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The Unified Method and UniPile over 40 Years

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The Unified Method of pile analysis considers force distribution as a function of soil shear built up due to the relative movement between the pile and the soil and from general subsidence at the site.

When first proposed in 1984, the Unified Method applied ultimate strength for the shaft resistance only realizing the importance of movement for the pile toe in considering the magnitude of the drag force and depth to the Equilibrium Plane (calling it "Neutral Plane"). Figure 1, copied from my 1984 paper[1)], shows how I then perceived the dependency of the magnitude of the drag force and the depth to the Equilibrium Plane ("Neutral Plane" was the term I used back then).

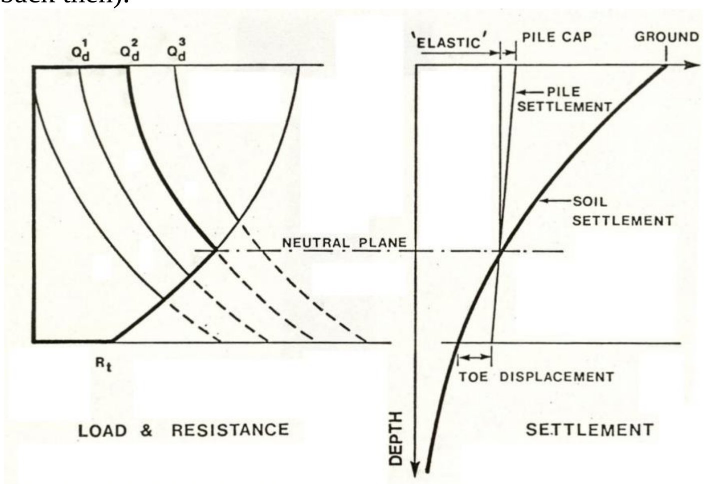

Fig. 1

Over the next four years, I realized that the within a zone of transition from negative to positive direction, the relative movement between the pile and the soil would make the pile force distribution to be curved as opposed to have a kink, now removed in Figure 2[2)]. But I still assumed that the shaft resistance would be plastic and ultimate conditions were still assumed to be part of the analysis.

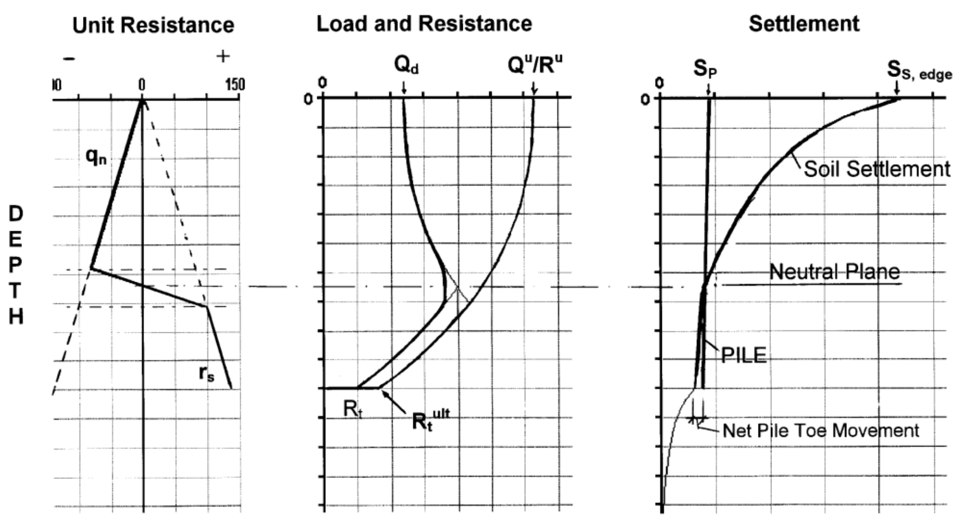

Fig. 2

[1)] Fellenius, B. H., 1984. Negative skin friction and settlement of piles. Second International Seminar, Pile Foundations, Nanyang Technological Institute, Singapore, November 28 - 30, 12 p).

[2)] Fellenius, B.H., 1988. Unified design of piles and pile groups. TRB Record 1169, pp. 75-82.

The insight produced an early application for PC analysis as incorporated in a VisiCalc spreadsheet (then Lotus123, then, Excel). In about 1990, Pierre Goudreault produced the first version of UniPile. Over the years, my understanding of the interaction between the pile and the soil gradually increased and was step-by-step incorporated by Pierre in updated versions of UniPile. UniPile5 (2014) incorporated the shaft and toe resistance stress-movement response as t-z and q-z functions, respectively. The particular functions for a particular case can very widely. Figure 3 shows commonly found functions (used in the typical example detailed below). After a small movement, the shaft resistance, represented by the t-z curve, has reached an approximately plastic state, as usually found to be the case. The toe resistance is strain-hardening.

