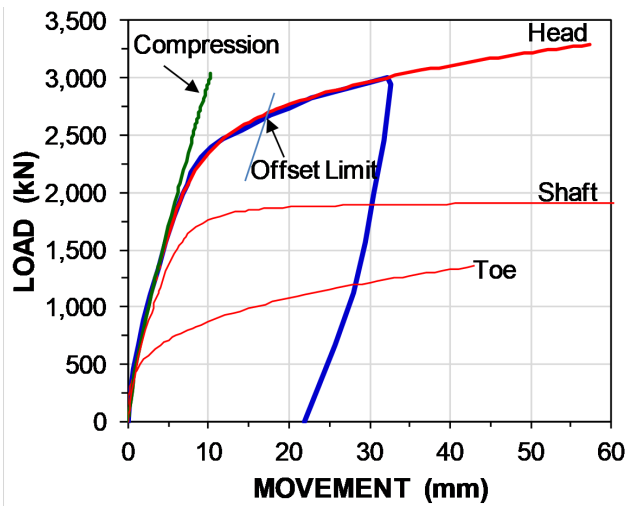


Figure 7. Reference precast concrete pile: Measured and simulated loading test results

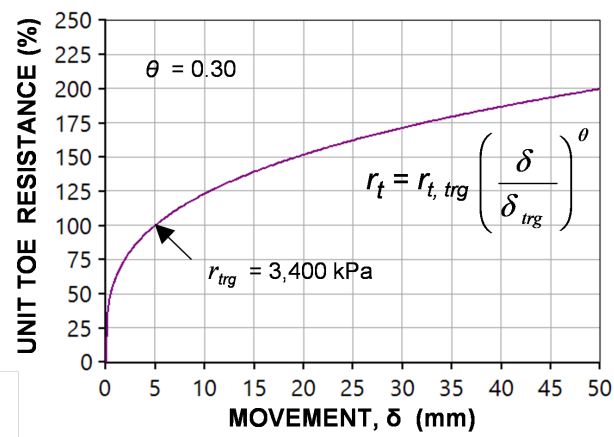


Figure 9. The q-z function and unit toe resistance coefficients used to obtain the fit

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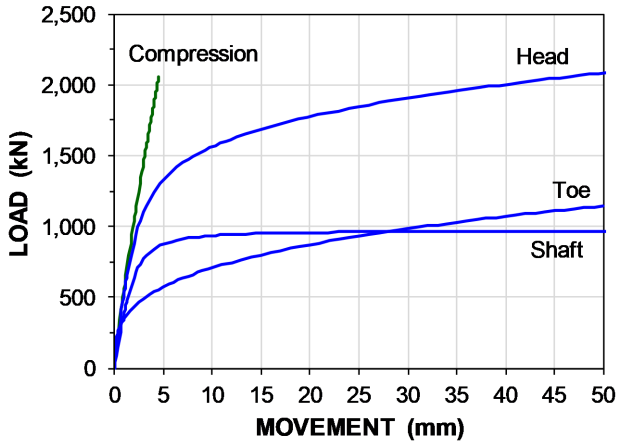


Figure 10. Loading-movement curves for the prediction pile calculated for unchanged input

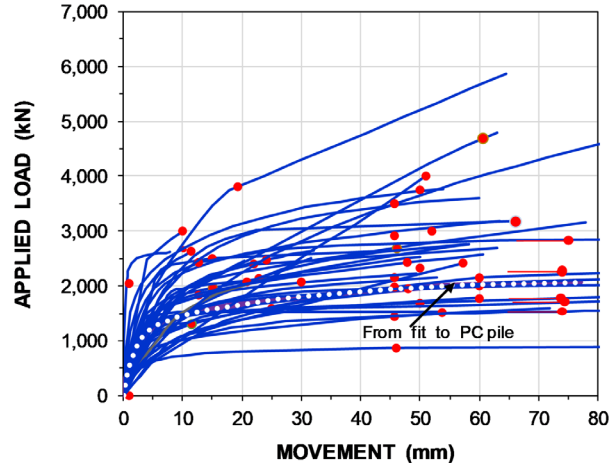


Figure 12. Submitted revised loading-movement curves and associated "capacities"

warranted. An additional five participants declined to submit a second response because of time constraints.

Figure 12 presents the loading–movement curves and reported capacity values submitted during the Second Go. The calculated loading–movement curve is shown using open circles. This curve was derived using soil parameters back-calculated from the response of the PC pile, subsequently adjusted for the conditions of the prediction pile, and then applied to the prediction pile analysis.

