A contemporary (1974) picture, but from a different site

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TWO CASE HISTORIES

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DYNAMIC MEASUREMENTS AS AN INSPECTION TOOL FOR DISCOVERING DAMAGE TO SPLICED AND UNSPLICED PRECAST CONCRETE PILES

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Two brief case histories are presented, where damage to concrete piles was discovered by means of dynamic measurements using the Pile Driving Analyzer.

Case A

At a site outside Montreal, Quebec, ordinary reinforced, 285 mm square, precast concrete piles were driven with a 45 KN drop hammer. The piles were driven in three segments, which were spliced in the field by means of mechanical splices. The hammer height of fall was 0.6 m. The soil consisted of about 30 m of clay followed by dense to very dense silty glacial till.

The pile segments were equipped with mechanical splices consisting of flat steel plates cast onto the end of each pile segment by means of four short reinforcing bars welded to the plate. In the field, the segments were connected by clamping the plates together at the corners.

Analyzer wave traces were taken during the driving of an arbitrarily chosen pile made up of two 12.2 m long lower segments and one upper 9.2 m long segment. At a depth of 15.2 m, shortly after splicing the middle segment to the lower and at very easy driving (7 blows/m), traces were obtained as shown in the upper set of curves in Fig. 1. The traces contain a very distinct "blip" just prior to Time L/c, consisting of a temporary rise in velocity and a simultaneous reduction of force, which originate from a reflection at the location of the splice and suggest the presence of a slack, or a gap, in the splice.

The width of the gap can be determined from the Analyzer measurements according to the method proposed by Rausche and Goble (1978) resulting in a value of about 2 mm. This width is considerably higher than what is normally accepted. For instance, the Canadian Manual of Foundation Engineering (1978) suggests 0.5 mm as an upper limit.

When driving spliced precast concrete piles in easy driving, the splices often show up as "blips" in the wave traces. Then, in the harder later driving, the "blips" disappear, as the slack is closed. However, in the example case of a pile made up of three segments, i.e., containing two splices, at a relatively easy driving (4 blows/0.2 m) at Depth 24.7 m, as well as at a hard driving (100 blows/0.2 m; 2 mm/blow) at Depth 31.1 m, both splices are clearly evident by the "blips" located 2L/c apart in the wave traces. This suggests that the "blips" are not just caused by a gap in the splice, but also by either wobbly plates (not machined properly), or by a "dogleg" being formed at the splice location. Calculations of the "blip" according to Rausche and Goble (1978) indicate a reduction in area of 60 % to 70 % of the cross section.

The effects of the "blips are that the reflections from the pile toe are delayed causing a Case Method Estimate (CMES) of capacity to become conservative. More importantly, however, the splice with its large gap, unevenness, and/or doglegged state raises serious concern over the adequacy of the pile and its ability to withstand continued hard driving.

In Fig. 2, wave traces are shown for an identical pile at the same job site that actually broke during the monitoring. The records from Depths 25.0 m and 29.6 m show similar "blips" as found for pile No. 1. At Depth 32.2 m, the pile broke. The break is located at the lower "blip", i.e., at or near the lower splice.

This pile, Pile No. 2, was later extracted. Only the upper and middle segments came up. Visual inspection revealed that the bottom end plate had broken off from the middle segment at the welds of the reinforcing bars connecting it to the pile.

Case B

At a marine site at the Port of Seattle, Washington, 43 m long, one piece, 420 mm diameter, octagonal prestressed test piles were driven by means of a Vulcan 020 air/steam hammer through about 8 m of loose sedimentary soils containing rip-rap and boulders. Below this layer, the soil consisted of about 12 m of loose silt and silty sand deposited on dense glacial till at a depth of about 20 m below the mudline and about 35 m below the mean water level. The density of the upper portion of the till was variable.

A total of six test piles were driven at the site and monitored with the Analyzer. Two of these were equipped with a 1.75-inch, Schedule 40, steel center tube from pile head to pile toe. The purpose of the tube was to provide a means for establishing through inspection down the tube that the pile was sound after the driving. (The penetration resistance was expected to be variable, even erratic, and be of limited use in judging the integrity of the pile).

