# Experimental Study on Kinematic Response of Soil-Pile-Superstructure System

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## 1. INTRODUCTION

When external forces acts on structures either through soil or directly to structures, the response of structure influences the motion of soil and pile and the motion of soil and pile influences the response of structure simultaneously. Neither the structural response nor the ground motions are independent of each other. This dependent process is referred to as soil-pile-structure interaction (SPSI).

The total mechanism of soil-structure-foundation interaction can be grouped into, a) inertial interaction and b) kinematic interaction. *Inertial Interaction*: Inertia developed in the structure due to its own vibrations gives rise to base to base shear and moment, which in turn cause displacements of the foundation relative to the free-field. *Kinematic Interaction*: The presence of stiff foundation elements on or in soil cause foundation motions to deviate from free-field motions as a result of ground motion in coherence, wave inclination, or foundation embedment. Kinematic effects are described by a frequency dependent transfer function relating the free field motion to the motion that would occur on the base slab if the slab and structure were massless.

It is evident that the behavior of soil-pile-structure system cannot be predicted by considering their individual response separately. That is why the importance of accounting for SPSI has received large attention in recent years. Contributors in SPSI research consider soil as an elastic material, which cannot be appropriate assumption in all conditions recognizing the fact that, the soil behavior is strain dependent and under strong excitation soil shows nonlinear behavior. Tazoh and Shimizu [1] proposed method for response analysis of pile foundation structure system considering nonlinear behavior of ground. This present experimental study considers the effect of site nonlinearity of soil to the kinematic response of soil-pile-superstructure system.

## 2. EXPERIMENTAL SETUP

Model test approach based on similitude theory presented by Kokusho and Iwatate [2] was applied for dynamic testing using shaking table owned by Saitama University. Geometric scaling factor adopted as 0.05, i.e. the model is 20 times smaller than the prototype and the density scaling factor adopted as 0.81.

Nine solid acrylic piles with diameter of 40 mm and length of 900 mm each, capped by a solid acrylic pile-cap of dimensions 280 mm x 280 mm x 100mm will be used to form a 3x3 pile group separated by a spacing to the diameter ratio (s/d) of 2.5. The size of the superstructure is 260 mm x 320 mm x 65 mm and the weight is 50 kg. The fundamental natural frequency of the superstructure is 14.7 Hz and the corresponding damping associated with it is 5.7 %.

The size of the table is 1800 x 1800 square millimeters and the capacity of the shaking table is 5 (t-G) in full load and has maximum of ±200 mm in stroke. The table operating frequency range is 1~100 Hz. The laminar shear box used to fit the model, has inner dimension of 1200 mm x 800 mm x 1000 mm.

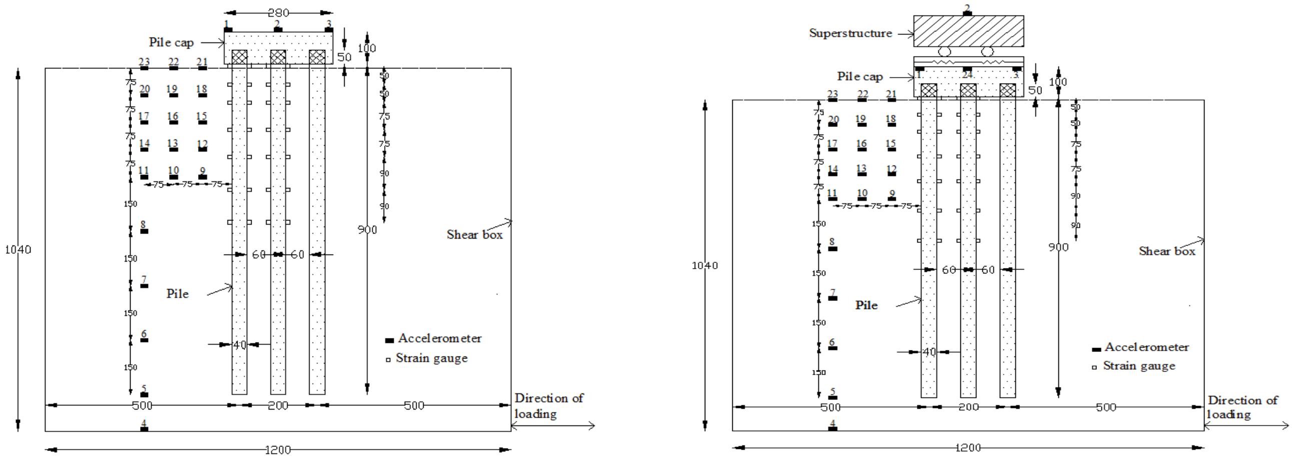


**Fig.1** Schematic diagram of experimental setup.

Non cohesive dry Gifu sand was used in experiments to make the soil body. There was no contact between the base of the pile cap and soil to erase any probability of resistance by soil friction. Sand was glued to the acrylic piles to prevent the slippage between piles and soil.

