# DETECTION OF UNDERGROUND WATER LEVEL BEHIND A RETAINING WALL USING VIBRATION-BASED IDENTIFICATION

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## 1. Introduction

It is well known that in free vibration, structures vibrate at inherent frequencies and patterns, if their conditions do not change with time. In other words, modal parameters will change with altered structure condition. This concept has been widely used in the Structural Health Monitoring field to assess damages in civil structures. Theoretically, this concept can also be used to detect underground water level behind a retaining wall. For a structure that includes soil and a retaining wall, the existence of water in soil means that the structure condition of the system is changed and therefore will be reflected in its vibration behavior. In this research, the relation between vibration modal parameters to water existence is discussed so that we can detect underground water level behind retaining walls using vibration measurement.

## 2. Experimental Outline

To verify the effect of water existence to vibration characteristics in a soil-wall system, an indoor experiment was built. An acrylic box with the size of 350 x 200 x 300 (mm3) x 10 (mm) is used to represent the wall. And the soil is represented by Toyoura sand. Combination between the box, sand, and water creates a wall model system. The system was excited by excitation equipments and the vibration velocity of one plane side of the box was measured by 2 lasers synchronously. The data was then processed and analyzed using Natural Excitation Technique and Eigensystem Realization System [1] method to get vibration mode frequency and its mode shapes. There were two measurement cases:

1. box filled with water only,
2. 2. full sand box (Dr=50%) with water until some level.

In each case, water level was set at 0%, 25%, 50%, 75% level cases to assess the sensitivity of modal parameters, especially mode shape, to the water level change.

## 3. Experimental Results

First, vibration measurement is done to the whole 2-D plane as in fig.5, 6 and then concentrated in the middle vertical part of the measured plane. The result of vertical measurement for case 1 when no sand involved is shown in fig.1. First we can see a natural frequency drop due to the mass addition of water. We can also observe the clear trend in mode shape curvature change. But

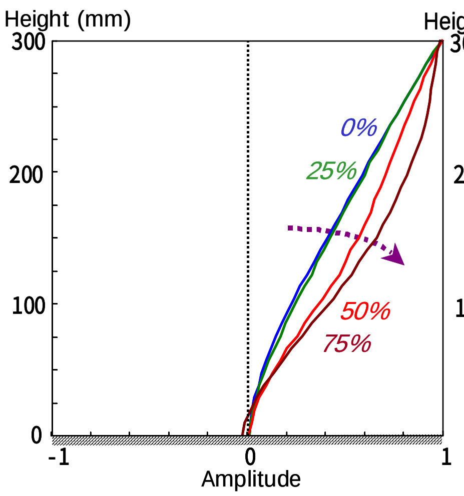

Fig.1 Case 1 mode shape

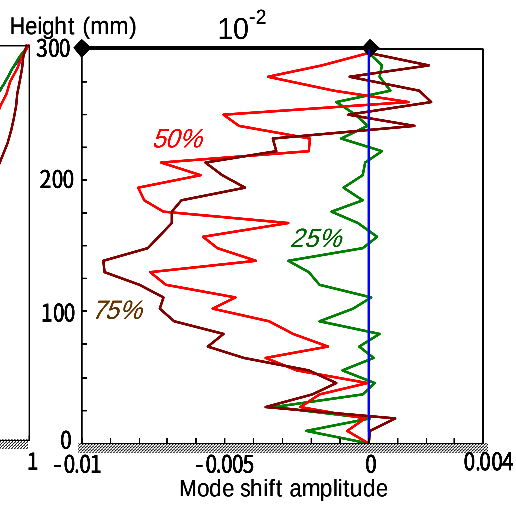

Fig.2 Case 2 mode SHIFT

when sand is filled into the box, the system becomes heavy and the water contribution to the system dynamic parameter is much smaller than before, thus creates a small mode frequency shift and a very small mode shape change. But, when we calculated the “mode shift” by subtracting each mode shape to the reference mode (0%) then we can see the

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curvature change trend between each case (fig.2).