Fig. 3 presents the wave traces from three consecutive blows of the hammer, when the pile toe had penetrated about 1 m into the glacial till with a penetration resistance of 70 blows/0.2 m. The first blow record shown, Blow 101 (as well as the not shown immediately preceding blows), indicates a pile with a somewhat large quake (about 8 mm), a substantial toe resistance, only little shaft resistance, and, generally, a sound pile. The black rectangle symbolizes Time 2L/c, and, also, the length of the pile.

The traces from the second blow shown, Blow 102, are very different. At time 2L/c, there is an obvious disagreement in the behavior of the velocity trace in relation to the force trace. Then, the third blow shown, Blow 103, is as if from a pile that is about 20 % (8 m) shorter than the original length. The 8 m shortening is symbolized by the open area of the rectangle. In fact, as was verified by the subsequent inspection through the center tube, the pile broke about 8 m from the pile toe.

In contrast to Case A, above, the break came without warning. Also, due to the varying penetration resistance or the individual piles, as well as between piles, the break was not readily recognizable even to the experienced personnel present at the test driving, which confirmed the value and the necessity of the measurements to positively identify the damage.

Fig. 4 presents a comparison of the driving diagram of the pile that broke to that of the second pile equipped with a center-tube for inspection. The two piles were driven at different mud-line elevations. However, the diagrams have been placed so that the elevation of the soi11ayering matches horizontally.

For the pile that broke, the location of the pile toe when the break occurred is marked out in the diagram. After the break had been confirmed, the driving was continued. A sketch in the diagram indicates how the pile behaved. The blow-count is plotted as if the pile still was sound and continued down.

From a visual comparison between the two diagrams, it is not evident that the broken pile actually did break. The diagram of the sound pile indicates a larger penetration resistance (PRES) at depth. However, the PRS for the other piles were smaller and all penetration resistance diagrams were uneven (jagged). Inspection through the center-tube in each pile, and/or the study of the wave traces confirmed that one pile was damaged and the other was sound.

Acknowledgements

The Case B data are obtained from an investigation in 1979 for Port of Seattle, Washington, carried out by CH2M Hill, Seattle, in collaboration with Goble & Associates, Cleveland, and the second Author.

Reference

RAUSCHE, F. and GOBLE, G. G., 1978. Determination of pile damage by top measurements, American Society for Testing and Materials, ASTM Symposium on Behavior of Deep Foundations, STP 670, R. Lundgren Editor, 1979, pp. 550-506.

