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Discussion

Discussion of "Load transfer and performance of an improved grouted enlarged toe (GET) precast concrete pile"

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The seven authors address the bearing response of the GET pile, a precast concrete cylinder pile installed with an enlarged toe with grout placed filling the annulus along the pile. Two means of making the enlarged pile toe were portrayed (Wu et al. 2026). One comprised attaching a steel plate wider than the pile diameter to the pile toe and the other was by attaching an inverted steel barrel with a diameter larger than the pile to the pile toe, letting it fill with soil during the pile installation.

The authors stated technical advantages of the GET pile:

(1) "*It improves drivability and lowers energy consumption by using the fluid grout mix as a lubricant during pile driving, which reduces soil friction on the pile shaft. This is especially advantageous for long piles and friction piles.*"
(2) "*GET piles simultaneously increase the bearing capacity at both the shaft and toe through low-pressure side grouting and an enlarged toe, while still allowing installation with conventional precast pile equipment (i.e., jacking and hammering). These advantages make the GET pile a more practical and economical solution.*"

The paper referenced their statements to two case histories reporting head-down loading test load–movement results of jacking-installed GET piles and ordinary cylinder piles (Precast piles). No records were provided of the jacking force. The static loading tests included no instrumentation or means to separate toe resistance from shaft resistance.

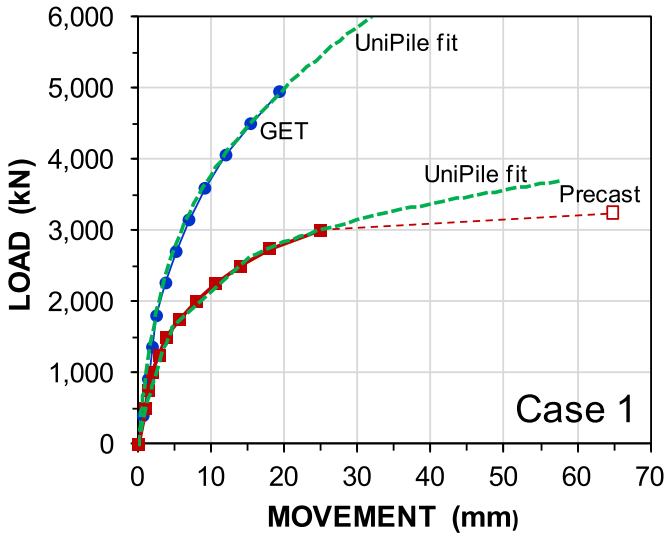
Case 1 compared loading test results (pile-head load–movement) of two cylinder piles. The piles were 15 m long, 500 mm diameter cast with a 250 mm center void. One, a GET pile, was equipped with a 700 mm diameter steel toe plate, creating a 200 mm annulus between the pile surface and the soil. The soil consisted of sandy silt with a 19.5 kN/m^3 density. Grout, consisting of sandy silt from the site mixed with cement, was placed as the pile was jacked down. Observations showed the volume of grout placed correlated to the volume of the annulus. The sandy silt profile showed a CPT-q_c of about 8 MPa within the upper 15 m depth (of a total reported 60 m CPT-profile) and a water content of about 25%. No depth to the water table was indicated.

Case 2 compared loading test results (pile-head load–movement) of three cylinder piles. The piles were 10 m long, 400 m diameter cast with a 120 mm center void. Two piles, GET piles, were equipped with a 600 mm high and a 600 mm wide inverted barrel with a 20 mm thick wall placed open-end at the pile toe. The soil profile comprised silt and silty clay with about 19 kN/m^3 density and having "*standard value of side friction*" and "*bearing capacity characteristic value*", of about 30 kPa and about 100 kPa, respectively. The grout incorporated local silt from the site and Portland cement with "*expansive additive material*".

The authors presented the pile-head load–movement results of the Case 1 and Case 2 loading tests graphically (authors' Figures 12 and 16) along with their fit ("*the pile-solidified soil–ground interaction*") to the measured curves simulating the shear resistance vs. movement between the natural soil and the grout and between the grout and the pile, aiming to fit a perceived "capacity" of the simulated pile. The software or method used by the authors was indentified as "MLT" and was used with an "*oblate spheroid cavity expansion in infinite space*". The Case 1 fits to the curves before that "capacity" point are not good. With the number of variables available for calculating a fitted curve and the calculation being unrestricted by having to fit any actual force distribution measurements, the calculated load–movement curves should result in a perfect fit. In my opinion, the Figures 12 and 16 fits do not enable drawing reliable conclusions from the simulations.

Figure D1 shows the pile-head load–movement curves for the two piles of Case 1 with my fits produced by using the UniPile6 software (www.UnisoftGS.com). The authors' simulation curves are excluded. For the test records of Case 1, the curve to the last load–movement point is shown dashed because they deviate from the trend of the test. The deviation is likely because the pore pressures induced by the last load increment were not dissipating because the jack pump was more or less continually activated to maintain pressure. Apart from this, both fits are "perfect" as they should be con-

Fig. D1. Case 1 load–movement curves with UniPile6 fits.



sidering the number of variables involved. The extrapolation of my fit (green dashed curve) is less representative for the actual response.

