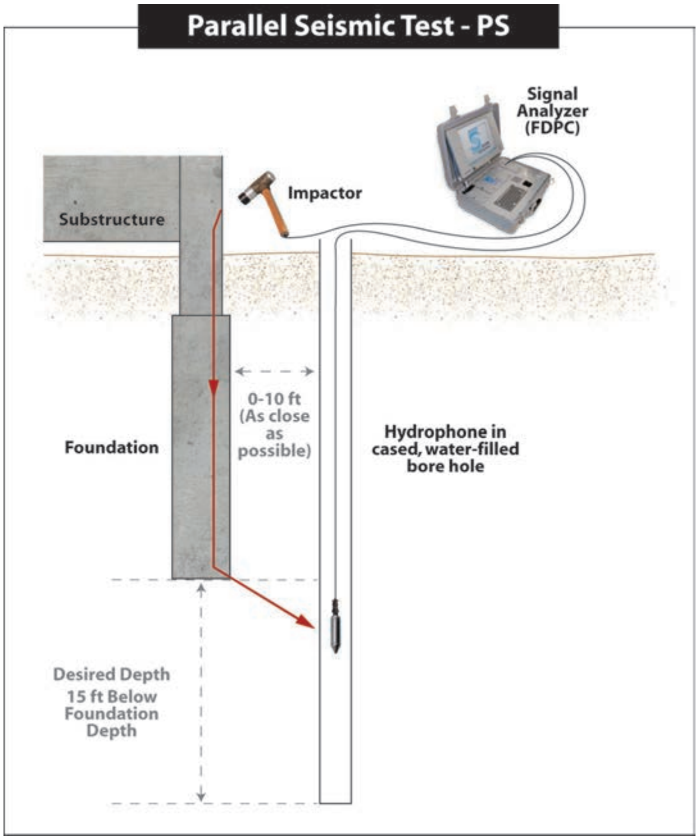
PARALLEL SEISMIC (PS)

METHOD BRIEF

APPLICATION

The **Parallel Seismic (PS)** method is used to determine the lengths of deep foundations when foundation tops are not accessible, or when the piles are too long and slender (such as H piles or driven piles) to be tested by echo techniques. The PS method can also provide information about the soil below the bottom of a foundation.

The PS method involves hitting any part of the test structure that is connected to the foundation (or hitting the foundation itself, if accessible). The resulting compressional and/or shear waves travel down the foundation and are received by a hydrophone or a geophone receiver. The PS method can be performed on concrete, wood, masonry, and steel foundations. The receiver is placed in a cased borehole that has been drilled adjacent to the foundation. In soft soil environments, an alternative to drilling a borehole is to push a seismic piezocone (geophone and hydrophone receivers) into the subsurface with a geotechnical Cone Penetration Test (CPT) rig. This PS/CPT method can simultaneously obtain accurate geotechnical soil property data (tip resistance, sleeve friction, and pore pressure) and unknown bridge foundation depths. Analysis of the PS data is performed in the time domain. In PS investigations, one relies on identifying direct arrival times of compressional and shear waves at the receiver locations, as well as the wave amplitudes. The PS investigation is performed at 1-2 ft vertical receiver intervals in the borehole. The field setup for PS investigations and the PS/CPT system is shown in the schematic at right.



STANDARDS

This method is performed in accordance with ASTM D8381-21 and ACI 228.2R.