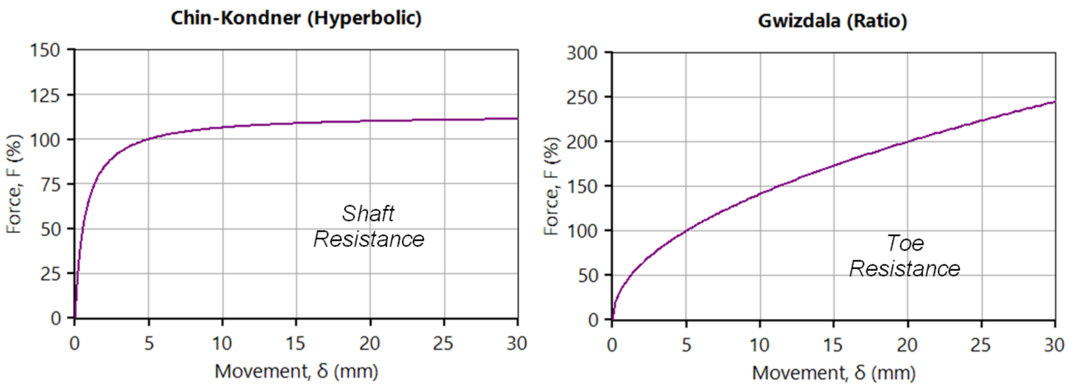

Fig. 3

From about 2010, by combining the UniPile software with calculations and plots in Excel, the full Unified Method analysis could be simulated for a piled foundation at a site where settlement was caused also from other sources than the load on the foundation as shown in Figure 4. The solid green curves show the distributions incorporating the t-z and q-z functions (the functions shown in Figure 3). The dotted red curve in Figure 4A is according to the original approach of applying ultimate shaft resistance values. Therefore, because the t-z function is slightly strain-hardening, shaft resistance is slightly larger beyond the transition zone than that represented by the ultimate (plastic) response, which is why the dashed red curve appears slightly to the left of the green curve.

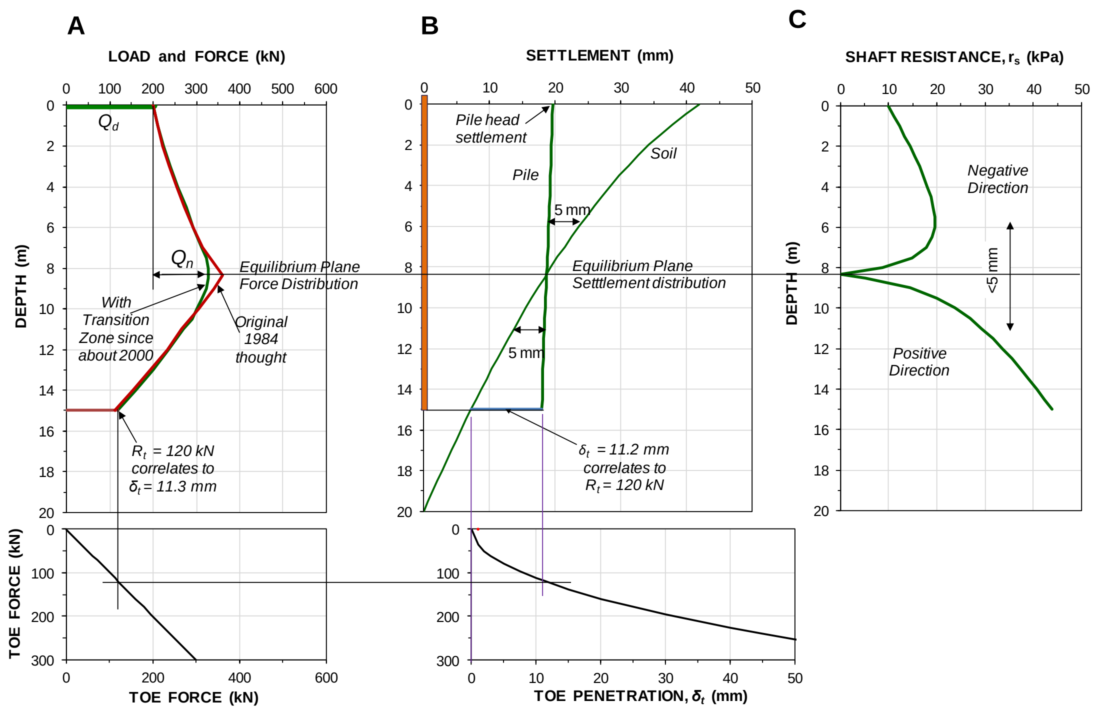

Fig. 4

Until recently, the analysis required using both UniPile and Excel in combination, a time-consuming analysis. The latest update of UniPile (UniPile6), operates without Excel, however, and includes an output option for Soil-Pile settlement incorporating the effect of force and soil movement interaction as a function of distribution of resistance and compression applying the force-movements dependency of pile and soil—the t-z/q-z relations.

