

Historic over the Unified Method and UniPile over 40 Years

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The Unified Method of pile analysis for pile bearing and settlement considers force distribution as a function of soil shear developed due to the relative movement between the pile and the soil caused by an applied load and/or general subsidence at the site.

In 1984, when I first proposed the Unified Method, I applied ultimate strength the shaft resistance and only realized the importance of movement of 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 paper¹, 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, a term with many other uses in engineering analysis. Therefore, I now prefer to use the term "Equilibrium Plane", EP).

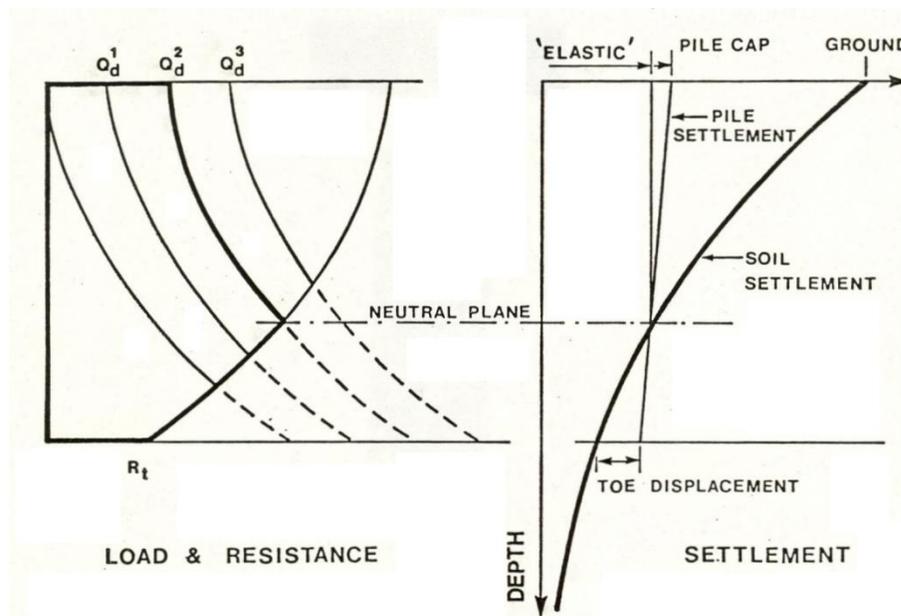


Fig. 1 Original force and settlement diagrams of 1984

A transition zone develops where the unit shaft resistance changes from negative to positive direction. The transition is not sudden, but occurs along a certain zone length or height. Over the next four years, I realized that the response to the difference in relative movement between the pile and the soil within the zone would make the pile force distribution to be curved as opposed to have a kink (Figure 2²). When the soil settlements are small, the length of the transition zone will be large. Moreover, the larger the toe resistance, the deeper lies the EP. And, the larger the sustained (dead) load, the shallower its depth.

In 1988, I still assumed, erroneously, that the shaft resistance would be plastic and that specific ultimate conditions would be governing the analysis. Not until about 15 years later did I realize that the force distribution is tied in with the relative movement between the pile and the soil and this must be expressed in $t-z/q-z$ functions.

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.

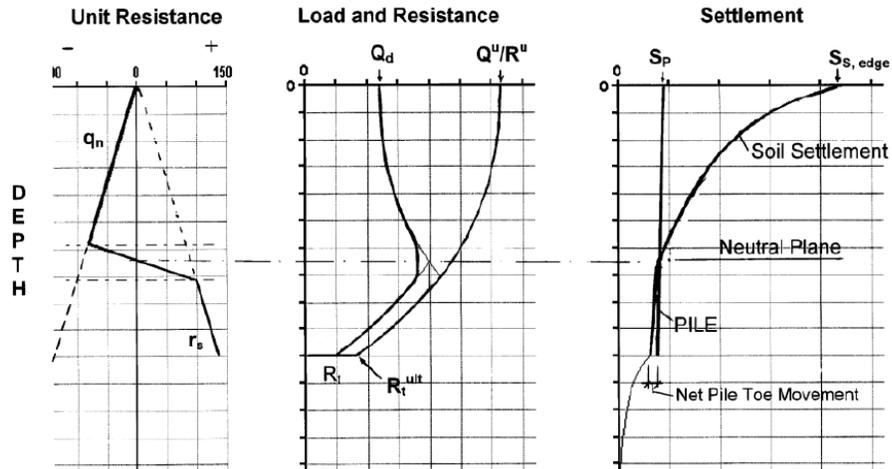


Fig. 2 Original force and settlement diagrams of 1988

In the mid-or late 1980s, I advanced the Unified Method to the newly available PC, notably a VisiCalc spreadsheet template (then Lotus123, then, Excel). In about 1990, Pierre Goudreault produced the first version of UniPile, UniPile1, a DOS program. Over the years, my understanding of the interaction between the pile and the soil gradually increased and was incorporated by Pierre in updated versions of UniPile. UniPile5 (2014) included the shaft and toe resistance stress-movement response per t - z and q - z functions developed for the analysis.

