Static Versus Dynamic Pile Bearing Capacity (Discussion to Session 4)

A. HOLEYMAN Manager of the Research and Geotechnical Department, Franki
Part-time Assistant Professor at the Université Libre de Bruxelles, Belgium

What I will say will most probably go against rather accepted ideas in the area of impact versus static behaviour of piles. My opinions are based on analytical procedures as well as on experimental evidence.

I will not go into the details of the analytical procedure I recommend to use in wave equation analyses because there is no time for this now and because these theoretical elements are presented in volume 2 of the proceedings of the XIth ICSMFE and in volume 1 of this symposium.

Figure 1 shows you however the essence of the approach, whose objective is to model more rationally the behaviour of the soil around the pile. I will restrict myself mainly to the base resistance which as you can see is handled by an equivalent solid of soil, which is easily incorporated in a wave-equation analysis. The shape of this solid handles the geometrical (or radiation) damping. The hysteretic damping is accounted for by a simple hyperbolic law of deformation of the elements, especially the ones close to the pile tip which undergo large deformations. At some distance from the base, the soil is supposed to behave elastically.

This model has been used to interpret dynamic measurements recorded during the diesel driving of a closed end cylindrical steel pipe pile into

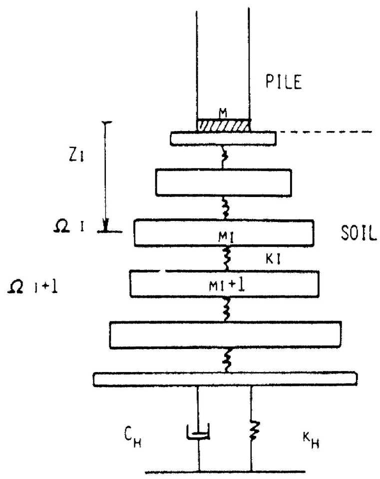

Figure 1 : Model for the soil resistance at the base of a pile being driven.

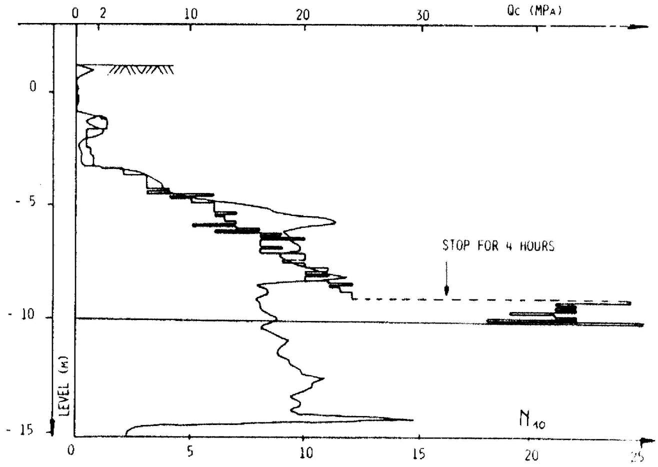

Figure 2 : CPT cone resistance diagram (Q_c) and blowcount diagram (N_{10}).

a dense sand. These measurements carried out by Franki were a fraction of a larger research program commissioned by the Ministery of Public Works of Belgium, and aiming at determining the difference in behaviour between driven and bored piles of identical geometrical and soil conditions. The piles had a diameter of 60 cm.

Figure 2 shows the cone resistance diagram at the site near Antwerp. This diagram indicates the high density of the tertiary fine to medium sand. The cone resistance at the base level is about 18 MPa. The equivalent SPT blowcount would be of the order of 40 to 50.

The blowcount is also represented in this diagram, with the lower scale expressing the number of blows per 10 cm. One must note that the driving had been interrupted for 4 hours just 1 meter before reaching the final level. Upon redriving, the blow count increased sharply and the final penetration was reached with a set of about 4 mm.

The dynamic measurements what will be discussed have been recorded by instruments placed about 60 cm from the top of the pile, and result from the last blow at the very end of driving. The velocity and force diagrams are shown on figure 3 as functions of time in the classical way used for measurements recorded on top of the pile.

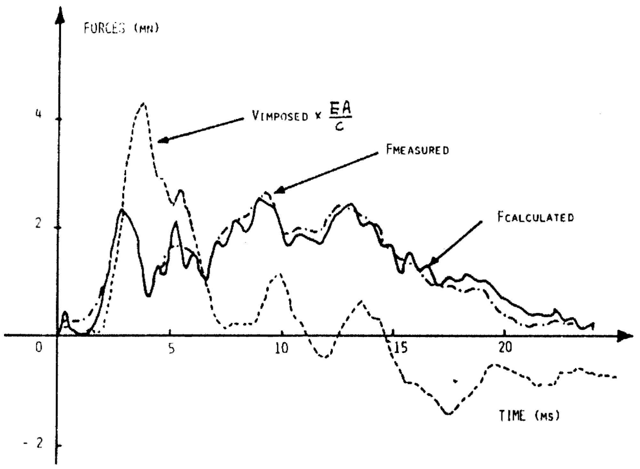

Figure 3 : Transient signals at the base of the pile.

What has been done then is to impose the measured velocity as a boundary condition on top of the base resistance model and back-calculate the basic parameters. For the best estimate of these parameters, the transient force calculated at the base is approximatively equal to the transient force measured at the base. It can be seen here that the match between calculated (full line) and measured force (dotted line) is not bad at all, considering that basically two parameters at the base have to be optimized. These are basically the ultimate base resistance and the stiffness at the initial loading.