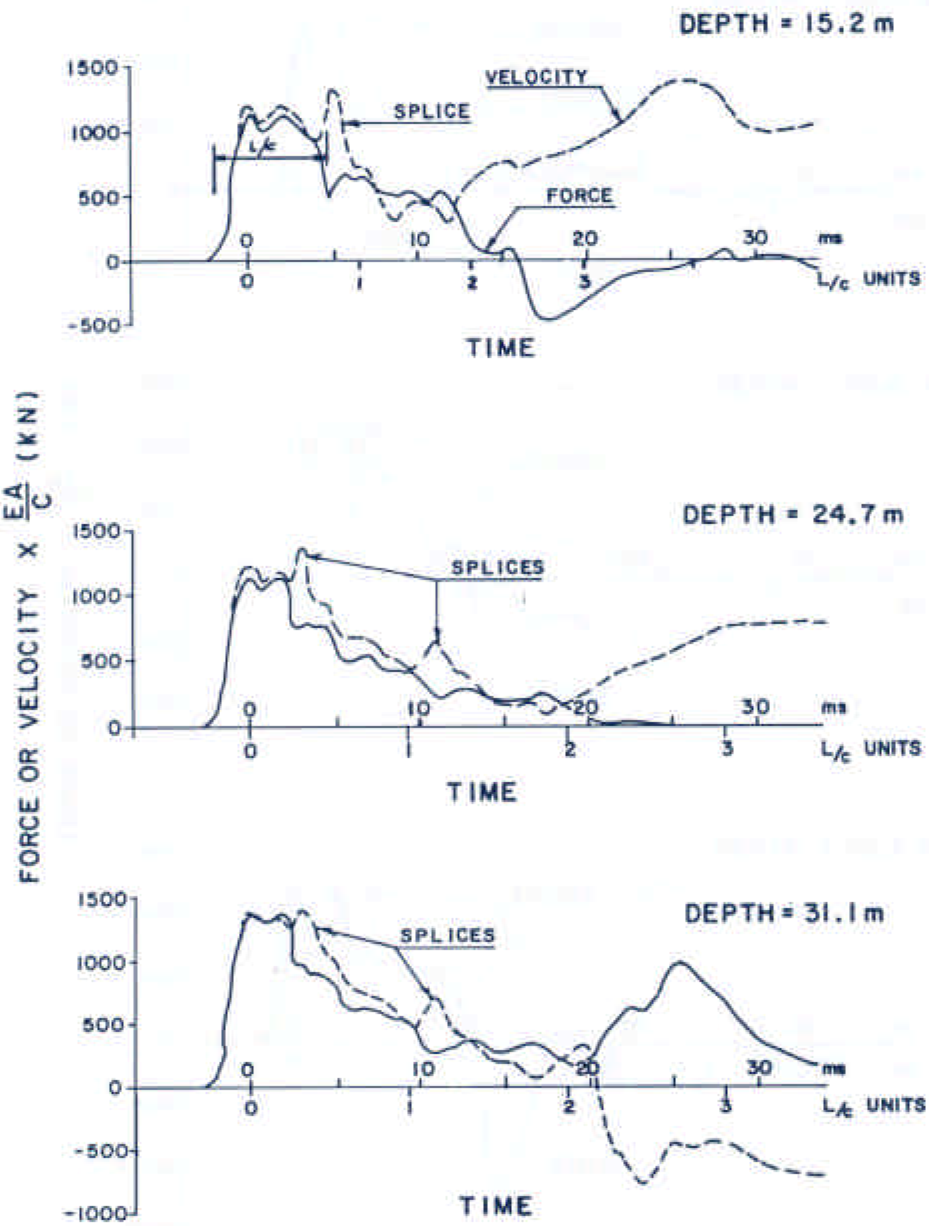

FIG. 1 Analyzer wave traces during driving of a 285 mm square spliced precast concrete pile.

