Pile Integrity Tester Model Comparison – PIT-X, PIT-V and PIT-FV June 2010

The Pile Integrity Tester is available in 3 models, with one (PIT-X and PIT-V) or two (PIT-FV) channels of data acquisition. All models come with a license of PIT-W Standard and a demonstration license of PIT-S.

This discussion is intended to help you select which model to purchase, as well as to decide if you should acquire a license of PIT-W Professional Software (PIT-W Pro) and / or a permanent license of PIT-S.

PIT-X and PIT-V have identical functionality, except PIT-X is much smaller and reads data from a wireless accelerometer, while PIT-V uses a traditional (cabled) accelerometer. It is possible to upgrade a PIT-V to a PIT-FV. Upgrades involve hardware modifications and are performed at Pile Dynamics Inc.

PIT-X (wireless) and PIT-V (traditional)

PIT-X and PIT-V both have **one** data input channel, used to record the **acceleration** measured on the pile. This is sufficient for many, and perhaps most, applications. The analysis of acceleration data is usually performed in the **time domain**.

The PIT-W Standard software is sufficient for most time domain analyses.

The PIT-W Professional software makes it possible to assess the severity of a defect (β-Analysis) from acceleration measurements. PIT-W Pro also estimates the profile (shape) of the foundation from acceleration measurements.

Profile estimates may also be obtained by performing simplified signal matching with the PIT-S software.

It is possible to perform a simple **frequency domain analysis** with PIT-X or PIT-V in the field, by employing the Fast Fourier Transform (FFT) feature which is standard on all PIT models. This analysis may aid in determining foundation depth or distance to a major defect.

PIT-FV

PIT-FV has **two** data input channels. The first input is the **acceleration** measured on the foundation, and is required for all testing. The second input is either from an **instrumented hammer** or from a **second accelerometer**. The second input becomes necessary when additional analyses are required, either by project specification or for technical reasons. These analyses usually require PIT-W Pro:

1) PIT-FV must be used if specifications require that the **Mobility** of the foundation be determined according to the **Transient Response Method**. Mobility may help the detection and location of defects in some situations where velocity alone does not, such as floor slabs or other short thickness members like tunnel liners (although there are minimum thickness restrictions, and the highest possible sampling rate should be selected).

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Mobility is defined as

$$M(f) = \frac{V(f)}{\square} F(f)$$

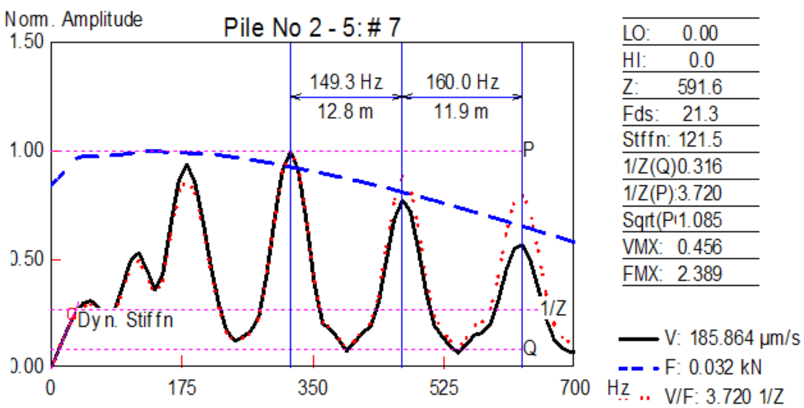

Figure 1: Mobility plot with dynamic stiffness

where $V(f)$ is the velocity at a frequency f and $F(f)$ is the force at a frequency f.

The calculation of mobility requires an **instrumented hammer** to measure the force signal in addition to the velocity signal. The Transient Response Analysis is performed with PIT-W Pro. Figure 1 shows the Mobility plot from PIT-W Pro. The pile length may be determined from the frequency intervals of the peak mobility values as in Figure 1; PDI suggests, however, checking the frequency based results with the standard time domain approach.

