**TESTING PROCEDURE**

This testing requires the attachment of the highly sensitive accelerometer to the pile top with viscous material. Accelerometer is connected to PIT Collector - computer with special purpose signal conditioning and A/D converter. After hammer impact downward compressive wave is generated traveling with wave speed "c". When this initial wave encounters a cross section change or concrete quality change at depth x, it generates an upward traveling wave which is observed at the pile top at a time equal to twice the distance of the cross section change from the top divided by the wave speed c (2x/c). The rest of the initial wave travels down to the pile toe and reflects. It is observed at the pile toe at time twice the pile length divided by wave speed (2L/C, L= pile length). Reductions in pile cross and concrete quality section generate tension upward traveling waves, while soil resistance and bigger pile cross section generates compression upward traveling waves.

From the known pile length and material the expected arrival time of pile toe reflect could be calculated. If the positive reflection is observed prior to the expected toe reflect time, the approximate defect location can be estimated from the assumed wave speed. The size of the defect can be estimated from the magnitude of the early reflection. Pile top velocity (integration of measured acceleration) for each hammer impact is recorded.

It is possible to perform fast Fourier analyze on time domain record to obtain frequency domain response, on which it is also possible to interpret pile cross section changes and pile concrete quality.

With PIT measurements it is possible to perform pile integrity control on bored and nearly all cast in place piles and driven concrete piles.

Piles with greatly varying cross-sectional areas may make it difficult to distinguish between reflections from significant discontinuities and those caused by the construction method. However, if large numbers of piles are tested, it is generally easy to spot the piles heaving unusual responses. Suspected piles can be subjected to further tests as wave analysis, borings etc.

**Limitations:**

L/D ratio \( \leq 30 \) (L=pile length, D = pile diameter)

Cracks – it is impossible to detect pile under the crack

**Pile preparation before test:**

All bad concrete from pile head should be removed, pile head should be clean and without cracks for successive test.

**TABLE 1: Table of possible pile states**
<table>
<thead>
<tr>
<th>No.</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No impedance changes detected, pile toe detected (pile OK)</td>
</tr>
<tr>
<td>2</td>
<td>Small pile impedance changes, pile toe detected (pile OK)</td>
</tr>
<tr>
<td>3</td>
<td>Large pile impedance change - reduction in cross section area, pile toe not detected / possible pile damage, pile damage/</td>
</tr>
<tr>
<td>4</td>
<td>Pile condition could not be stated (reasons: pile toe not detected, large and more impedance changes, bad concrete on pile top (BTC), cracks on pile top,)</td>
</tr>
</tbody>
</table>

**REMARKS:**

Impedance is defined with \( Z = \frac{EA}{c} \), where \( E \) is elastic modulus, \( A \) is cross section area and \( c \) wave speed.

- \(^*1\) results in range of typical response with differences up to \( c < 5\% \) and \( v(t) < 5\% \) of incident wave
- \(^*2\) results in range of typical response with differences up to \( c < 10\% \) and \( v(t) < 20\% \)
- \(^*3\) large impedance reduction detected

**TABLE 2: Concrete quality in relationship with impact wave velocity**

<table>
<thead>
<tr>
<th>Concrete quality</th>
<th>Impact wave speed in concrete (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>bad</td>
<td>&lt; 2700</td>
</tr>
<tr>
<td>acceptable</td>
<td>2700 – 3300</td>
</tr>
<tr>
<td>good</td>
<td>3300 – 3800</td>
</tr>
<tr>
<td>very good</td>
<td>3800 - 4000</td>
</tr>
<tr>
<td>excellent</td>
<td>4000 - 4200</td>
</tr>
<tr>
<td>not possible in normal conditions</td>
<td>&gt;4200</td>
</tr>
</tbody>
</table>

_S.PESSIKI & M.JONSON:_

![Graph showing the relationship between prepared cylinder strength and impact wave velocity](image)
MEASUREMENTS AND ANALYSIS RESULTS

Method and testing procedure is standardized with ASTM D-5882-00 “Standard test Method for Low-Strain Integrity Testing of Piles”.

Pile Integrity results are presented on table and graph. Table data for each pile:

- Pile Name
- Date Collected
- Pile Length—as reported on site
- Wave Speed—defined from reported pile length
- Magnification—exponential graph magnification
- Comments—from table of possible pile states

For each tested pile v(t) graph is presented. Below is basic v(t) graph explanation:

Comments in v(t) graphs:

+Z  — Impedance increase or pile cross section increase
-Z  — Impedance decrease or pile cross section decrease
BTC — Bad concrete on pile top
SR — Soil resistance
Toe — Pile Toe

Remarks 1:
Impedance is defined with $Z = \frac{EA}{c}$, where $E$ is elastic modulus, $A$ is cross section area and $c$ wave speed. Wave speed higher than 4100 m/s, defined from known pile length, could be result of pile toe damage or shorter pile.

Remarks 2:
Results of PIT measurements on piles over foundations constructions are not interpretable. Reasons could be:
- bad connection between foundation construction and pile head (bad concrete on the pile head)
- more sequenced variables in Impedance ($Z$) in pile lenght

Remarks 3:
Testing piles must be prepared for PIT test as follow:
- bad concrete on the top (head) of pile has to be removed and pile head must be cleaned and without cacks
- piles head should be accessible and above the water level

Limitations: L/D ratio $\leq$ 30 (L=pile length, D = pile diameter)
Cracks – it is impossible to detect pile under the crack
EQUIPMENT FOR PILE INTEGRITY TEST-PIT

DATA COLLECTOR Model PIT-FV; Ser. No.: 2777C
ACCELEROMETER; Ser.No.: 18839; Calibration Factor: 18.4 g/V
INSTRUMENTED HAND HAMMER; Ser.No.: 26321; Calibration Factor: 1175 g/V