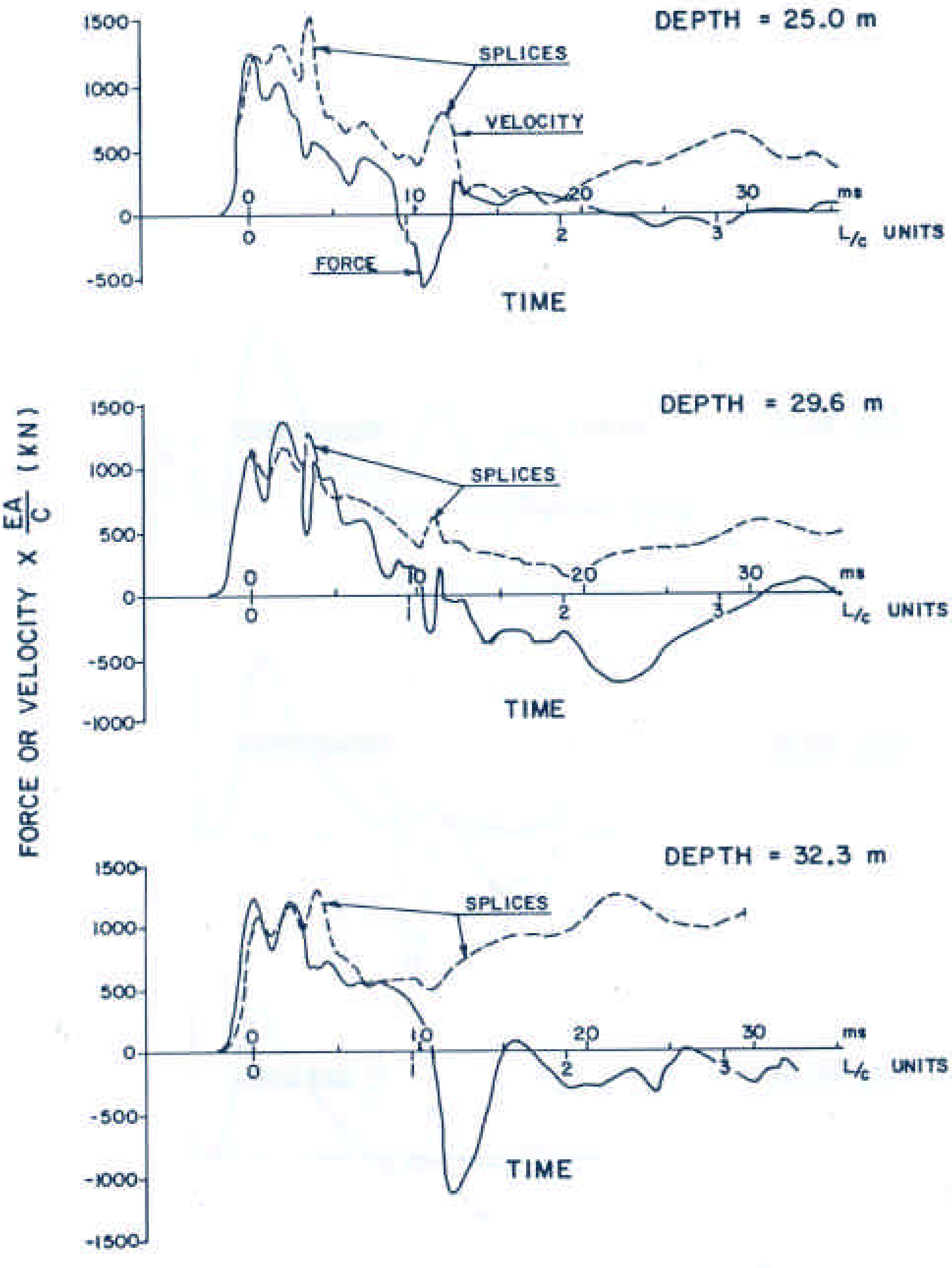

FIG. 2 Analyzer wave traces during driving of a 285 mm square spliced precast concrete pile
The pile broke at Depth 32.3 m.

