Pile Design and Construction Control by Dynamic Methods - A Case History

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Dynamic testing methods are frequently employed in piling projects during design and construction and/or as evaluation agents after installation. Depending on significance and magnitude of the pile foundation project, potential savings, and difficulties expected, a dynamic test programme can be an elaborate pre-planned event or simply involve testing a few of the early production piles to confirm design and installation criteria. In most cases today, dynamic testing is a straightforward routine procedure. This article presents a case history where dynamic testing was creatively applied in a non-routine manner.

The project was a small part of a very large job involving the construction of many bridges and buildings for a major public facility. The owner preferred to use 305 mm (12 inch) O.D. pipe piles with 6.4 mm (0.25 inch) wall thickness (area = 60cm^2; 9.25 in^2) which he had in stock. The contractor wanted to use his ICE 520 double acting diesel hammer, the only hammer available to him at the time. The soils consisted of silty clayey sand to a depth of 40 m (130 ft) where a bearing layer of fine dense sand existed. The required pile capacities ranged between 1,600 kN and 2,140 KN (360 and 480 kips).

According to the GRLWEAP wave equation program, for 250 MPa (36 ksi) yield strength steel, the pipe pile shell could not be driven to the required capacity (Figure 1). However, it is commonly observed that many soils exhibit strength changes with time after pile driving. The rate of change is often well known in local areas, and is the reason for many local codes specifying a wait period after driving and before static tests. Fortunately, there was substantial experience on other project phases of significant soil strength increase with time (set-up), and the foundation engineer agreed to rely on this fact provided that a test programme would confirm similar soil set-up capability.

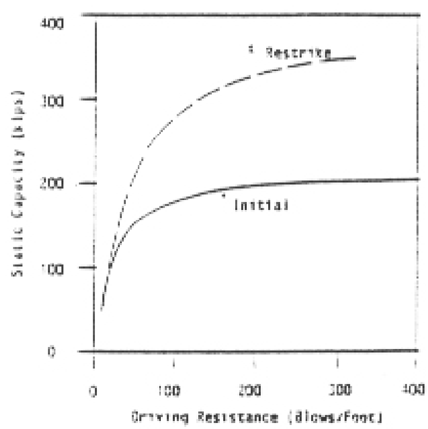
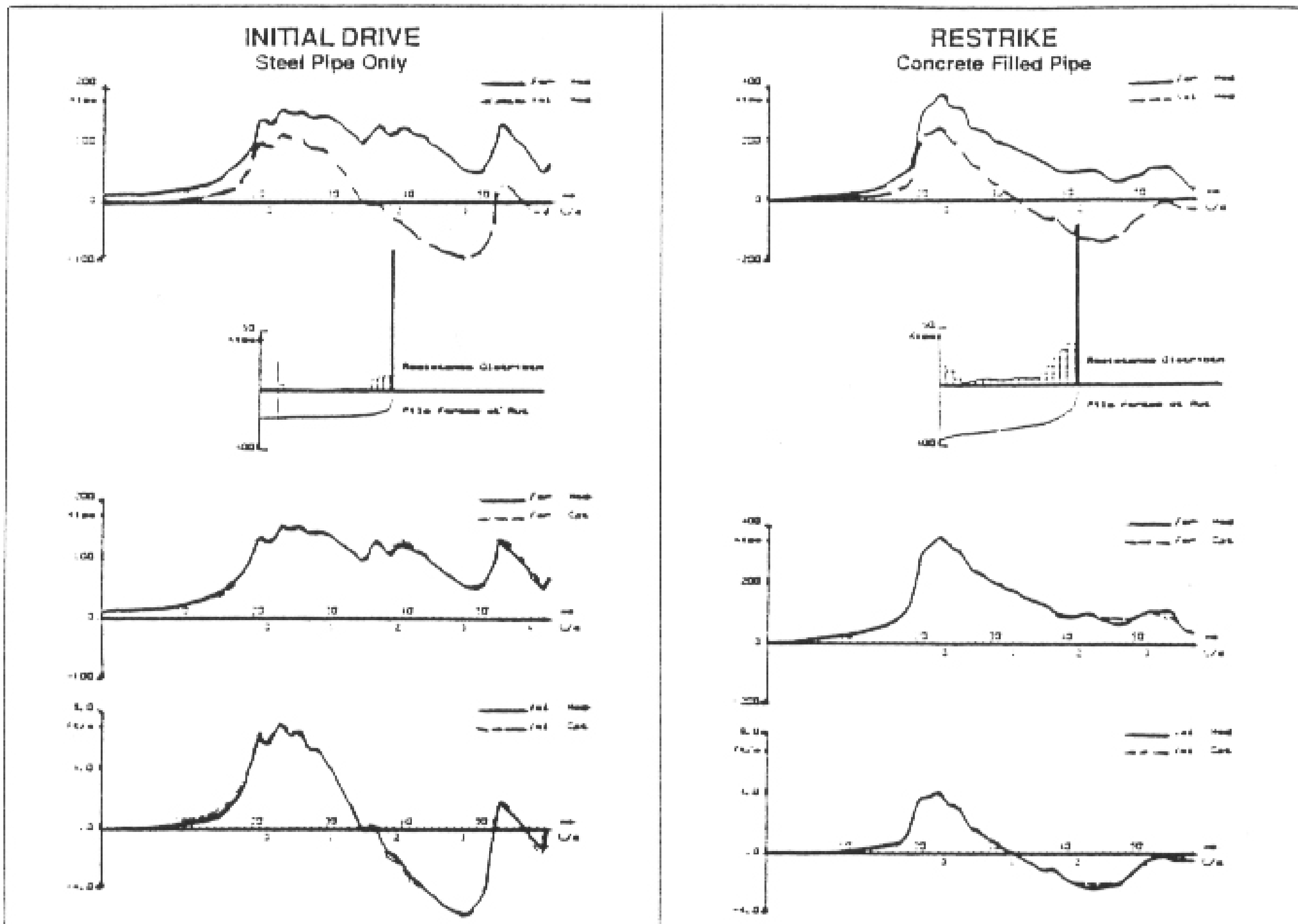