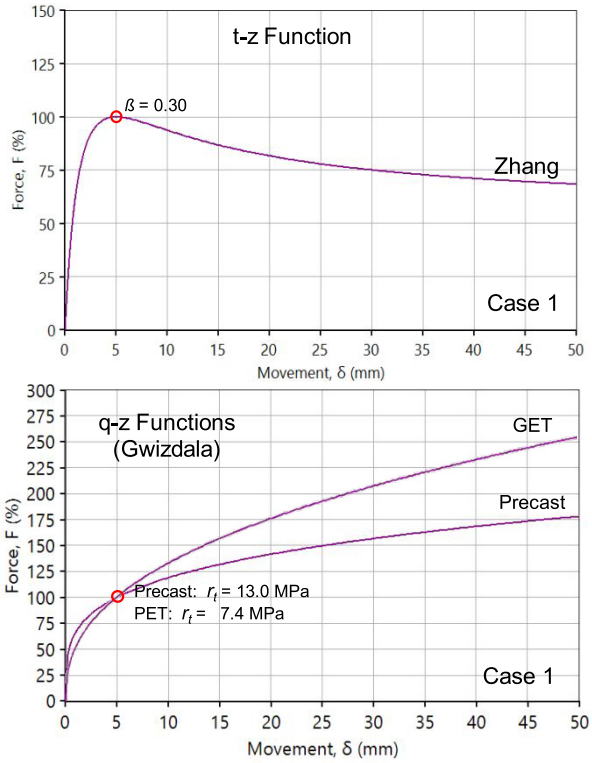
The fits were produced in effective stress analysis assuming that the shaft shear and toe resistance develop according to *t*–*z* and *q*–*z* relations. The piles were assumed built-up of a large number of short elements with the geometry of the cylinder pile and an E-modulus of 40 GPa. (The cylinder pile is usually a prestressed, spun-pile with higher than normal concrete strength cured under heat, resulting in a larger E-modulus than the 30 GPa assumed by the authors). The simulation assumed that all elements responded in terms of stress vs. movement (*t*–*z* and *q*–*z* functions) passing through a target point (here chosen at 5 mm movement).

In the absence of measurements, perfect fits can be realized with almost any set of input. To make sense, therefore, some restricting assumptions have to be imposed. I have assumed that the grout zone would bind solidly to the pile and the shaft shear would develop between the soil and the grout, and that the unit shaft resistance—beta-coefficient and *t*–*z* function—would be the same for the two types of piles. This meant that the GET pile would have a diameter equal to the enlarged toe. I also imposed the additional restriction that the two piles have the same beta-coefficient and same *t*–*z* function, while accepting that the unit toe resistance, r_t, and the *q*–*z* function could differ between the two pile types.

The analysis retained the freedom of choosing the *t*–*z*/*q*–*z* functions, the beta-coefficients (but same for both piles), and the unit toe-resistances, and it proceeded interactively between the Precast and GET piles, adjusting the input by trial and error.

Figure D2 shows the *t*–*z* and *q*–*z* functions applied to the final simulation, which resulted in a beta-coefficient of 0.30 and a strain-softening *t*–*z* function, equal for both the Case 1 piles. The *q*–*z* curves indicate that both Case 1 piles are affected by residual toe-force and soil densification. The GET pile toe response was softer than that of the Precast pile.

Fig. D2. Case 1. Final *t*–*z* and *q*–*z* functions for the fit to the load–movement curves.



Likely because the smaller shaft resistance in the liquid grout probably prevented building-up a similarly large residual toe force. However, the almost twice larger toe area made up for the difference. In effect, despite the absence of measured force-movement distribution other than for the applied load and pile-head movement, the Case 1 test results support the authors' conclusion that the Case 1 GET pile provides stiffer bearing than the ordinary cylinder pile.

The load–movement curves of the three piles of Case 2 are shown in Fig. D3. The Case 2 Precast pile showed a similar diverting response for the last two increment as shown by the Case 1 Precast pile. Possibly due to the same effect but more likely due to some mistake in the test execution. The three last records of the GET 2 pile showed an unlikely increasing trend for the curve.

Figure D4 compares the *t*–*z* and *q*–*z* functions of the Case 2 fit analyses. The authors' fit (Figure 16, Analytical results) to the Precast pile is acceptable, but the fit to the GET pile is poor. My fit to the Precast pile is, again, "perfect" (disregarding the last two diverting points). In contrast to Case 1, it was not possible to impose the same shaft response for the two piles. To obtain my fit to the load–movement curve of the ordinary cylinder pile (Precast pile), I needed to employ a hyperbolic *t*–*z* function, Chin-Kondner, whereas the fit to the curve of the GET, similarly to the that of Case 1, required a strain-softening function, Hansen. The shape of the *q*–*z* functions for the toe responses are closer to each other than shown for Case 12. However, the target toe resistance of

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Fig. D3. Case 2 load–movement curves with UniPile6 fits.