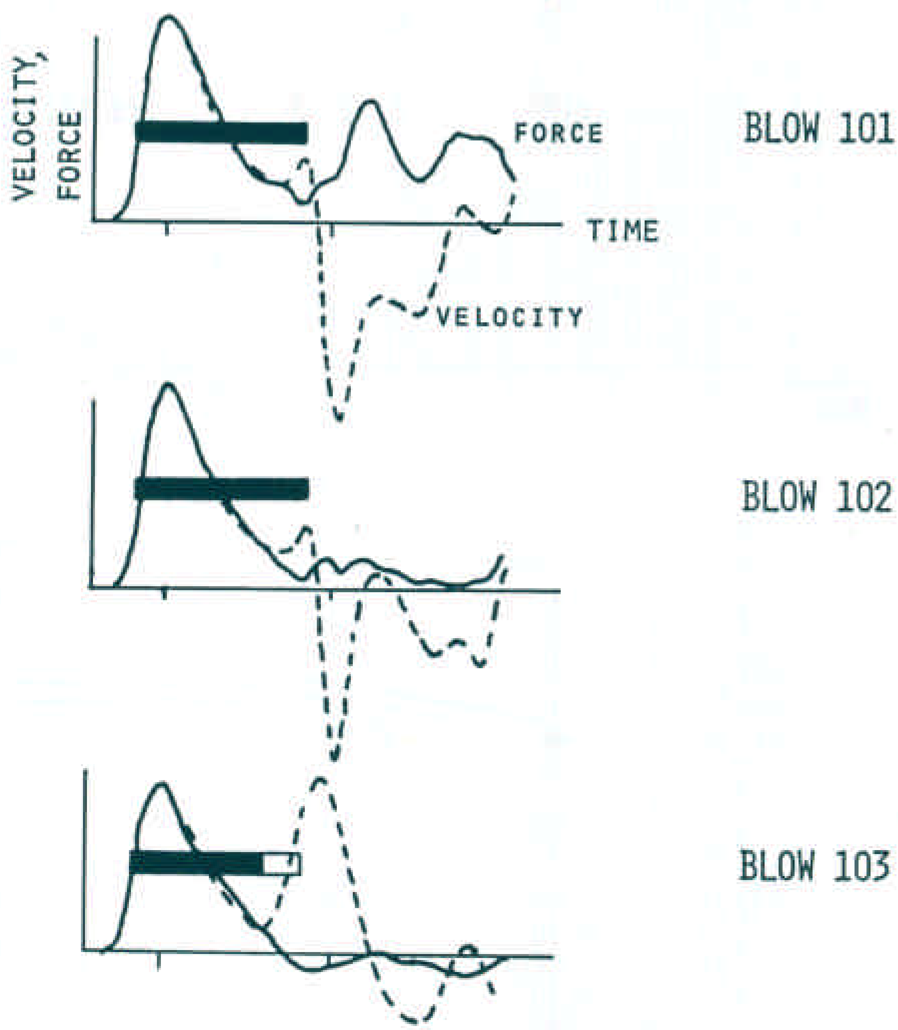

FIG. 3 Analyzer wave traces during three contiguous blows on
a one-piece 43 m long, 420 mm diameter, octagonal prestressed concrete pile
The pile broke in the midst of Blow 103.

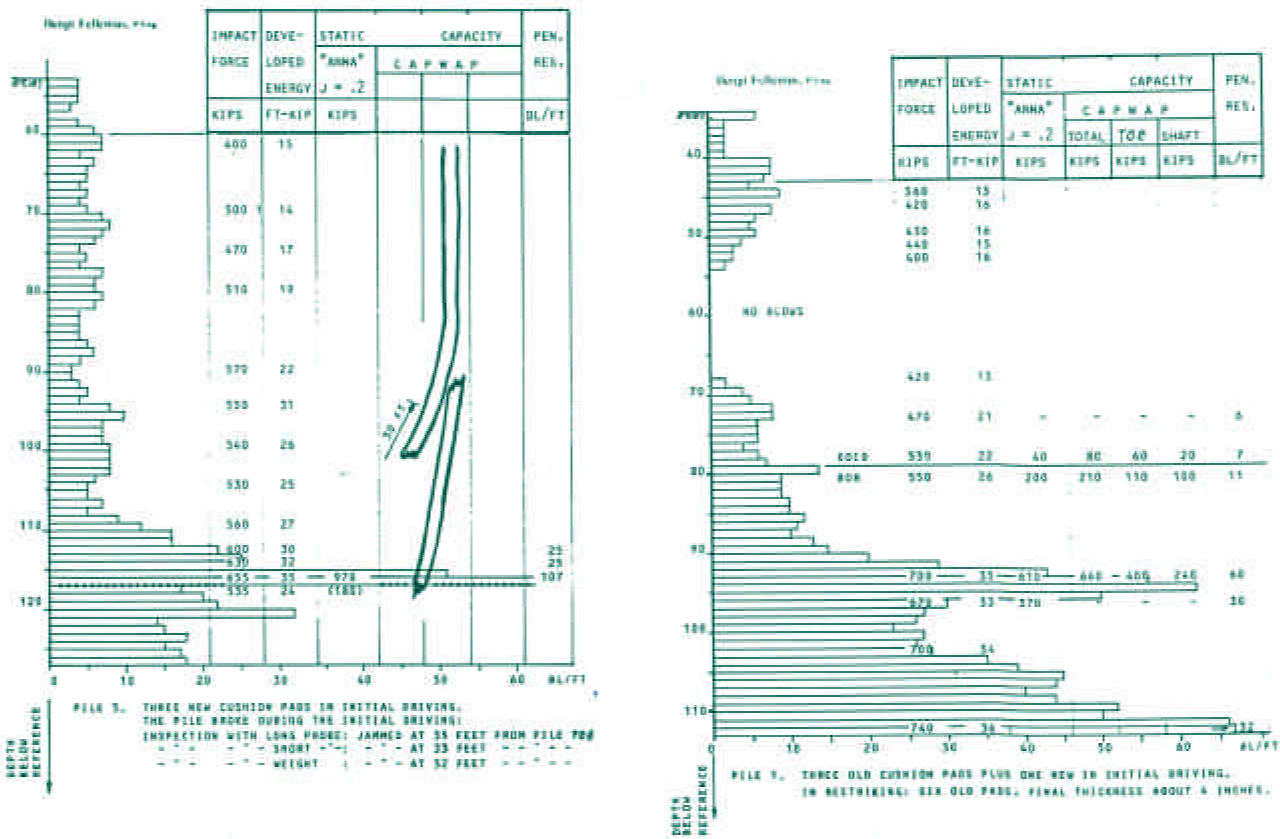

FIG. 4 Comparison of driving diagrams for the broken and sound piles.