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PILE INTEGRITY, AND SOIL SET-UP AND RELAXATION

JEAN AUTHIER and BENGT H. FELLENIUS

In an earlier paper by the Authors (Authier and Fellenius, 1980), an example was given of dynamic monitoring results that revealed damage to and breaking of concrete piles equipped with a mechanical splice of inferior quality. After publishing the paper, an extension of the piling work at the site provided the opportunity for a comparison of the results from the earlier measurements with new measurements on a different type of pile and splice that now were used.

The earlier piling contract used 285 mm square piles (area 812 cm^2) with a mechanical splice consisting of two steel plates, each equipped with welded dowels connecting it to the segment end. The splice was locked by means of clamping the plates together at the corners.

The new contract used 300 mm hexagonal piles (area 800 cm^2) equipped with a bayonet splice type Herkules with six uniformly spread locking lugs located inside the concrete cover. The plate dowels were threaded and bolted to the splicing plate.

Both pile types were driven with a drop hammer. In the earlier case, a 45 KN ram was used, and in the new case, a 36 KN ram. The nominal heights of fall were in both cases 0.45 m in easy driving and 0.60 m at the end of driving. Both piles were composed of three segments. The earlier pile had two lower segments of 12.2 m and one upper of 9.2 m, a total of 33.6 m. The new pile was composed of a bottom 13.2 m segment, a middle 12.2 m segment, and an upper 9.1 m segment, to a total length of 34.5 m. The soil consisted of about 30 m of clay followed by dense to very dense silty glacial till.

Fig. 1 shows representative driving diagrams of the two piles compared. Both diagrams include a representation of the measured values of impact force (FIMP) and transferred energy (EMAX). As seen, the driving of the two piles types was similar.

Pile integrity

In Fig. 2, the force and velocity wave traces are shown, as taken from Pile Driving Analyzer measurements on a representative new pile. "EOID" denotes traces taken at the End of Initial Driving, and "FRST" denotes traces taken at First Blow of Restrike. Above the traces, open horizontal bars indicate the length of the pile (2 L/c) and the location of the splices in the pile. The upper bar starts at the time of the beginning of the records, and the lower bar at the time of impact.

Both EOID and FRST traces show a small "blip" at a time corresponding to a reflection from the location of the upper splice. This splice is located in very soft soil. The lower splice is not discernible in the traces.

Calculations (Goble and Rausche, 1978) of the opening width in FRST, as indicated by the blip, show that the opening is minimal, only about 0.1 mm. This value is smaller than the upper limit value of 0.5 mm suggested by the Canadian Foundation Engineering Manual, and compares very favorably with the 2 mm value found for the earlier case.

In the comparison of the two cases, essentially only the shape of the pile and the type of splice are different. Therefore, the new case provides a direct reference to the earlier case and confirms that the smaller width can be achieved.

The Authors wish to point out that the criticism on the splice in the earlier piling contract relates only to the splice actually used, and not to the splicing as such. For instance, in Fig. 3, force and velocity traces are shown for a diesel driven two-segment concrete pile of the same size and equipped with the Herkules splice. The traces in Fig. 3 do not contain a blip effect. If a small opening of the splice would have been present, it is possible that the initial slow wave-rise during hammer precompression could have obscured it. However, a gap greater than 0.5 mm would still have shown up in the records. The splice used is, obviously, of adequate manufacturing quality.

Soil set-up and relaxation

The Analyzer traces shown in Fig. 2 and the results of the CAPWAP analyses tabled next to the traces provide some interesting additional information, as follows:

In Fig. 2, traces at EOID, the almost overlapping force and velocity traces before Time 2L/c indicate that only little shaft resistance is acting on the pile at end of initial driving. In first restriking, FRST, however, there is a distinct separation of the traces indicating a substantial shaft resistance. The results of the CAPWAP analyses verify this, quantitatively, and show an ultimate shaft resistance at EOID of 300 KN increasing to 800 KN at FRST.

Simultaneously, however, the CAPWAP results show that the ultimate toe resistance is reduced to 1100 KN at FRST from 1500 KN at EOID. In other words, the CAPWAP results show that the soil set-up along the shaft is counteracted by a soil relaxation at the pile toe.

The CAPWAP calculated maximum pile toe displacements (DMAX) are 5.6 mm and 5.3 mm, respectively, and the soil exhibits a large quake of nearly the same size. Therefore, it is possible that the full toe resistance has not been mobilized. However, Fig. 4, which shows a comparison between the first blow of restrike, FRST, and the fifteenth blow, LRST, indicates a reduced shaft resistance between the FRST and LRST, and a slight increase of toe resistance. The maximum toe displacement of 5.6 mm in LRST is appreciably greater than the quake of 3.8 mm, and, therefore, the full static toe resistance has been mobilized. This confirms that a toe relaxation occurred between EOID and FRST.