The particular t - z / q - z functions for a particular case can vary widely. Figure 3 shows two commonly found functions (used in the typical example detailed below). The figure shows that after a small initial 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 most often strain-hardening, i.e., it progresses toward increasing force—normally, there is no plastic response, no ultimate toe resistance. The functions are best implemented by selecting a target force at a target movement. The figures show the target force as 100 % of the assigned force.

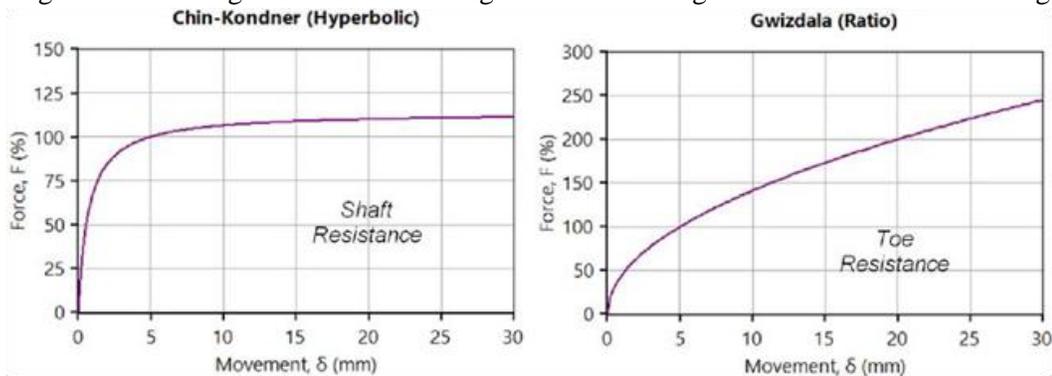


Fig. 3 Example of t - z and q - z function curves

From about 2010, by combining the UniPile software with calculations and plots in the Excel template, 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 for the 1988 example. The solid green curves show the distributions incorporating the t - z and q - z functions (the functions shown in Figure 3). The red curve in Figure 4A is according to the original approach of applying ultimate shaft resistance values. The third graph, C, shows the distribution of unit shaft resistance after relating it to the movement.

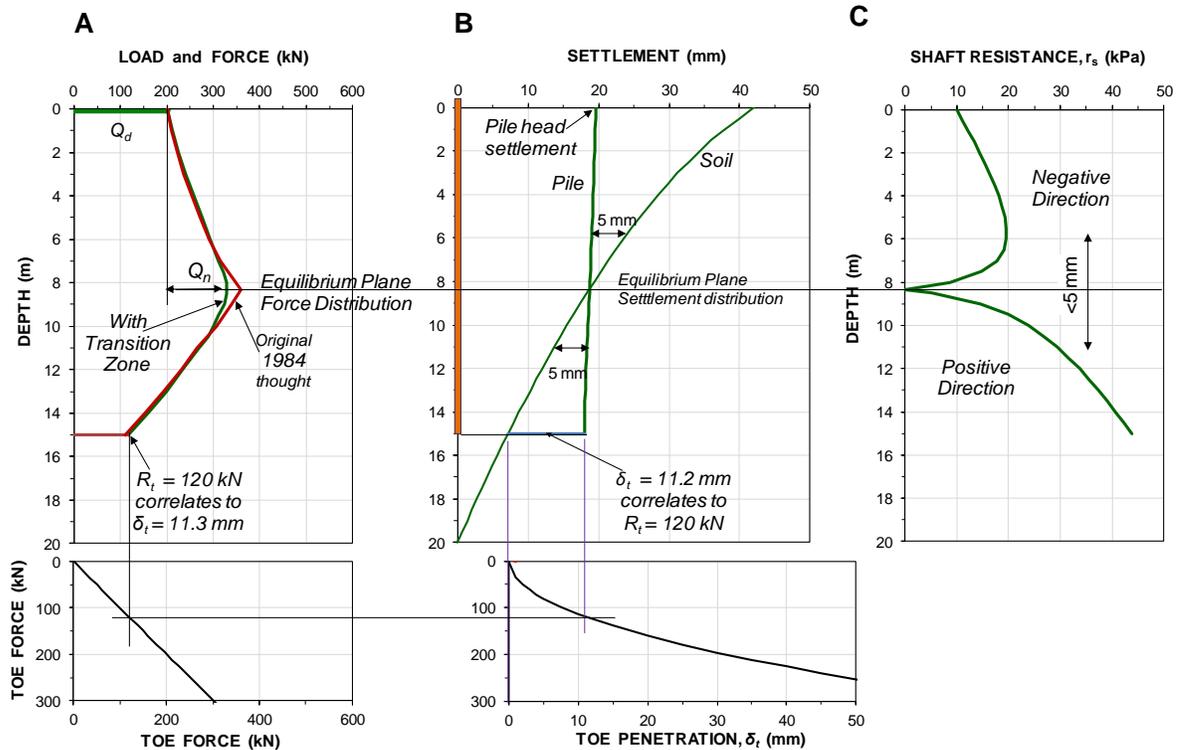


Fig. 4 Force and settlement diagrams produced from UniPile5 and my Excel template

Until recently, the full Unified Method analysis required using both UniPile and Excel in combination, a time-consuming analysis. However, UniPile6, developed by Pierre in 1924, operates independently of outside aid and includes an output option for Soil-Pile settlement that incorporates the effect of force and soil movement interaction as a function of the distribution of resistance and compression in 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"!

