## APPLICATION

In the **Induction Field Method (IF)**, an AC current flow is impressed into a steel pile (or the rebar in a reinforced concrete pile) from which the current couples into the subsurface and finally to a return electrode. The return electrode can be another steel pile, or it can be a pipe or piece of rebar driven into the ground at some distance from the test pile. A receiver coil or magnetic field sensor is suspended in a nearby boring and used to sense the magnetic field induced by the alternating current flow in the pile, as shown in the schematic below.
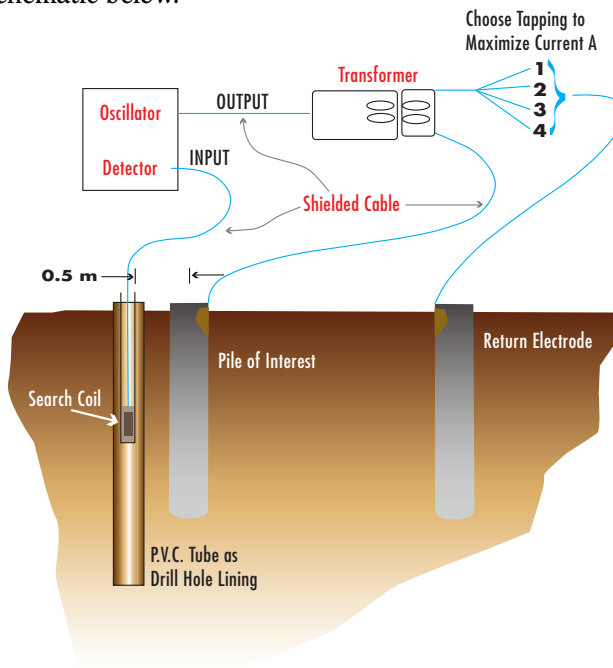
This method was developed in New Zealand for foundation length determination of reinforced concrete piles and steel piles. The method is the electromagnetic analog to the Parallel Seismic (PS) test. A current is passed down the reinforcement or steel of a deep bridge foundation to a return electrode which can be a metal object with an area of about 1 m² (11 ft²) or an adjacent deep foundation having no direct electrical contact with the test foundation as shown in the schematic above. The steel pile acts as one turn of a transformer, generating a magnetic field alongside the pile that can be measured using a search coil or magnetic field sensor in a cased boring. This search coil is then connected to a detecting instrument that shows the relative field strength of the magnetic field. As the depth of the search coil increases, the induced voltage should decrease linearly down the length of the pile, provided there is a constant current leakage into the soil versus depth down the pile.

The Induction Field method is a proven technology for the determination of the depth of steel piles and reinforced concrete piles, particularly when they are very long or conditions preclude the use of acoustic techniques. One important consideration with respect to unknown bridge foundations is that while the method can detect the presence of pile under a buried footing, it requires that the piles be electrically connected through the footing to the bridge superstructure or some other accessible element to allow connection of the current source. Another important consideration is that the method requires a boring. However, the method could be performed in conjunction with the Parallel Seismic or Downhole Seismic methods, which also require a borehole.

F I E L D   I N V E S T I G A T I O N

ACCESS

A return electrode must be placed at some distance away from the foundation to be investigated. A driven rebar is acceptable. The figure at right shows the borehole in between the driven rebar and the foundation, this allows the magnetic field sensor to be located in the middle of the induced magnetic field.

COLLECTION OF DATA

In an IF investigation, the current is adjusted to maximize the magnetic field in the system. The magnetic field sensor is lowered down the borehole and an Olson Instruments Freedom Data PC is used to capture the magnetic field data. The sensor is adjusted at constant intervals, typically, 1-2 ft. This process is continued until the bottom of the borehole is reached.
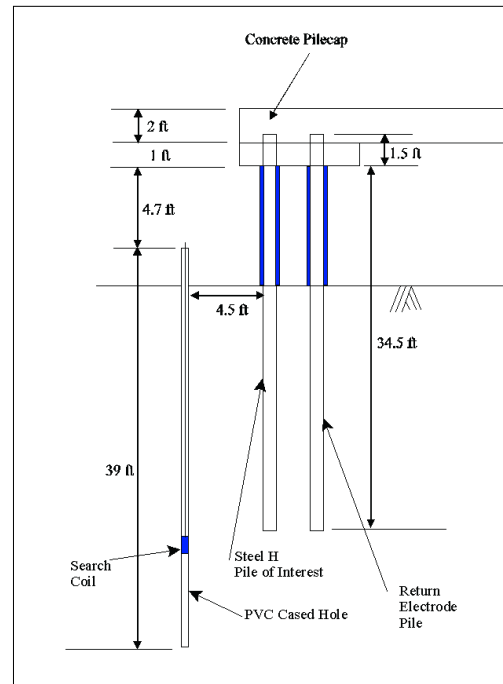
D A T A   R E D U C T I O N