REFERENCES

AUTHIER, J. and FELLENIUS, B. H., 1980. Dynamic measurements as an inspection tool for discovering damage to spliced and un-spliced precast concrete piles Two case histories. Proceedings 1st International Conference on the Application of Stress-Wave Theory to Piles, Stockholm, 1980. A. A. Balkema, Rotterdam, pp. 121 - 127.

CANADIAN FOUNDATION ENGINEERING MANUAL, 1978. Canadian Geotechnical Society, Four Parts: Properties of Soil and Rock, Shallow Foundations, Deep Foundations, and Excavations and Retaining Structures.

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, Boston, STP 670, R. Lundgren Editor, 1979, pp. 500 - 506.

ABBREVIATIONS

CMES = Case method estimate of static capacity
EMAX = Maximum transferred energy in the pile
FIMP = Impact force
SIMP = Impact stress
CAPWAP = Wave equation analysis by means of matching calculated trace to measured trace
RULT = Ultimate static pile resistance
QUAKE = Displacement at limit between elastic and plastic soil resistance (the point of maximum soil resistance)
DMAX = Maximum displacement
STFF = Secant stiffness of soil
PRES = Penetration resistance

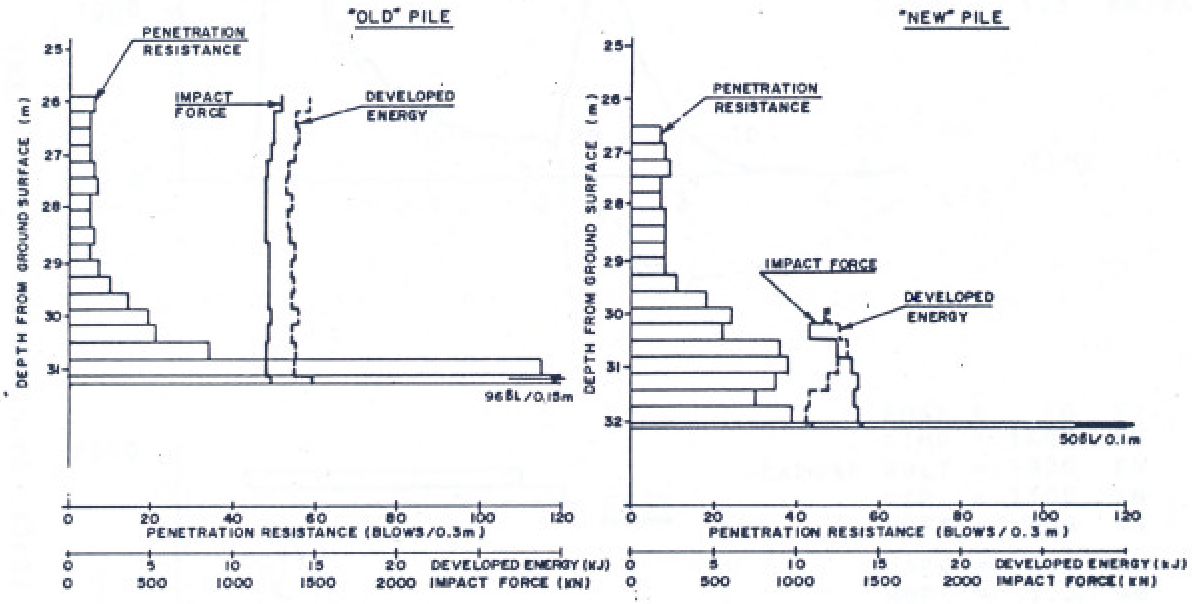

FIG. 1 Driving diagrams comparing the penetration resistance, the impact force, and the transferred energy of the "old" and the "new" piles.