2) PIT-FV with an **instrumented hammer** must be used if it is necessary to calculate the **Dynamic Stiffness**, Z(fo).

Dynamic Stiffness is defined as

$$Z(fo) = \frac{F(fo)}{\frac{V(fo)}{2\pi fo}} = \frac{\left(\frac{F(fo)}{V(fo)}\right)}{2\pi fo} = \frac{2\pi fo}{M(fo)}$$

$\frac{V(fo)}{2\pi f0}$ is the displacement (velocity divided by frequency) at a low frequency fo; Z(fo) is a pseudostatic stiffness. By comparing the stiffness of various shafts, it is possible to single out the one with the lowest stiffness. This is the weakest shaft, and therefore might have a defect.

3) PIT-FV with an **instrumented hammer** must be used to check the **integrity of a foundation near the**

top. This application does not require PIT-W Pro. In this application one compares the velocity pulse width with the force pulse width. In intact foundations the force – time pulse is typically wider than the velocity - time pulse. If the velocity pulse is wider (as in Figure 2 top) then this may indicate an impedance reduction close to the pile top which is not easily detected when only the velocity pulse is measured (since the reflection superimposes on the input, making the apparent velocity longer). This procedure may help detect defects at depths smaller than the pulse width. Upper portion defect detection may also be achieved by comparing the velocity pulse widths on all tested shafts. Because a given hammer has a nominal pulse

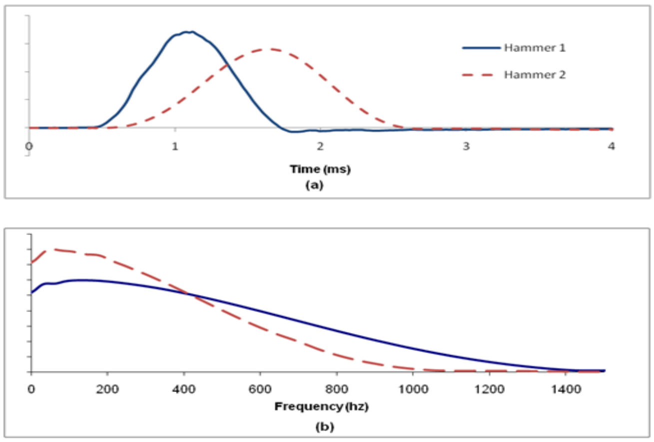

Figure 2: Force and velocity pulse vs time (top) and vs frequency (bottom)

width, shafts with unusually wide velocity pulse widths are likely to have defects near the top.

4) PIT-FV with a **second accelerometer** must be used to measure two velocities separated along the shaft by some known distance. This is useful in the case of **piles under existing structures**, where it is necessary to separate downwards from upwards reflections (Figure 3). The two velocity measurements are further analyzed by PIT-W Pro.

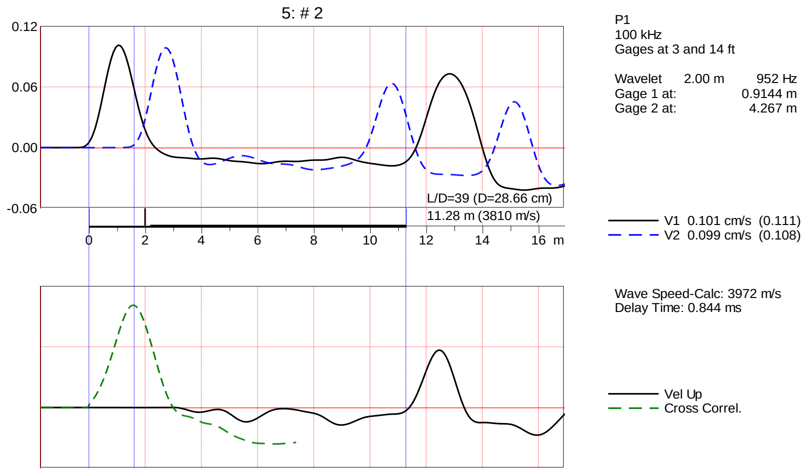

Figure 3 top: Two velocity measurements taken with two accelerometers at two vertically separated locations on a pile.
Figure 3 bottom: wave up velocity component (solid) calculated for the upper accelerometer location from both accelerometer measurements.