PROCESSING AND INTERPRETATION TECHNIQUES

By plotting the magnitude of the induced voltage versus the depth of the search coil, an indication of the length of the pile is provided. The presence of a ground water-table will somewhat affect the results of this measurement, but as long as the foundation bottom is not at the exact depth of the water-table, this should not be a big factor. Once the search coil is below the bottom of the foundation, the measured induced voltage tends to stabilize at a low value because of background noise and the residual conductivity of the soil or bedrock. A tangent point to the linear portion of the curve is then used to estimate the foundation depth at the inflection point of the change in voltage with depth as shown in the figure at right.
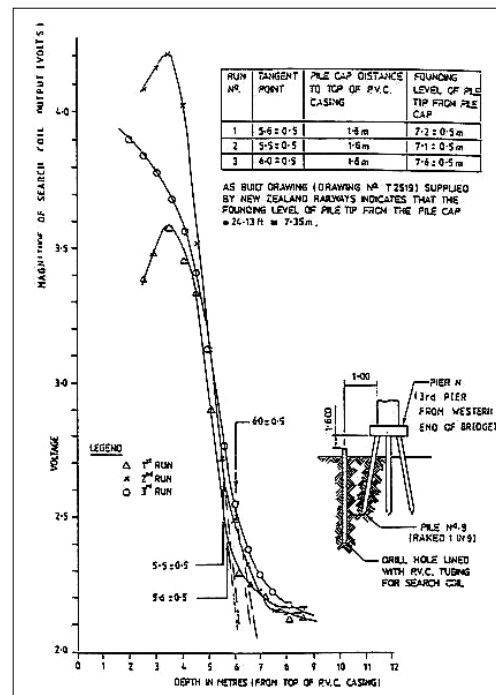
EFFECTIVENESS

Interpretation of the data from the Induction Field method is complicated by the existence of ferrous or other conductive materials in the bridge structure, and can be further complicated by the presence of conductors (such as cables or pipes) or conductive layers in the ground around the pile. Also, these tests can only work for reinforced concrete or steel piles that have electrically connected rebar which is accessible at the ground surface. The boring should be drilled within 0.5 m (1.6 ft) of the foundation and extend about 4 m (13 ft) below the bottom of the foundation. The basic limitation of this method is that the foundation substructure must contain electrically continuous steel for its entire length, and the steel used must be accessible at the top to allow for the electrical connection. Steel and reinforced concrete pile depths can be obtained from this type of survey. However, it is doubtful that the integrity or shape of piles can be discerned. In addition, piles which are not electrically connected to the connection point at the pile top will not be testable unless some other electrical connection can be made to the pile steel directly.

EXAMPLE RESULTS

IF - STEEL H-PILE

The figure to the right shows IF results from investigations performed on a steel H-pile. The IF measurements were performed at intervals of 0.3m (1 ft) using a 3-axis magnetometer to measure the strength of the magnetic field generated around the steel pile produced by an AC current flow through the pile. The current was generated by a function generator operating at a frequency of 5 kHz, and then amplified by an audio power amplifier to provide several amps of total current flow down the pile and through the soil to a reference pile spaced 4-5 m (13-16 ft) away. The depth shown in the figure is the depth from the top of the borehole. The predicted depth was equal to 8.23 m (27 ft). This is the depth at which there was a significant drop in signal amplitude, signifying the tip of the pile. In this case, the top of the borehole was 1.43 m (4.7 ft) below the top of the pile. Thus, the length of the pile is equal to 9.66 m (31.7 ft) with a reference point as the top of the pile. The actual design length of the pile was equal to 10.5 m (34.5 ft). The difference in length between the predicted and design length of the pile was equal to 0.84 m (2.8 ft), a good agreement with a difference of -8%.

Pile tip at 27 ft
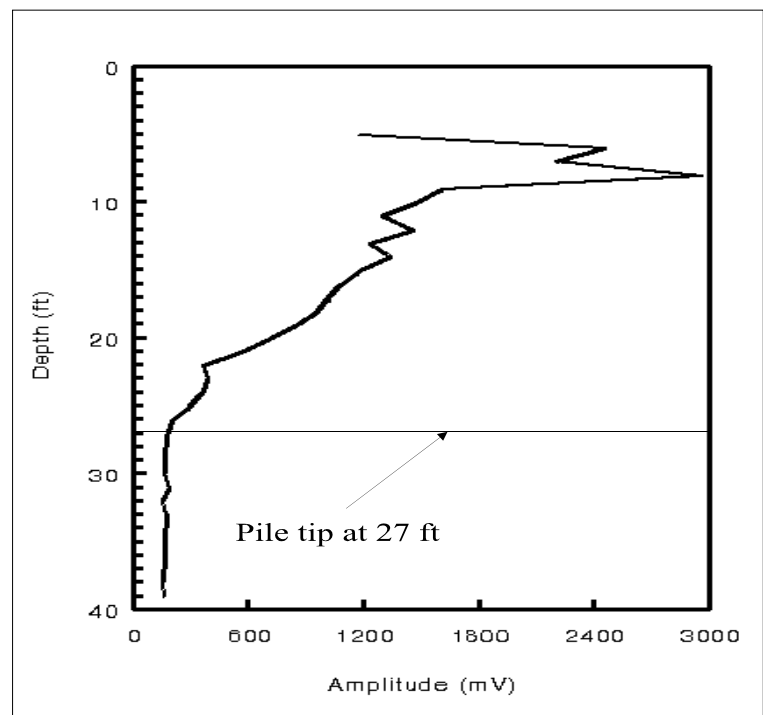
Comments:

Depth shown in figure above is depth below top of borehole

Near-zero amplitude (background noise only) below 27 ft in depth

Bottom depth = 27 ft (reference is top of borehole)

Top of borehole is 4.7 ft below top of pile

Actual pile length = 27 + 4.7 = 31.7 ft (reference is top of pile)

REFERENCES

OLSON ENGINEERING PUBLICATIONS

■ "Unknown Subsurface Bridge Foundation Testing", *Larry D. Olson, P.E. and M. F. Aouad, (2001),* National Cooperative Highway Research Program Transportation Research Board National Research Council.

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