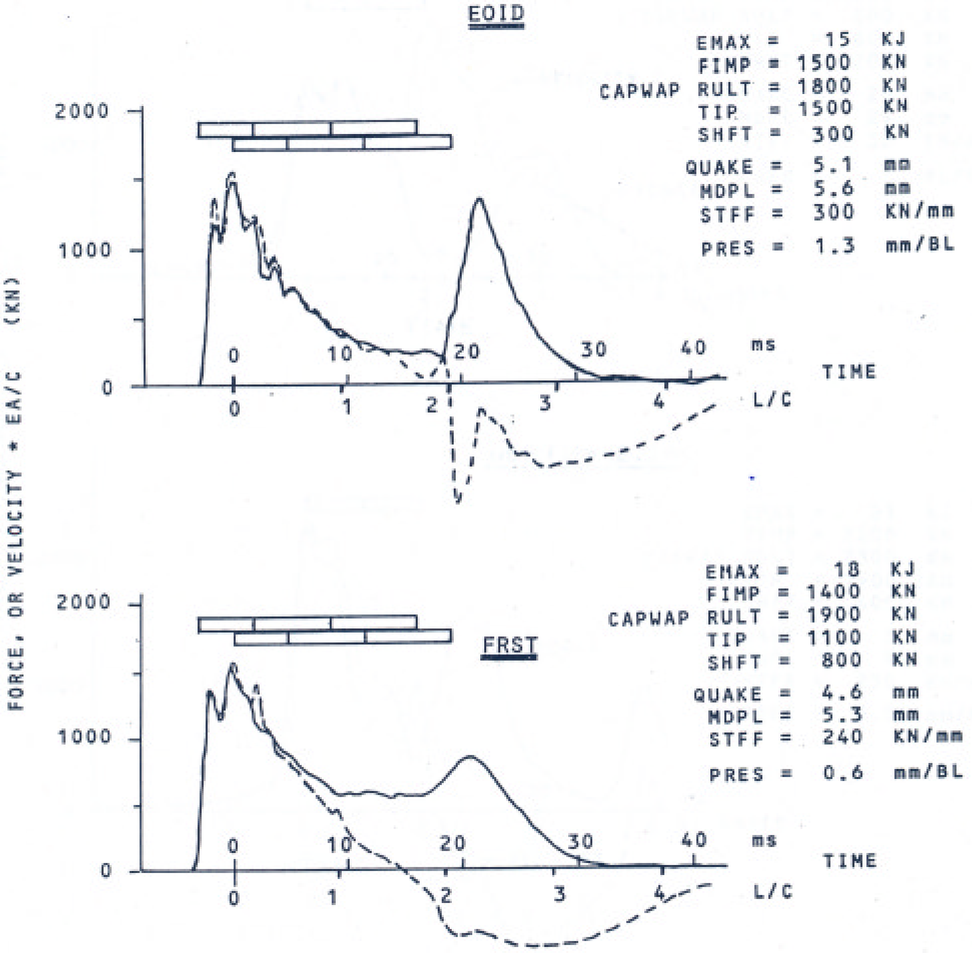

FIG. 2 Analyzer wave traces during the driving and restriking of a 300 mm hexagonal, spliced, precast concrete pile at Depth 30 m

