A Measuring Method for Shear Wave Velocity of Marine Sediment Using
Radiation Impedance

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Abstract: In this study, it is derived numerically that the shear wave velocity of the visco-elastic media such as marine sediments can be obtained from the frequency at which the radiation reactance becomes zero. Next, the radiation impedance for dry and water saturated beach sands were measured using two different-sized vibrating plates, and the shear wave velocities of these sands were gotten from the frequency. It is shown that the shear wave velocity obtained from the measured result using smaller plate is slower than the shear wave velocity from that using larger plate.

RADIA~ON IMPEDANCE

Radiation impedance of a circular vibrating plate with the radius of $a$ on the surface of visco-elastic media is expressed as

$$ z_r = r_r + jx_r = \frac{4\alpha\mu}{j\omega(1-\sigma)} \int_0^{\infty} \theta(t) dt. $$

(1)

where, $r_r$ is radiation resistance, $x_r$ is radiation reactance, $\sigma$ is Poisson's ratio, $\mu$ is shear modulus, $\omega$ is angular frequency. And $\theta(t)$ is the function which satisfies the second kind of Fredholm integral equation. The above equation can be solved numerically. The calculated normalized radiation reactance $x_{r_0}(= x_r / z_0$, $z_0$: acoustic characteristic impedance) versus $k_\lambda a (k_\lambda = \omega / c_\lambda$, $c_\lambda$: longitudinal wave velocity) is shown in Fig.1. In Fig.1, $\lambda$ and $\mu$ are Lame's constants. The relationship between $k_\lambda a$ at which the radiating reactance becomes zero and $\mu / (\lambda + 2\mu)$, derived from Fig.1, is shown in Fig.2. From Fig.2, it is seen that the value of $k_\lambda a$ at which the radiation reactance becomes zero is proportional to the value of $\sqrt{\mu / (\lambda + 2\mu)}$. Therefore, the next equation can be obtained as

$$ c_r = \frac{2\pi a}{2.5} f \Big|_{x_r = 0}. $$

(2)

The above equation shows that the shear wave velocity can be obtained from the measured value of the frequency at which the radiation reactance becomes zero.

FIGURE 1. Calculated normalized radiation reactance versus $k_\lambda a$.

FIGURE 2. $k_\lambda a \Big|_{x_r = 0}$ versus $\mu / (\lambda + 2\mu)$.
TABLE 1. Measured values of the frequency at which
the radiation reactance becomes zero.

<table>
<thead>
<tr>
<th>Radius ( a ) (mm)</th>
<th>16</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry ( f_{x=0} ) (Hz)</td>
<td>1163</td>
<td>463</td>
</tr>
<tr>
<td>Water saturated ( f_{x=0} ) (Hz)</td>
<td>877</td>
<td>315</td>
</tr>
</tbody>
</table>

TABLE 2. Determined values of shear wave velocities.

<table>
<thead>
<tr>
<th>Radius ( a ) (mm)</th>
<th>16</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry ( C_s ) (m/s)</td>
<td>47</td>
<td>58</td>
</tr>
<tr>
<td>Water saturated ( C_s ) (m/s)</td>
<td>35</td>
<td>40</td>
</tr>
</tbody>
</table>

FIGURE 3. Measured radiation reactance for
dry sand.

FIGURE 4. Measured radiation reactance for
water saturated sand.

MEASUREMENTS OF SHEAR WAVE VELOCITY USING RADIATION REACTANCE

The beach sand with the mean grain size of 0.19mm was used for the experiments. Dry and water saturated sands were contained in vessels with the size of 900x900x300mm. Two circular vibrating plates with the radius of 16mm and 50mm were used. The radiation reactance is obtained from the measured values of the force and the acceleration of the plate. The measured results of the radiation reactance are shown in Fig.3 for dry sand and Fig.4 for water saturated sand. Frequencies at which the radiation reactance becomes zero, are shown in Table 1. And the shear wave velocities obtained from these frequencies using Eq.(2) are shown in Table 2. From Table 2, it is seen that the shear wave velocity in dry sand is faster than that in water saturated sand. Moreover, the shear wave velocity using 16mm plate is slower than that using 50mm plate. It is considered that this fact is due to the depth dependence of shear wave velocity in sand.

CONCLUSIONS

Numerical analyses for radiation impedance of a circular vibrating plate on the surface of visco-elastic media such as marine sediments show that the shear wave velocity can be obtained from the frequency at which the radiation reactance becomes zero. Next, the shear wave velocities of dry and water saturated beach sands were obtained by measuring the radiation impedance. It is seen that the shear wave velocity by smaller plate measurement is slower than that by larger plate measurement. This fact shows the possibility of the measurements of the depth dependence of shear wave velocity in marine sediments.

REFERENCES