Approximately ten predictions may be identified as outliers, including one below and nine above the principal group of predicted curves. At a pile-head movement of approximately 15 mm (1 inch)., the lower and upper bounds of the main group of predictions correspond to pile-head loadings of approximately 1,200 and 2,800 kN, respectively.

Compared with the "First Go" submissions, the ratio of the largest to the smallest reported capacity was about 5, representing a reduction of about 50%. However, the corresponding ratio of the predicted pile-head movements at capacity remained approximately 10.

The predicted force distributions are presented in Figures 13 and 14. The overall scatter and distribution of the results were not substantially different from those obtained during the First Go invitation. A closer convergence of the predicted curves had been anticipated following calibration against the reference loading test.

The test pile was driven on March 26, 2025, and the static loading test was conducted on April 4, 2025. Figure 15 presents the loading–movement curves submitted during the Second Go, the curve calculated from the reference loading test, and the loading–movement response measured during the static loading test. The submitted capacity values are not included in the figure.

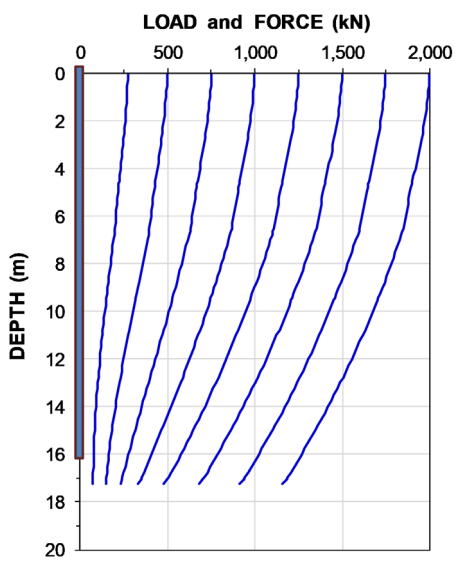


Figure 11. Predicted force distributions

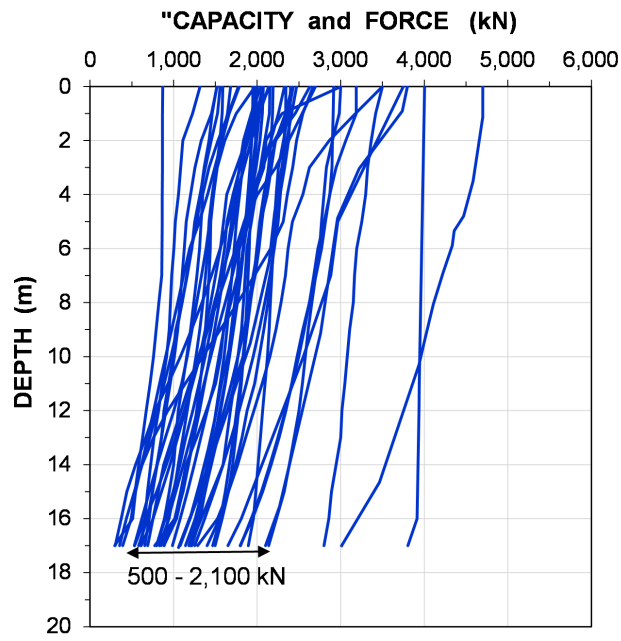


Figure 13. Submitted revised force distributions at an applied loading equal to "capacity"

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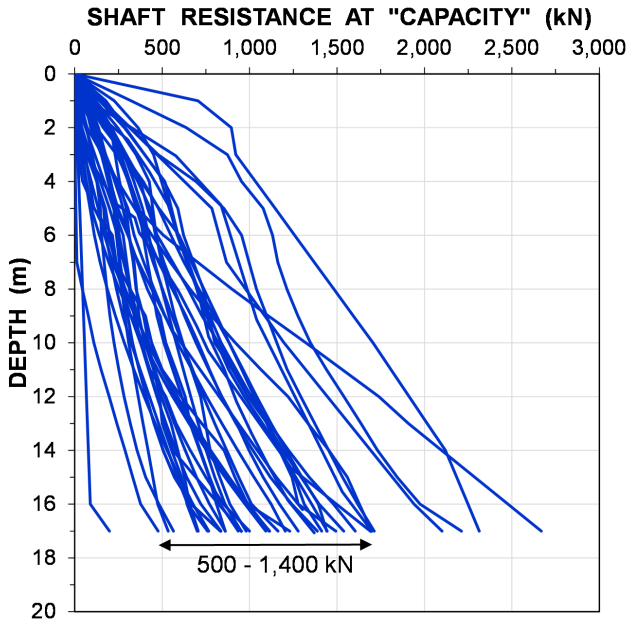


Figure 14. Distributions of revised shaft resistance extracted from the submitted records

At the time of the static loading test, the groundwater table was measured at a depth of 5 m, approximately 2 m below the groundwater level recorded during the CPTU soundings. The dashed curve in Figure 15 represents the calculated loading–movement response for a groundwater-table depth of 3 m rather than the measured depth of 5 m. The 2-m reduction in groundwater level was estimated to produce only a minor upward shift in the pile-head loading–movement response relative to the response that would have been obtained had the groundwater level remained at the depth observed during the CPTU soundings. This effect is illustrated by the small difference between the curves labeled "Actual Test" and "GW at 3 m."