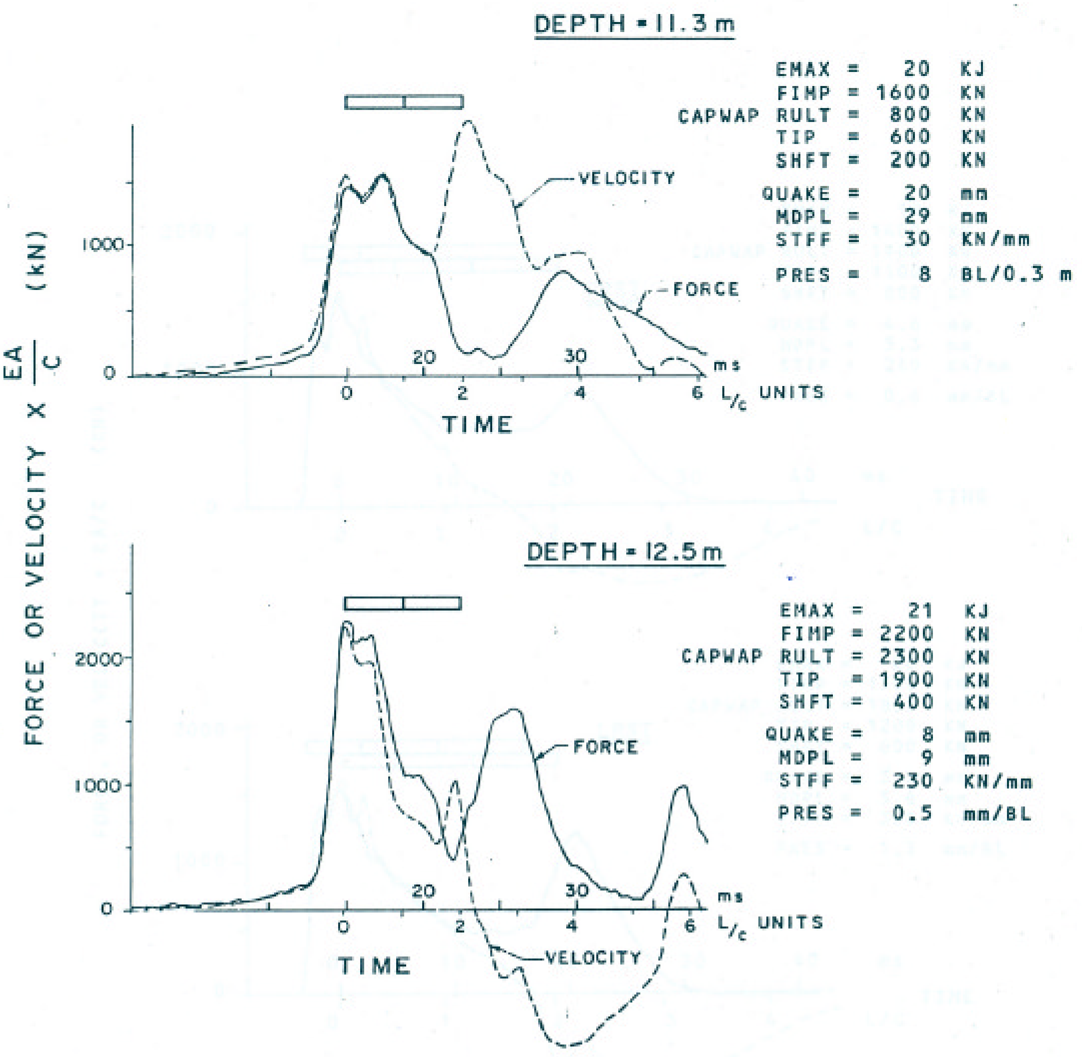

FIG. 3 Analyzer wave traces during the driving of a 280 mm spliced square precast concrete pile

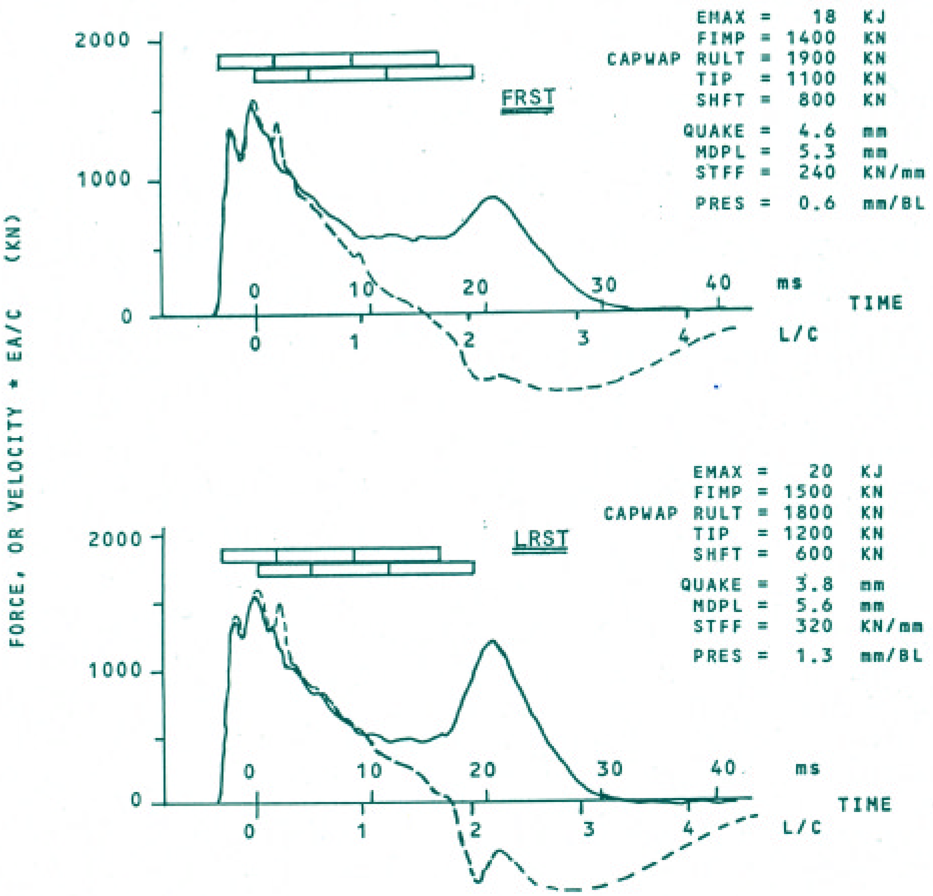

FIG. 4 Analyzer wave traces during the restriking of a 300 mm diameter, hexagonal, spliced, precast concrete pile at Depth 30 m