Figures 5A and 5B show the output of force distribution and of soil and pile settlement. The force distribution is calculated considering the input t-z relations in the various soil layers, be they plastic, strain-softening, or strain-hardening, and the pile toe response is that determined by the q-z function. Piled foundations can now be designed for forces and settlement considering actually occurring conditions of the case and site. No longer is there any excuse for holding the often false assumption that the "safety factor is good, so the foundation will not settle"!

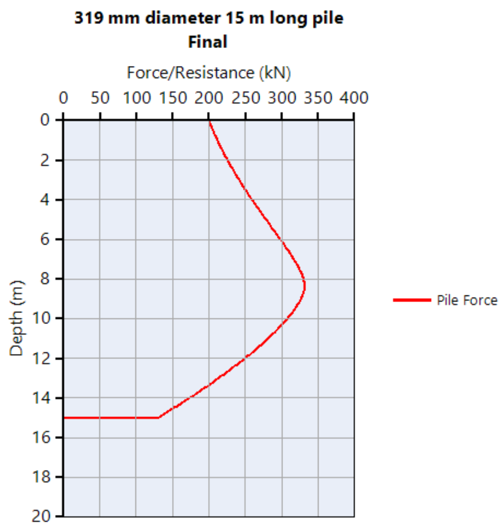

Fig. 5A

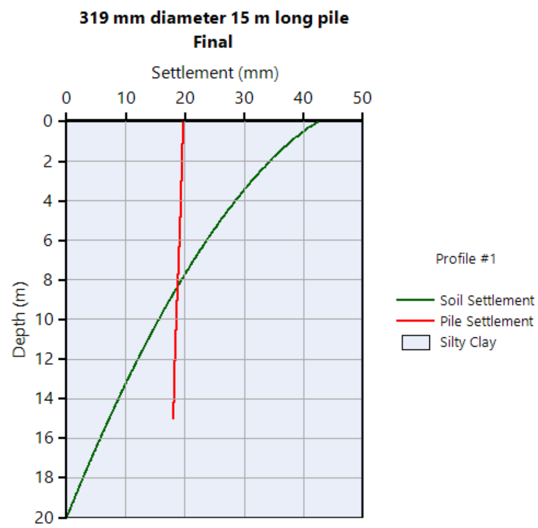

Fig. 5B

The UniPile analysis also produces simulated load-movement curves (Figure 6). The ultimate resistance of the pile can be deduced from the graph according to the User's preferred method. Whatever that preference is, the decision on whether or not the pile is accepted for a particular sustained load rests with what settlement the structure can tolerate. (Note, the example is fictitious aiming to show principles of the Unified Method. The actual numbers matter not). UniPile can be used to fit a simulation, pile element to pile element, to the results of an actual test to calibrate the t-z/q-z functions. Then, with input of the soil compressibility, the software produces the Soil-Pile Settlement results. That is, the results of a static loading test (Figure 6)can be used not just for simulating the load-transfer movement due to an applied load, but also be applied to an analysis of long-term settlement of the piled foundation.

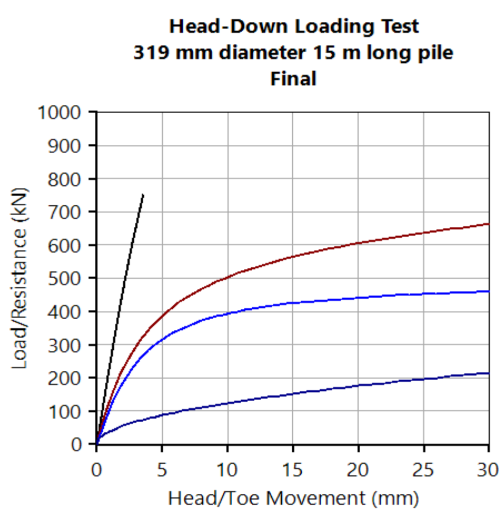

Fig. 6