5) PIT-FV with a **second accelerometer** is necessary to determine to determine the **length of existing foundations** with accuracy better than plus or minus 10%. This is accomplished by accurately determining wave speed from the analysis, with PIT-W Pro, of two velocity measurements Note that it is possible to perform frequency domain analysis with PIT-FV in the field, by employing the Fast Fourier Transform (FFT) feature which is standard on current PIT-FV models. This analysis may aid in determining foundation depth.

6) PIT-FV with an **instrumented hammer** is recommended to evaluate the integrity of **floor slabs, bridge decks**, columns or other structural components. In this case the hammer impact generates a stress wave that arrives at a second accelerometer, allowing for the calculation of the wave speed. The value of the wave speed is typically affected if the structural element is deficient. The hammer frequency spectrum (obtained by converting the force pulse to a frequency spectrum by Fourier analysis) shows the maximum frequency, max f, and therefore the shortest pile length or slab thickness, min t, that can be tested for the given wave speed c of the material of the structure.:

$$min\ t = \frac{c}{2} max\ f$$

Dynamic Stiffness and Mobility determination would be as useful in this case as in the case of tests on piles by the Transient Response Method.

7) PIT-FV with a **second acceleromete**r permits the elimination of Rayleigh wave components from the PIT records of **relatively large piles**. To accomplish this record enhancement, both vertical and horizontal accelerations have to be measured at the pile top surface at the same location. Subtracting the scaled horizontal motion component from the vertical one reduces the vertical top motion to that corresponding to the compressive axial wave. Figure 4 shows that a remarkable improvement of data quality can be achieved in this manner.

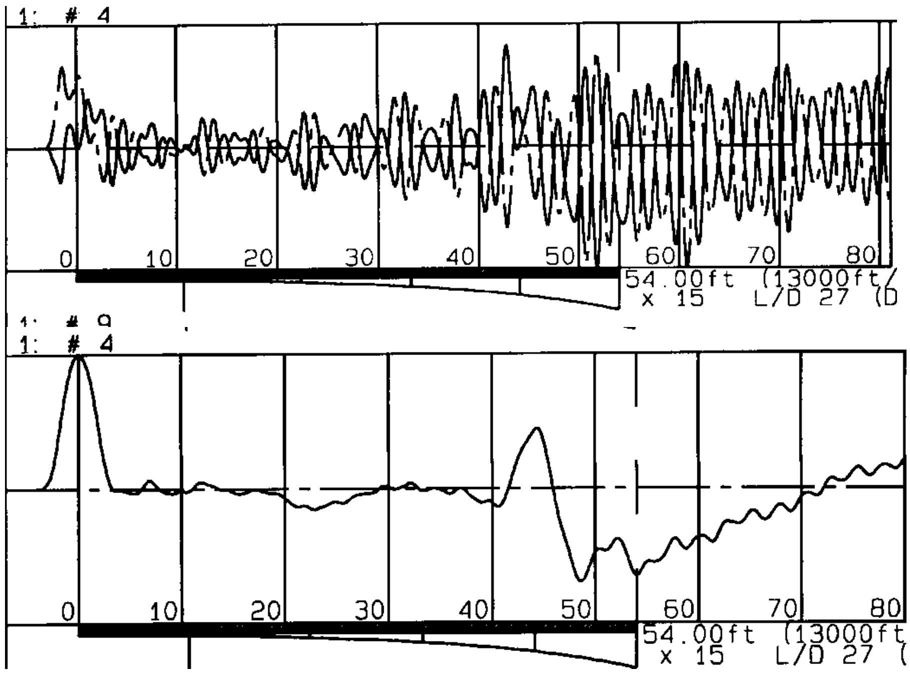

Figure 4 top: Vertical (Dash-dot) and horizontal (solid) pile top velocity measurements reduced to axial motion signal by Raleigh wave analysis.