THE APPLICATION OF QNDE TO THE TEST OF PILES

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INTRODUCTION

At present, piles are used in most of the high buildings as their foundations. Almost all bridges are supported on piles. Anything wrong with the underground piles will destroy the buildings. The test of piles, therefore, is very necessary. One of the ordinary pile tests is static-load-applying test, i.e. putting a heavy load on pile to observe its descent. Another method is drilling a hole and taking core for checking the integrity of piles.

All these tests take lots of work and time. It costs 3-6 days or more to test a single pile. Various dynamic tests invented in recent years are with either huge equipment or low accuracy. The hydroelectric effect QNDE test we invented has the advantage of detecting the defects and calculating the bearing capacity of piles in a few munities with simple equipment, and it can give the P-S curves if necessary. There have been about a hundred units in China using the technique.

THE PRINCIPLE OF THE HYDROELECTRIC EFFECT TEST

The principle of the hydroelectric effect test is as follows:

The capacitor is charged by the high voltage D.C transformed from a power network (see Fig. 1), and is discharged instantaneously in water through a switch when all is ready. This generates a very high pressure in water vibrating the pile.

Discharging in water can generate very large power to vibrate the pile because of the small loop impedance. The vibration of pile is received by hydrophone and recorded by the data recorder. The disturbances decrease greatly for there are only longitudinal waves in water. The maximum current in discharging is

\[ I_m = \frac{U_e}{\omega_0 L} \exp \left[ -\frac{R}{2L} \cdot \frac{1}{\omega_0 \sqrt{1 - \alpha^2}} \cdot \tan^{-1}(\sqrt{1 - \alpha^2}/\alpha) \right] \]  

(1)
The principle of the hydroelectric effect test.

\[ \alpha = \frac{1}{2} R \sqrt{C/L} \]

where \( \alpha \) = charging voltage
\( C \) = capacity of capacitor
\( L \) = loop inductance

\[ \omega_0 = \sqrt{L/C} \]

The pressure generated in discharging is

\[ P = 10^{-3.1} \left( \frac{CU^6}{r L^2} \right)^{1/5} \]  

where \( r \) is distance form the electrode to the testing point.

For example the pile diameter \( d = 0.6 \text{m} \), the total force applying to the pile top is

<table>
<thead>
<tr>
<th>U(kv)</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(ton)</td>
<td>65</td>
<td>80</td>
<td>97.2</td>
<td>114</td>
</tr>
</tbody>
</table>

By discharging on pile top at different voltage we can obtain different displacements and dynamic rigidity, and draw P-S curve to determine the bearing capacity.

THE MAJOR METHODS OF PILE QNDE

Previously, the way stress-waves propagates in piles is analyzed mainly in time field. When the stress-wave meets, the diameter changes, it will be reflected back due to a different impedance, and the position of defects can be determined from stress-wave propagation times.

The impedance of pile:

\[ Z_1 = \rho_1 C_1 A_1 \]
The impedance in the place where defects exist:

\[ Z_2 = \rho_2 c_2 A_2 \]

According to reflection law, the reflection coefficient is

\[ \beta = \frac{Z_2 - Z_1}{Z_1 + Z_2} \] (4)

Some figures of wave shape and frequency spectrum are shown in Fig. 2.

Normally, the defects condition can be seen by the two method. But the defects position can’t be determined exactly from the transient wave shape, for "the reverberation" often appears due to the shorter pile length than wave length. For example, the transient wave shape and frequency spectrum from a 15 meters long pile with at least two defects is shown in Fig. 3.

Fig. 2. Schematic diagram of stress-wave in piles.

Fig. 3. Transient wave shape and amplitude spectrum of a pile.
From the peak value of the spectrum the position of defects can be determined quite accurately, and the diameter change can be calculated also. But in the frequency spectrum in Fig. 3 harmonics exist. This means not every peak is corresponding with defects, thus it's necessary to draw the autocorrelation or cepstrum. The cepstrum is a function of the frequency spectrum, with can eliminate harmonics, take out the basic frequency and thus has strong reflection at defects. It definition is

$$G_x(\tau) = \left| \int -\infty \log G_{xx}(f) \cdot \exp(-2\pi f \tau) df \right|^2$$

(5)

It can be seen from Fig. 4, the strong reflection in pile bottom is at 7.23ms, and the stress-wave velocity $C = 2l/\Delta t \approx 4149$ m/sec. Besides there are defects at 11m and shallow part.

APPLICATION OF THE MODEL IDENTIFICATION

It is required not only to find the position of defects but also to know the physical parameters of all parts of a pile. The model identification is a method by which the frequency spectrum or transient wave shape is resolved into several vibration units, and the model parameters and physical parameters are given. It's a subject developed in recent years.

Let's see how a multi-vibrating system gives complicated frequency spectrum. See Fig. 5. The transfer function of multi-freedom is [3]

$$H_{ip}(\omega) = \frac{\sum_{i=1}^{N} \Psi_{ii} \cdot \Psi_{ii}}{K_{ii} \left(1 - \omega_i^2\right)^2 + ig}$$

(6)

where $\bar{\omega} = \omega/\omega_n$, $g = 2C_c \bar{\omega}$

$\omega$ is exciting frequency, $\omega_n$ is inherent frequency, $C_c$ is critical damping $C_c = 2m\omega n$. $C$ is damping coefficient, $\Psi$ is model vibration shape of each order.

It can be seen from equation (7) that composite vibration is the superposition of several simple vibration.
There are many methods of model parameter identification, such as component analysis, vector analysis and klosterman method, etc. The general way of them is to resolve the frequency spectrum into several simple free vibration, fit them with "the least squares" method, and finally calculate the mass M, damping coefficient C₁ and resonant frequency F₁ of each unit. All these can be accomplished in special signal processors now. For example, the above wave shape in processed by Japan CF--940, and the results obtained are shown in Fig. 6.

It can be seen in Fig. 6, the highest peak is at 137.73 Hz, but with very large damping. There are also several other peaks at 469.02 Hz and 705.39 Hz, etc. The parameters of each part can be calculated from model parameters.

For example, the model mass \( M_r = \frac{K_r}{\omega_r^2} \), and damping and rigidity are known, so the physical parameters of every sections can be calculated.

REFERENCES