The UniPile analysis also produces simulated load-movement curves (Figure 6) for an analyzed pile (the figure shows the output for the 1988-example pile. The ultimate resistance of the pile can be deduced from the graph according to the User's preferred method³). Whatever and regardless of that preference, 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 do not matter here). Moreover, UniPile can be used to fit a simulation to the results of an actual loading test in order to establish the t-z/q-z functions, pile element to pile element for the test pile. Then, with input of the soil compressibility and added soil stress, the software produces the Soil-Pile Settlement results of the Unified Method. That is, the test results 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

³ Fellenius, B.H., 2025. What's capacity? Is the concept at all useful? The Pile Driver, Issue 2025(6), pp. 109-116.

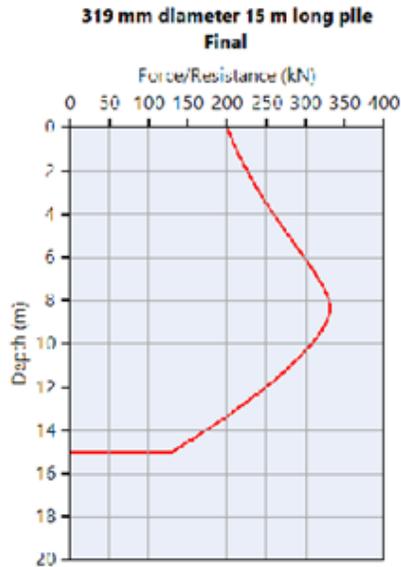


Fig. 5A Force distributions

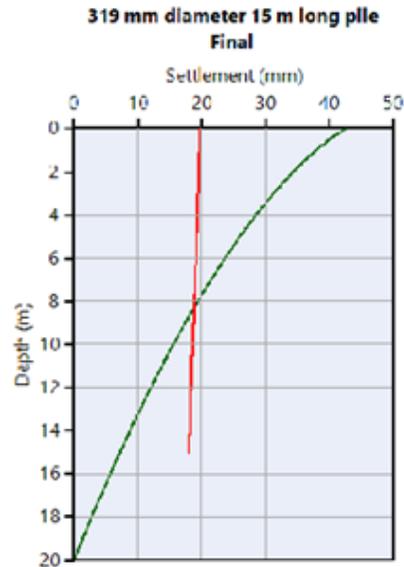


Fig. 5B Settlement distributions

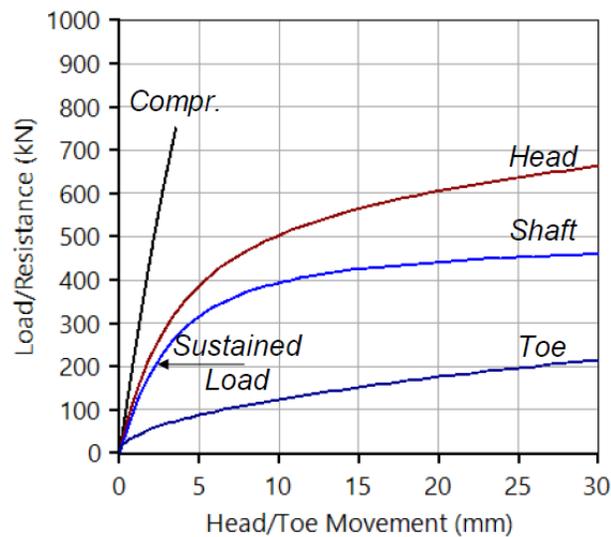


Fig. 6 UniPile6 output of results of a simulated static loading test

Pile settlement is often a function of the various construction events during and after the completion of the supported structure, when settlement is rarely of concern, as well as over time after end of construction, when it is of concern due to continued downdrag due to area subsidence, current or future area activities, and interaction between foundations. All effects can be considered by means of the Unified Method and UniPile6.

The Unified Method is equally applicable to group piles and the UniPile software can also be used to produce group analysis simulation results (Fellenius 2025⁴; 2026⁵).

⁴ Fellenius, B.H., 2025. Revisiting Okabe (1977), Cooke et al. (1981), Hansbo (1984), and Russo and Viggiani (1995). The response of a wide pile groups to load. Journal of the Deep Foundation Institute, 19(1) 10 p.

⁵ Fellenius, B.H., 2026. Basics of foundation design—a textbook. Electronic Edition, www.Fellenius.net, 572 p.