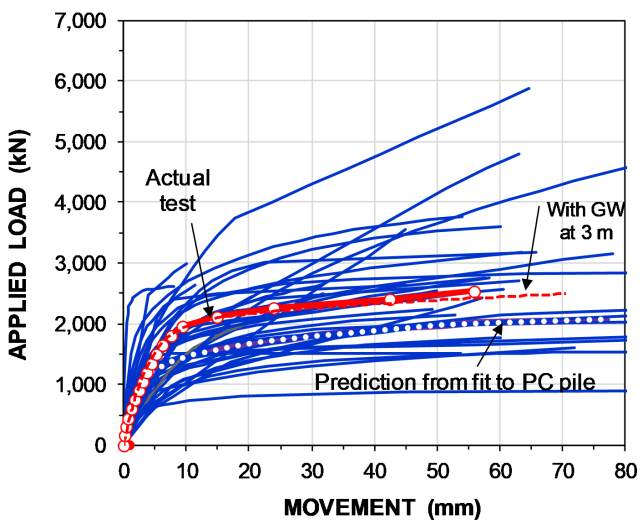


Figure 15. Actual loading-movement and Second-Go predicted curves

Accordingly, the difference between the groundwater condition assumed for the predictions and that present during the static loading test was considered to have an insignificant effect on the pile-head loading–movement response. Although groundwater lowering could potentially induce compression of the surrounding soil, the observed groundwater fluctuation was seasonal and repetitive. The associated loading–unloading cycle would therefore be expected to produce only minor soil compression, with no meaningful influence on the measured pile response during the static loading test.

Results of The "Third Go"

All participants were provided with the results of the static loading test and were asked to assess the "capacity" of the measured loading–movement curve using the same definition applied to their predicted curve. A total of 48 of the 74 participants responded.

Figure 16 presents the measured loading–movement curve with all submitted capacity values plotted on the curve; four values required extrapolation.

The submissions included the same assortment of capacity definitions. However, for all but one of these submissions, the reported value corresponded to a pile-head movement equal to 10% of the pile diameter.

Most participants who applied the Davisson offset limit assumed a pile elastic modulus and apparently disregarded that the (EA) line would be unlikely to have a slope steeper than that represented by the final portion of the measured pile-compression curve.

The ratio between the smallest and largest values of "capacity" assessed from the actual test curve was about 1.5, but the ratio of movement at the "capacity" was still about 10. The number of assessments allows extracting specific statistics, albeit hardly meaningful in view of the differing background of the participants. Nevertheless, the statistically enticed may find interest in the fact that the average "capacity" was 2,274 kN, the standard of deviation was 198 kN, and the coefficient of variation was 8.7 %. The average movement needed to mobilize the "capacity" was 28 mm, the standard of deviation was 16 mm, and the coefficient of variation was 55 %.

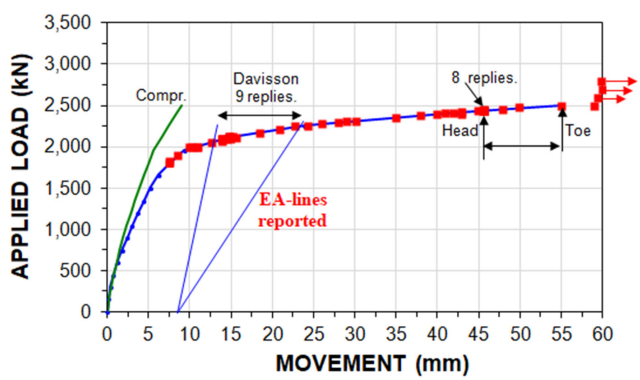


Figure 16. Loading-movement curve for actual test with assessed "capacities" (square symbols)

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Discussion and Conclusions

Prediction surveys are often described as "capacity prediction" events, implying that "capacity" is the main characteristic of pile response rather than a single value interpreted from the loading–movement curve. Consistent with previous prediction events, the present survey demonstrates that pile "capacity" is a tenuous and largely contrived concept that is defined and applied with considerable inconsistency across the profession, both in prediction exercises and in actual design practice. The concept is so approximate—and, in many respects, so poorly defined—that its abandonment could appear justified. However, because "capacity" remains important for maintaining continuity with historical design practice and accumulated experience, it cannot simply be discarded. Instead, the capacity-based design recommendations presented in current textbooks, codes, and standards should be critically reviewed (Fellenius 2025).