Figure 1 Results from Wave Equation (curves) and CAPWAPC (points)

Dynamic drivability analysis performed using GRLWEAP indicated that the hammer would only be able to initially drive the pile to a capacity between 800 and 900 KN (180 and 200 kips) at a penetration resistance between 100 and 250 blows per 0.3 m (foot). In the field, the pile, consisting of three 15 m (50 ft) welded sections, was driven to 159 blows in the last 0.3 m (foot). The PDA determine capacity was 820 KN (184 kips) at the end of installation. The measured dynamic data along with Case Method and CAPWAP analysis computed dynamic variables are included in Figure 2. As illustrated by the original wave equation analysis, testing the unconcreted pile during restrike would not reveal significantly more static capacity because refusal blow counts had already been encountered during the initial driving (i.e., the drivability limit of the system had been reached).

Filling the pipe with concrete, however, increases the stiffness of the pile and results in a higher drivability limit. A second wave equation analysis was therefore performed to assess this



Blow Count: 159 bl/0.3 m
Max. Compressive Force: 710 KN (160 kips)
Max. Transf. Energy: 13.5 KJ (10.0 ft kip)
Shaft Resistance: 290 KN (66 kips)
TOC Resistance: 520 KN (118 kips)
Total Capacity: 820 KN (184 kips)
Smith Damping; shaft and toe: 0.08 and 0.03 s/m (0.280 and 0.09 s/ft)
Soil Quake; shaft and toe: 2 and 3 mm (0.09 and 0.12 in)

Blow Count: 192 bl/0.3 m
Max. Compressive Force:1.720 KN(388 kips)
Max. Transf. Energy: 14.1 KJ (10.4 ft kip)
Shaft Resistance: 990 KN (223 kips)
TOC Resistance: 410 KN (137 kips)
Total Capacity: 1.600 KN (360 kips)
Smith Damping; shaft and toe: 0.08 and 0.03 s/m (0.27 and 0.09 s/ft)
Soil Quake; shaft and toe:2 and 3 mm (0.09 and 0.13 in)

Figure 2

drivability of the concrete filled pile and indicated that for a penetration resistance of 180 blows per 0.3 m (foot) a static capacity of 1,470 KN (330 kips) would be mobilized (Figure 1).

Static and dynamic restrike tests at various times after driving performed on similar piles on other portions of the job concluded that the soil strength continued to increase even after two weeks after initial driving. Based on this known strength versus time experience, the dynamic test results from end of initial driving, and the wave equation prediction, it was decided to restrike the concreted piles only six days after initial installation when they were then estimated to be already at the drivability limit and then project the final capacity after several weeks.

During restrike after the six-day wait, the observed penetration resistance was 192 blows per 0.3 m (foot) and the computed pile capacity was 1,730 KN (390 kips) from the dynamic testing. This computed restrike capacity was sufficient for some piles, but less than required for others; however, it verified past experience regarding the trends of soil strength increase with time and the design engineer was satisfied that the long-term capacity would after additional time be sufficient for the required load for all piles.

Design, tests, and analyses, combined with past experience on the local soil strength behaviour as a function of time, allowed piles to be accepted as driven by the only hammer available to a successful conclusion without generating significant additional expenses for static loading tests or the purchase of new piles.

References

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