# EXPERIMENTAL INVESTIGATION ON SEISMIC RESPONSE OF ADJACENT STRUCTURES ON LIQUEFIABLE GROUND

〇Zhuocheng ZHANG, Kyohei UEDA, Yuko SERIKAWA

## 1. INTRODUCTION

During earthquakes, saturated sandy terrains can induce liquefaction, causing buildings in close proximity to settle unevenly, crack, and tilt. Notable instances include the 1999 Adapazari earthquake in Turkey and the 2018 Hokkaido Eastern Iburi earthquake in Sapporo, Japan. Shallow foundation structures, particularly vulnerable, exhibit excessive settlement and tilting.

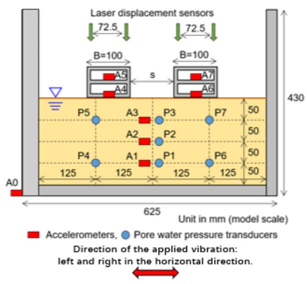
Numerical investigations by Konstantinos et al.[1)] found that as the distance between two structures decreases, they tend to rotate inwards. Increasing distance leads to outward rotation, with the angle decreasing as the distance grows. To validate these findings and explore seismic-induced soil liquefaction behaviors, we conducted model shaking tests in a centrifugal field. Our experimental design aligns with simplified models for shallow foundation design on liquefiable soils, extensively researched by Ishihara et al. and Tokimatsu et al.[2)3)]

## 2. METHODOLOGY

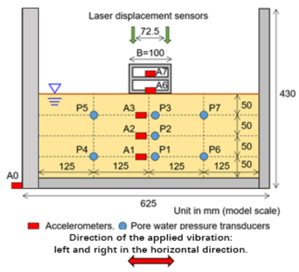
This chapter introduces the experimental model dimensions on a 1/50 scale, subsequently expressed on the prototype scale. The s/B value, representing the spacing-to-building breadth ratio, is crucial for data processing. Four spacing cases as shown in table.1 and Fig.1 (5 mm, 40 mm, 70 mm, and 100 mm) correspond to s/B values of 0.05, 0.4, 0.7, and 1.0. The experiment involves two standardized steel models (100 mm × 100 mm × 70 mm), with a constant model breadth of 100 mm. Silica Sand No. 6 and METOLOSE solution simulate ground conditions. Various sensors, including

**Table 1** Configuration of building model spacing and s/B values. *Parentheses denote the prototype values.

| Case No. | Gap (s value) | s/B | $D_r$ (%) |
|---|---|---|---|
| 1 | 5 mm (0.25 m) | 0.05 | 70.0 |
| 2 | 40 mm (2 m) | 0.4 | 72.2 |
| 3 | 70 mm (3.5 m) | 0.7 | 70.0 |
| 4 | 100 mm (5 m) | 1 | 73.3 |
| Single | - | - | 70.0 |




(a) Twins structures case




(b) Single structure case

**Fig. 1** Model configuration.

accelerometers and pore water pressure transducers, monitor different aspects.

A total of 37.2 kg of sand, deposited in four batches using the air pluviation method, and the METOLOSE solution, 50 times more viscous than water, facilitated

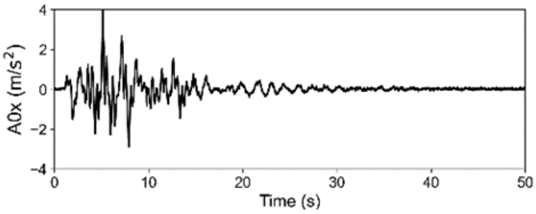



**Fig. 2** Five-fold amplified Kobe wave.

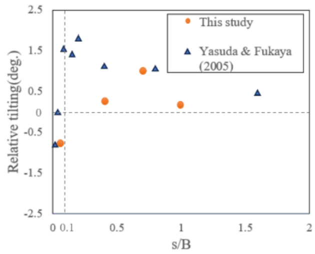



**Fig. 3** Relationship between s/B and relative tilting degree

saturation. Challenges with solution infiltration were addressed through repeated evacuations. The consistent saturation method ensured successful liquefaction for specific cases.

Seismic excitation gradually increased centrifugal acceleration to 50g. The five-fold amplified Kobe wave shown as Fig.2 was chosen based on its observed effectiveness in preliminary testing to ensure liquefaction. Experiments with non-amplified and three-fold amplified waves preceded confirming the five-fold amplified Kobe wave. A systematic approach with three-fold waves initially, followed by five-fold waves, ensured reliability and consistency in experimental outcomes.

## 3. RESULTS ANALYSIS OF TILTING

In this experiment, tilting is defined by settlement measurements ($D_L$ and $D_R$) on the left and right sides of the model, with the distance between laser displacement sensors represented as L. Tilting (T) is calculated considering counterclockwise as positive and clockwise as negative (Equation 1). Relative tilting between two structures is computed by subtracting left structure tilting ($T_L$) from right structure tilting ($T_R$) (Equation 2). The experiment explores tilting behaviors for different distances (s/B values).

Konstantinos et al. observed that at close distances (s/B = 0.1), structures tilt inward, transforming into outward tilting as distance increases. The experiment aligns reasonably well with simulations, but real-world conditions introduce asymmetry. For s/B = 0.4 and s/B = 0.7, asymmetry is observed with counterclockwise and clockwise tilting. As distance increases to s/B = 1.0, outward tilting decreases, consistent with simulations.

$$T = \arctan\left(\frac{D_L - D_R}{L}\right) \quad (1)$$

$$Relative\ tilting = T_L - T_R \quad (2)$$

Soil-Structure-Soil Interaction (SSSI) enhances stability but amplifies relative tilting. As distance decreases, relative tilting increases until a critical point, after which it decreases. When s/B < 0.05, structures shift from outward to inward tilting. Analysis of single structure cases aligns closely with s/B = 1.0. Comparisons with Yasuda & Fukaya's[4)] data confirm alignment in most scenarios as shown in Fig.3, with inward tilting observed only when s/B < 0.1.

The experiment suggests that as buildings approach, inner sides experience smaller settlement due to offsetting shear stresses. Robust soil columns form between structures, hindering shear deformations. Smaller settlement on inner sides supports this observation.

## REFERENCES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