** See end of document for full references.*

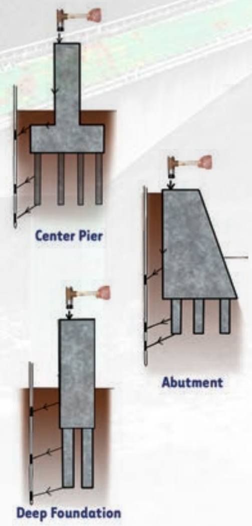
FIELD INVESTIGATION

ACCESS

Either the foundation or some portion of the test structure connected to the foundation must be accessible for the hammer impacts. A borehole is typically required but the test can also be performed with a CPT rig when soft soils are present. Typically a 2-4 inch diameter hole is drilled as close as possible to the foundation (within 5 feet preferred). The CPT rig used for the PS/CPT system allows the probe to be pushed into the soil at locations as close as 5-7 feet from the foundation edge, depending on access conditions. The borehole or CPT Push Depth should extend at least 10 to 15 feet below the expected bottom of the foundation. When a hydrophone is used, the borehole must be cased, capped at the bottom, and filled with water. When a geophone is used, the borehole must usually be cased and grouted to prevent the soil from caving in during testing.

COLLECTION OF DATA

In a PS investigation, the structure is struck by a hammer and the response of the foundation is monitored by a hydrophone or a geophone receiver placed in the borehole or the seismic piezocone placed in the subsurface. The hammer input and the receiver outputs are recorded by an Olson Data Collection Platform equipped with a PS System and stored for further analysis. The receiver is first lowered to the bottom of the hole and a measurement is taken. Then, the receiver is moved up 1 or 2 feet and the second measurement is taken. This process continues until the receiver has reached the top of the borehole. An alternative method is to reverse the data collection from the top of the borehole to the bottom. precise timing and accurate positioning. The data are then automatically processed for identification of thickness echo peaks and signal energy. The identified peaks or energy are processed to calculate thicknesses and the thicknesses are plotted out on a graph of thickness versus location.



PS System

FDPC

NDE 360

DATA REDUCTION

PROCESSING TECHNIQUES

Some geophysical processing techniques can be used to help optimize the Parallel Seismic data. These techniques include Auto Gain Control (AGC) and filtering to enhance weak events. IX Foundation, a seismic analysis and display program, allows the full range of data to be viewed at one time. This improves the ability to identify the bottom of the foundation being investigated.

Hydrophone Data

The time arrival of compressional waves is picked from the data for all receiver locations. A plot of the depth versus arrival time is generated. For uniform soil conditions, two lines are identified in the plot. The slope of the upper line is indicative of the velocity of the tested foundation, and the second line is indicative of the velocity of the soil below the bottom of the foundation. The intersection of the two lines gives the depth of the foundation. For nonuniform soil conditions, the interpretation of Parallel Seismic data can be more difficult due to the nonlinearity of the first time arrival.

Geophone Data

For uniform soil conditions, the geophone data can be interpreted in a similar way as the hydrophone data. When variable soil velocity conditions exist, an alternative to the first arrival time in data interpretation is used. All the traces are stacked and a V-shape is searched for in the data because the bottom of the foundation acts as a strong source of energy (a point diffractor and a reflector), which produces upward and downward traveling waves. When a geophone is used, the borehole is generally not filled with water. As a result, tube waves are minimized so that later arrival of reflected and diffracted shear and compressional waves can be identified.

INTERPRETATION OF DATA

The use of seismic analysis software, such as IX Foundation, allows for the determination of approximate pile length. The diffraction, or change in slope, that occurs in the data as a result of the pile tip acting as a point diffractor and a reflector is shown in the example data set presented in the Example Results section. The software is capable of determining velocity based on the slope of the line and a depth is determined based on where the two lines of the differing slopes intersect.

EFFECTIVENESS

The PS method is more accurate and more versatile than other nondestructive surface techniques for the determination of unknown foundation depths. The accuracy of the method depends on the variability of the velocity of the surrounding soil, as well as the spacing between the borehole and the foundation element. Depths are normally determined to within 5% accuracy or better. A borehole is typically needed for Parallel Seismic tests, which adds to the cost of the investigation (unless borings are also needed for other geotechnical purposes). For soft soil environments, a PS/CPT rig can be used to push a seismic piezocone into the subsurface, thereby eliminating the need for a borehole.