The only problem with such an optimization technique is that the solution is not unique. Indeed, a number of curves with different sets of parameters could be found with about equal satisfaction. This raises the question of the reliability of the deducted parameters when trying to use these for a static prediction.

In order to elucidate this problem we have plotted in figure 4, the static load-settlement curve that would have been predicted with 3 equally satisfactory solutions determined from dynamic measurements. These curves differ mainly by the ultimate base resistance but are pretty similar for smaller displacements. In fact they all go through about the same point which represents the point of maximum dynamic loading. Therefore the most reliable characteristic which can be determined from dynamic measurements at the base level is the initial portion of the loading curve. On the other hand, the assessment of the ultimate bearing capacity is a matter of extrapollation. We are in the same position when we would like to guess the failure load from an incomplete static load test.

The middle curve was finally selected to calculate the static load curve, taking then into account the skin friction along the shaft, also deducted from dynamic measurements recorded on top of the pile. Figure 5 shows the results in comparison with the curve obtained from the real static load test conducted up to failure.

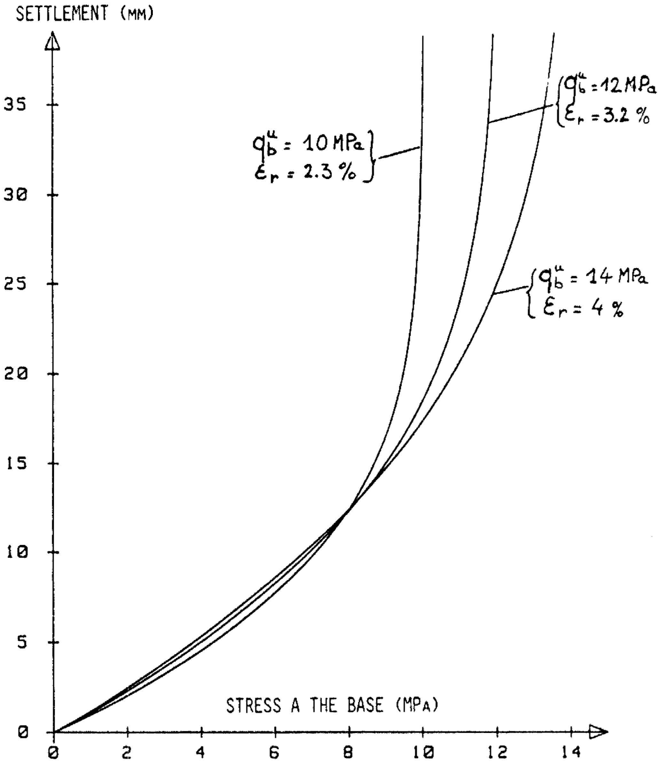

Figure 4 : Stress - settlement curve at the pile base

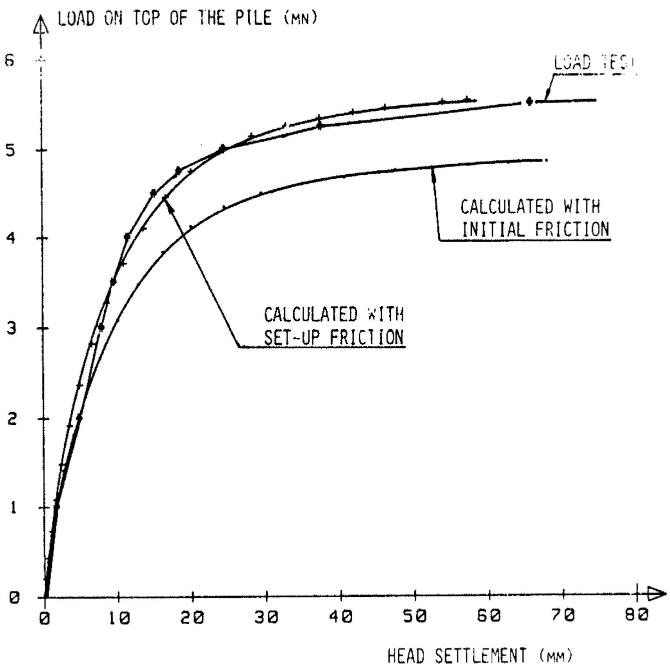

Figure 5 : Load settlement curves at the pile head.

One can see that the match is not perfect. In order to have a better match, it was necessary to increase the skin friction by as much as 50 %. This increase was attributed to soil freeze, or set-up.

In conclusion, dynamic measurements can be used to predict the static bearing behavior with some limitations. It is our experience in dense sand that the initial stiffness, better than the ultimate bearing capacity can be assessed at the base of a pile. We expect this limitation to be more severe when piles are driven to higher blowcounts.

REFERENCES

HOLEYMAN, A. (1984) - "Contribution à l'étude du comportement dynamique non-linéaire des pieux lors de leur battage". Doctoral thesis, Université Libre de Bruxelles, ICC, July 84, 584 p.

HOLEYMAN, A. (1985) - "Unidimensional modellization of dynamic footing behaviour", Proceedings of the XIth ICSMFE, San Francisco, Vol. 2, paper 1/B/12, pp. 761-764.

HOLEYMAN, A. (1985) - "Dynamic Non-Linear Skin Friction of Piles", Proceedings of the International Symposium on Penetrability and Drivability of Piles, San Francisco, Vol. 1, paper 4/6, pp. 173-176.