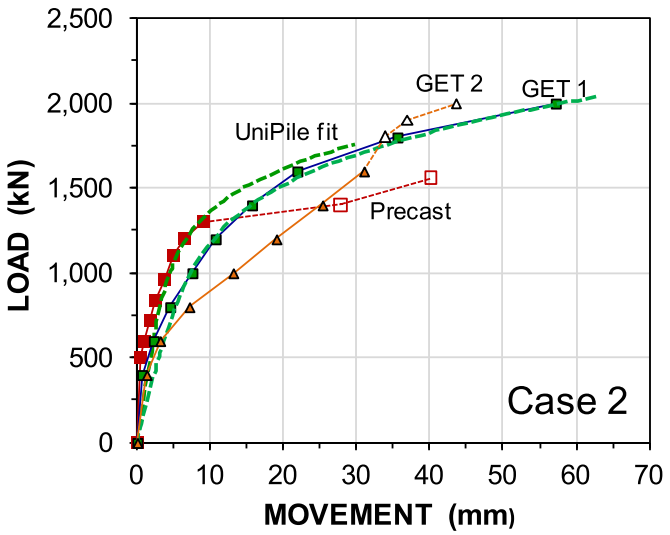
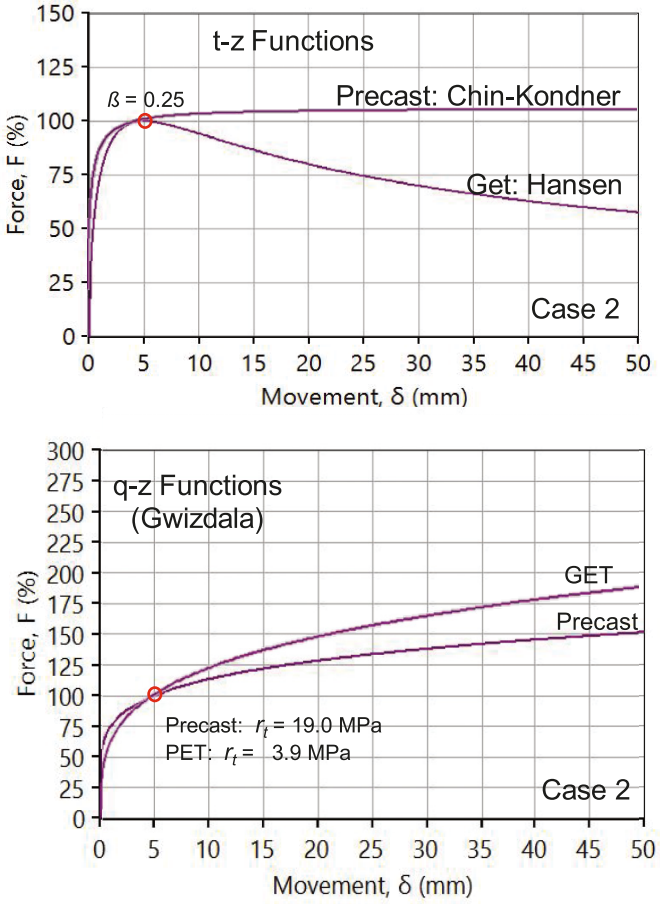


Fig. D4. Case 2. Final *t*–*z* and *q*–*z* functions for the fit to the load–movement curves.



the GET pile is only about 20% of the ordinary cylinder pile, indicating a similarly smaller stiffness for the barreled GET.

In comparing the response shown in the figure between the Case 2 Precast and GET piles, it is quite clear that the Case 2 GET piles showed softer response than the Precast pile despite their more than double toe area due to the barrel and the potential additional resistance along the 0.6 m length extension of the pile. The compacted soil inside the barrel does not appear to have provided a similar stiffness as the enlarged toe plate for the GET pile of Case 1. I do not see that the authors' two stated technical advantages of the GET pile over the ordinary cylinder pile have been affirmed.

I disagree with the authors basing their conclusion on applying a "capacity" reasoning, disregarding the pile movement. "Capacity" is a probabilistic reference to a worst case scenario. However, the everyday function of a piled foundation depends on deformation and settlement—stiffness response—and by this important condition, the barreled GET pile does not measure up to the ordinary cylinder pile.

Moreover, the authors' refer in different places to "*the failure criterion of 10% of the pile diameter displacement, as recommended by Terzaghi*." This reference is misconstrued from an 80-year old statement by Terzaghi in an ASCE Journal discussion on bearing response of pile loading-test on a 300 mm diameter pile. His actual statement was that bearing (considered for the pile head) should not be considered unless the pile toe had moved at least 10% of the pile toe diameter (Likins et al. 2012). He knew better than to suggest that a pile movement equal to 10% of the pile-head diameter could constitute "capacity". He simply meant that that much toe movement was necessary to enable the test results to be properly assessed.

I emphasize that correlation between theoretical simulation of pile response to applied load needs to be to results from loading test on instrumented piles that clearly separate the shaft response from the toe response. For example, as was presented in regard to the effect of enlarged pile toe versus straight piles by Fellenius et al. (2018).

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The authors declare there are no competing interests.

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