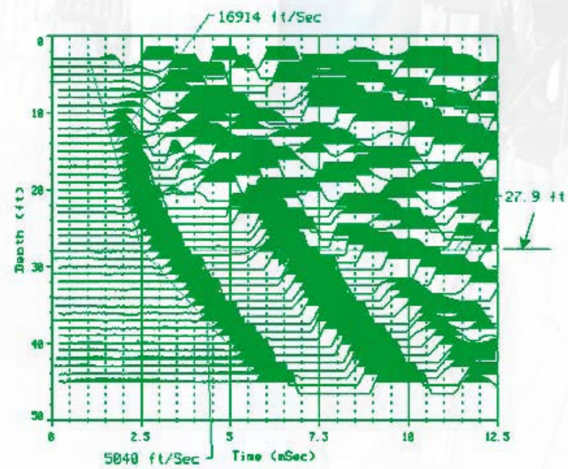
If a borehole is used, it should be within 5 ft of the foundation, which sometimes cannot be achieved due to field constraints. Note that for very uniform soils (such as saturated sands), a successful test can be performed with up to 15-20 feet of spacing between the source and the borehole. As the borehole moves further away from the foundation, the interpretation of the PS data becomes more difficult and the uncertainty in the tip depth determination becomes greater. The PS/CPT system is cannot be used at sites with shallow bedrock, rock, or boulders. Additionally, it cannot be used where piles bear into bedrock. The PS/CPT system is best suited for testing driven piles or other foundations placed into relatively soft soils.

EXAMPLE RESULTS

To illustrate the concepts of the PS method, two example results are presented in the figures below.

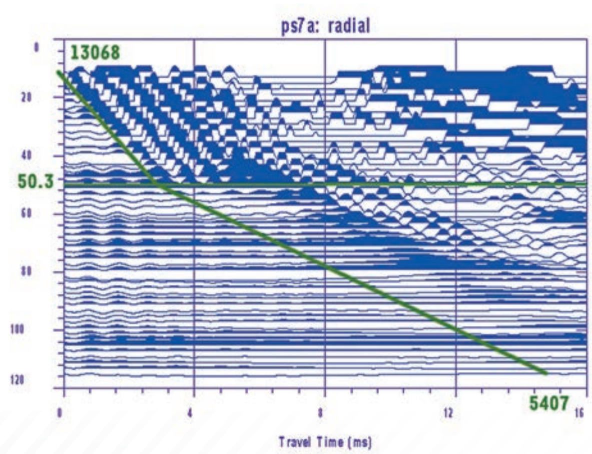
PS – SHEET PILE

The first figure shows PS results from tests performed on a sheet pile in saturated soils. The bottom of the sheet pile is identified at 27.9 ft where the compressional wave velocity changes from 17,000 ft/sec (velocity of steel) to a velocity of 5000 ft/sec (velocity of water). Note the clear PS data due to the favorable surrounding saturated soil conditions. In a case such as this, it is very easy to interpret the PS results.



PS – CONCRETE PILE

The figure to the left shows PS results from tests performed on a concrete pile in saturated soils. The bottom of the concrete pile is identified at 50.3 feet where the compressional wave velocity changes from 13,000 ft/sec (velocity of concrete) to a velocity of 5,400 ft/sec (velocity of water).



REFERENCES

OLSON ENGINEERING PUBLICATIONS

- "Stress Wave NDE Methods for Condition Assessment of the Superstructure and Substructure of Concrete Bridges," Olson, L. D. (2004) TRB 2004 Workshop, 2004.
- "Combined Measurement of Unknown Foundation Depths and Soil Properties with NDE Methods,"Olson, L. D., Sack, D. A., Slaughter, S. H. (2003) Transportation Research Board.

STANDARDS AND GOVERNMENTAL REPORTS

- ASTM D8381/D8381M-21 Standard Test Methods for Measuring the Depth of Deep Foundations by Parallel Seismic Logging
- ACI 228.2R, "Nondestructive Test Methods for Evaluation of Concrete in Structures", ACI Manual of Concrete Practice, Part2, Construction Practices and Inspection, Pavements, ACI International.

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