Keywords: Soil-pile-structure Interaction, Kinematic Interaction, Site nonlinearity
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## 3. RESULT AND DISCUSSION:

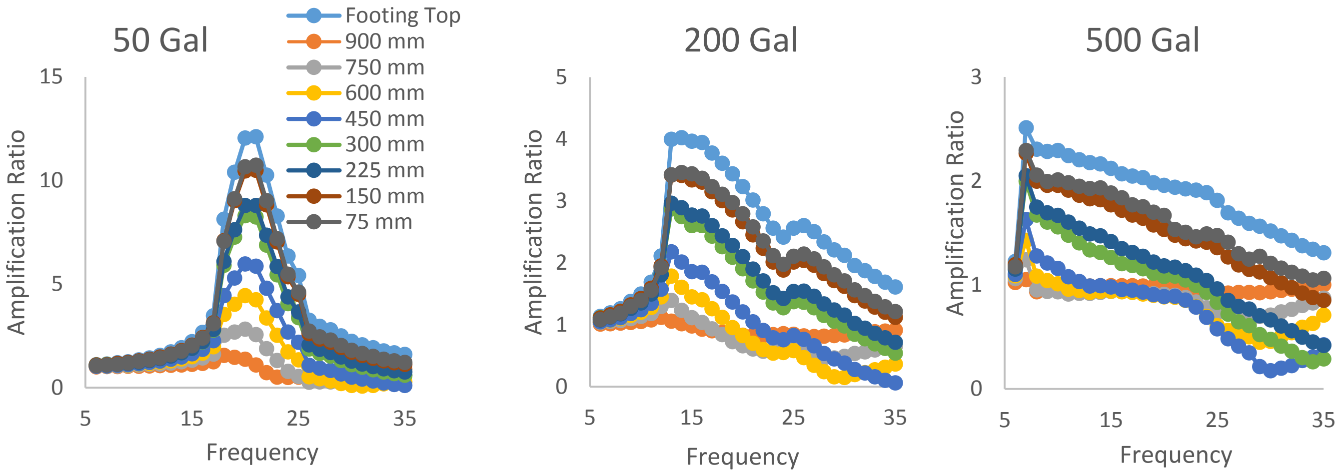


**Fig 2.** Amplification of input ground motion at different soil depth and footing top.

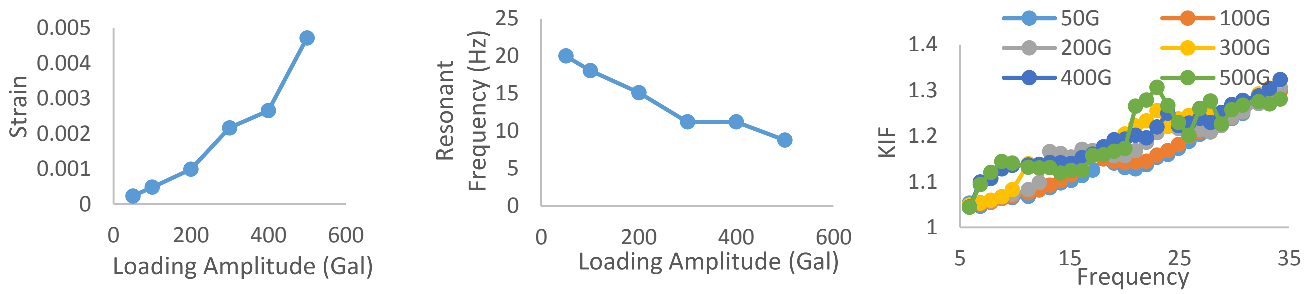


**Fig 3.** Soil strain level, Resonant frequency of the system and Kinematic interaction factor.

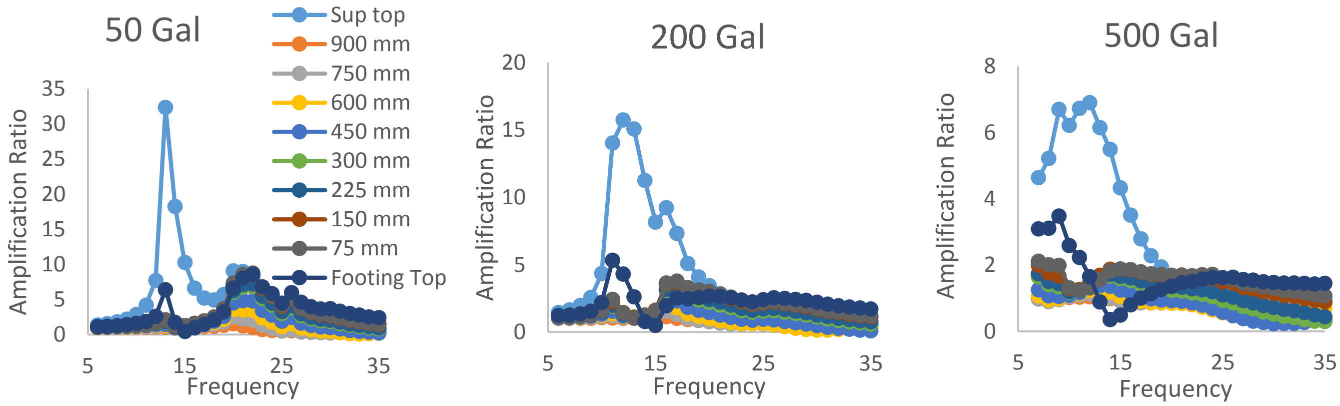


**Fig 4**: Amplification of input ground motion at different soil depth, footing top & superstructure top.

Figure 2 shows the kinematic response of soil and footing obtained in the form of amplification ratio between base and different soil level & top of footing for 50 Gal, 200 Gal and 500 Gal of loading amplitudes. Figure 3 shows the increase in the mean shear strain in soil and decrease in resonant frequency with the increasing loading amplitude and the kinematic interaction factor of the SPSI system. The amplitudes of strain in soil suggest site nonlinearity induced in soil by higher input motions. Figure 4 shows the response of ground, footing and superstructure for the loading amplitude of 50 Gal, 200 Gal and 500 Gal. It has been seen from figure 2 and figure 4 that the kinematic responses has similar trend around corresponding frequency with similar amplitude in each corresponding case.

Effective foundation input motion calculated from the experimental results can be used in theoretical computation of superstructure and footing response using single sway model of soil and foundation system. Comparison of theoretical and experimental response of footing and superstructure will be useful in determining the effect of soil site nonlinearity on the response.

## REFERENCES

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