In fact, "capacity" is among the least informative results obtained from a static loading test and it often has limited relevance to the design of a piled foundation. The ambiguity and lack of a rational, consistent basis for the concept are the reasons the term is deliberately placed within quotation marks throughout this paper. Considering that many codes and standards relate permissible foundation loadings directly to "capacity," the wide variation in definitions and interpretations demonstrated by the present survey is, at the very least, a matter of serious concern.

The compilation of submitted predictions is sometimes considered to represent the profession's ability to apply the state of the art under conditions comparable to those of an actual foundation design. This is wrong. A prediction event demonstrates only how practitioners combine site-investigation data, textbook guidance, and recommendations from codes and standards to calculate an expected loading–movement response.

It would, in fact, be surprising if all predictions submitted by the geotechnical engineers participating in a survey such as the present would closely match matched the measured loading–movement response. The loading–movement response adopted for an actual design is generally evaluated using substantially more information than is available from a typical geotechnical site investigation, regardless of how extensive that investigation may be. For an actual project, the engineer would also consider the known effects of local geology, observations from previous construction, results from earlier loading tests, and other relevant information obtained from personal experience or from other practitioners. Consequently, a local practitioner participating in a prediction event may sometimes estimate the measured response more accurately, despite applying only limited analytical effort, than an outside practitioner using a more sophisticated theoretical approach.

Nevertheless, the wide scatter among the predicted loading–movement curves is disappointing. Estimation of the loading–movement response is directly related to the assessment of piled-foundation settlement, which, unlike "capacity," represents a real design concern. The approximately tenfold range in the submitted movements corresponding to the assessed "capacities" is therefore particularly disconcerting. The results clearly indicate that greater attention should be given to the movement, or settlement, of a pile under applied loading.

Acknowledgments

The prediction event was extracted from a full-scale static loading test programme in Mobile, Alabama, arranged by Browning Enterprise, Inc., Gadsden, AL, J. Hart. The test compared the response of three tapered steel pipe piles (TSFP) to that of two straight piles, one was used for the event. The reference test records were provided by AL Dot, K. Davies, Mobile, AL, the pile driving and test set-up was by Jordan Pile Driving, C. Johnson, Mobile, AL, and the test instrumentation and monitoring was conducted by SACL, Inc., H. Salem, Ottawa, ON.

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Survey Participants

Abrams, T.
Alheid, P.
Alinejad, M.
Ameida, A.
Amirhossein, E.
Antony, O.
Born, R.
Boyero, M.
Cadena, M.
Caloza, J.
Camacho, C.
Camp, B.
Chow, W.F.
Coleman, T.
Comodromos, E.
Creten, S.
Dajani, T.
Davari, M.
de Chaunac, H.
Dias F., V.
Diaz, L.
Dyka, I.
Ebrahimipour, A.
Edde, Robert
Eriksson, H.
Esrafili, S.
Fakharian, K.
Falcone, F.
Fellenius, B.H.
Fikret, A.
Fiorillo, M.
Garcia, J.
Ghiassian, H.
Gidley, I.
Golafzani, S.
Gonçalves, M.
Gong, R.
Graham, D.
Gwidala, K.
Harris, D.
Haugen, M.K.
Hu, F.
Izala, G.
Jeong, S.
Kania, J.
Kriege, A.
Kristiansen, H.
Kumar, D.
Kumar, J.
Leopold, A.
Lourde, M.
Marcus, P.
Mayne, P.
Mia, T.
Mo, P-Q
Mucheti, A.
Mudasser, N.
Nguyen, H.
Oliviera, P.
Olson, S.
Paraiso, S.
Pawan, S.
Phetteplace, B.
Poulos, H.
Raison, C.
Restrepo, M.
Reuter, G.
Salem, H.
Schneider, J.
Sekulski, E.
Shrestha, B.
Sideras, S.
Siegel, T.
Smith, D.
Soormeie, A.
Sousa, W.S.
Sozio, L.
Stone, R.
Synac, O.
Taylor, C.
Terzariol, M.
Terzariol, R.
Thouit, J.
Togliani, G.
Toraman, E.
Torres, L.
Vara, D.
Volmer, B.
Whenham, V.
Xenia,
Zak, K.
Zubrowski, C.

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