## 4. Modeling

To assure the effect of water to the dynamic parameter of the wall as in experimental results, geometrical models of each case was built by FEM. The model construction was decided by 2-D mode shape of each case. From 2-D mode shape of 1st case (fig.5), it is clear that this is a first mode of 3-fixed 1-free boundary rectangular plate. To simplify the geometry model, the 2-D plane was divided into horizontal and vertical 1-D bars. Then the horizontal bar effects to the vertical one was replaced by equivalent springs (fig.7). Water existence was represented by addition of bar mass density. The addition value is fitted from 75% water level experimental result and we can see the analysis result for other cases (fig.3). In the 2nd case when sand is inside the box, the box behaves in shear as seen in its 2-D mode shape (fig. 6). Therefore, for case 2, the box is assumed as a 1-D short beam and Timoshenko beam theory was applied to include shear deformation. The result of the analysis can be seen in fig.4. Material and geometry property of the beam is averaged from the property of box and sand.

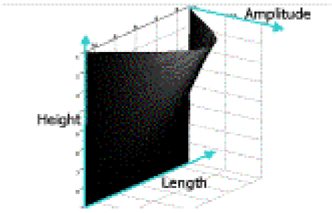



Fig.5 Case 1 (2-D)

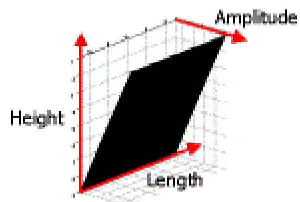



Fig.6 Case 2 (2-D)

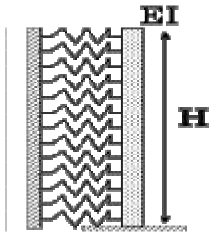



Fig.7 Case 1 model

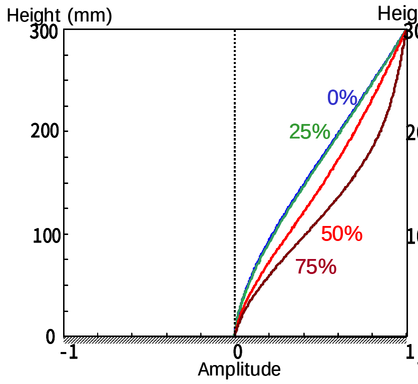



Fig.3 Case 1 analysis

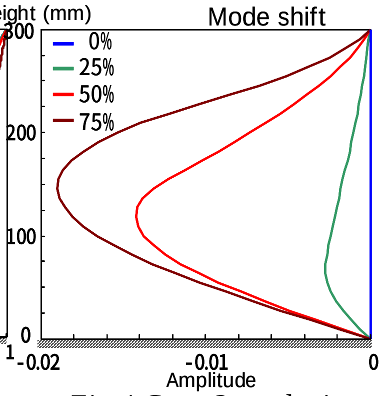
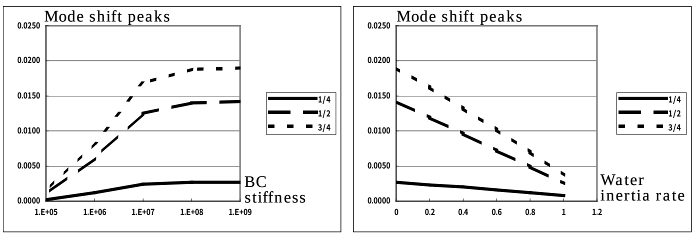



Fig.4 Case 2 analysis

In case 2, although measurement and analysis result showed similar trend in the mode shift, the shift peak of analysis was twice of measurement. This may be due to some uncertainties in analysis such as: inertia of water in soil-water dynamics [2], boundary-fixing rate (stiffness of boundary) etc. Parametric study was performed to investigate the effect of these uncertainties as shown in fig.8. The result shows that although the absolute value of the mode shift peaks in each water level case changed due to the uncertainties, the relative position between peaks in each water level case did not change. From this result, it can be confirmed that the mode shift rate in the measurement result was indeed affected by the water level.




## 5. Conclusion

From the measurement and analysis, it can be concluded that water existence is reflected in the wall mode shapes and by comparing relative peak value between mode shifts of each case we can estimate the water level change.

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