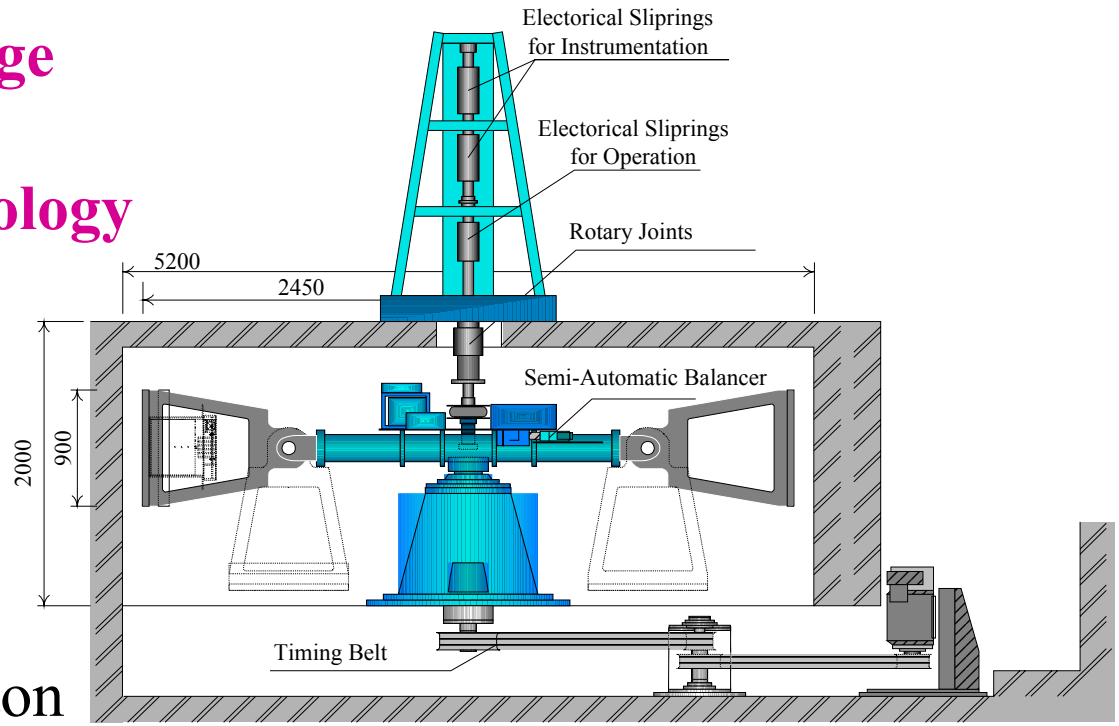
# Applications of Centrifuge Modelling Technology in Geotechnical Engineering Practice

By

Charles Ng, Osamu Kusakabe and C.F. Leung

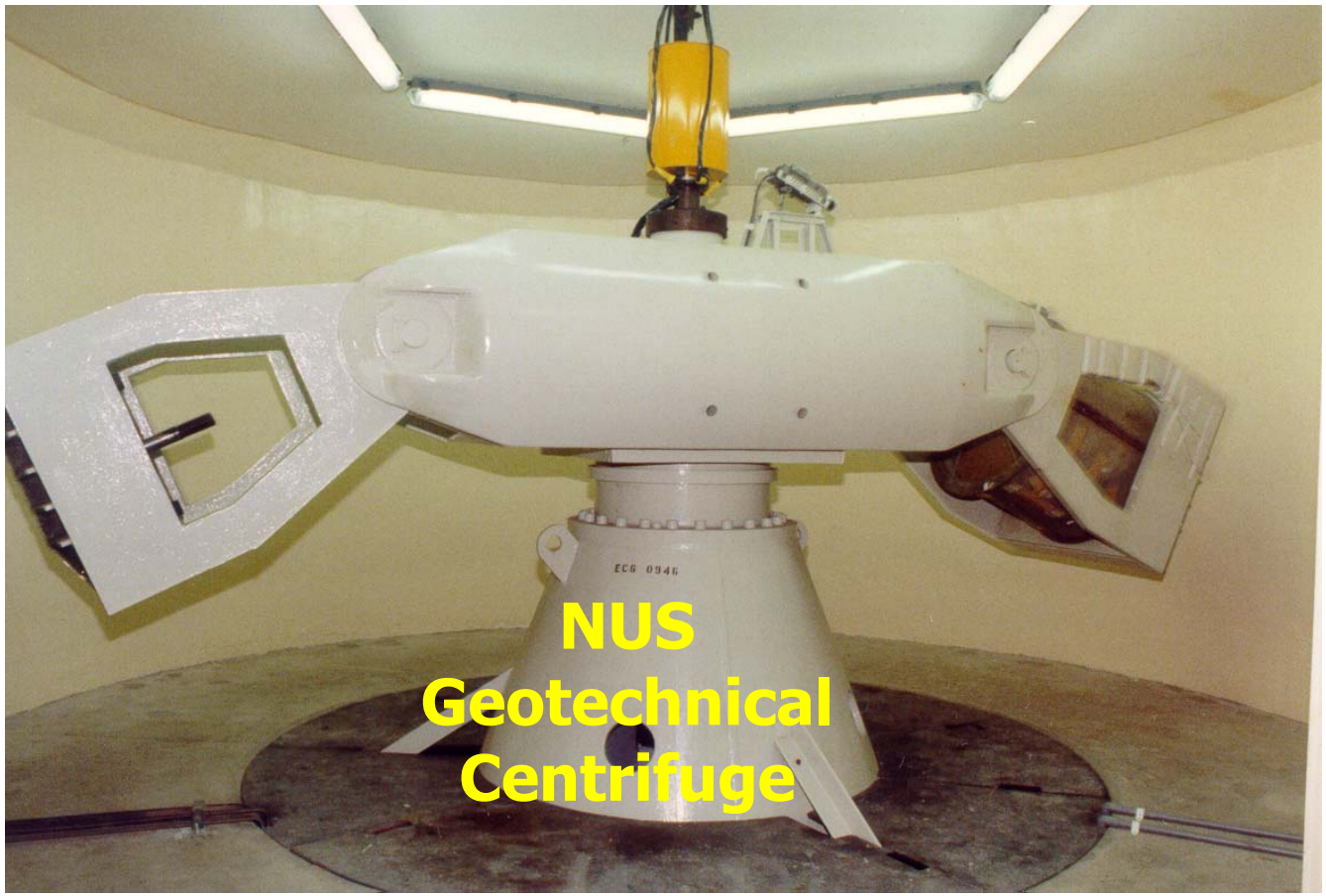
# Geotechnical Centrifuge at Tokyo Institute of Technology




5m diameter, payload 50 g-ton

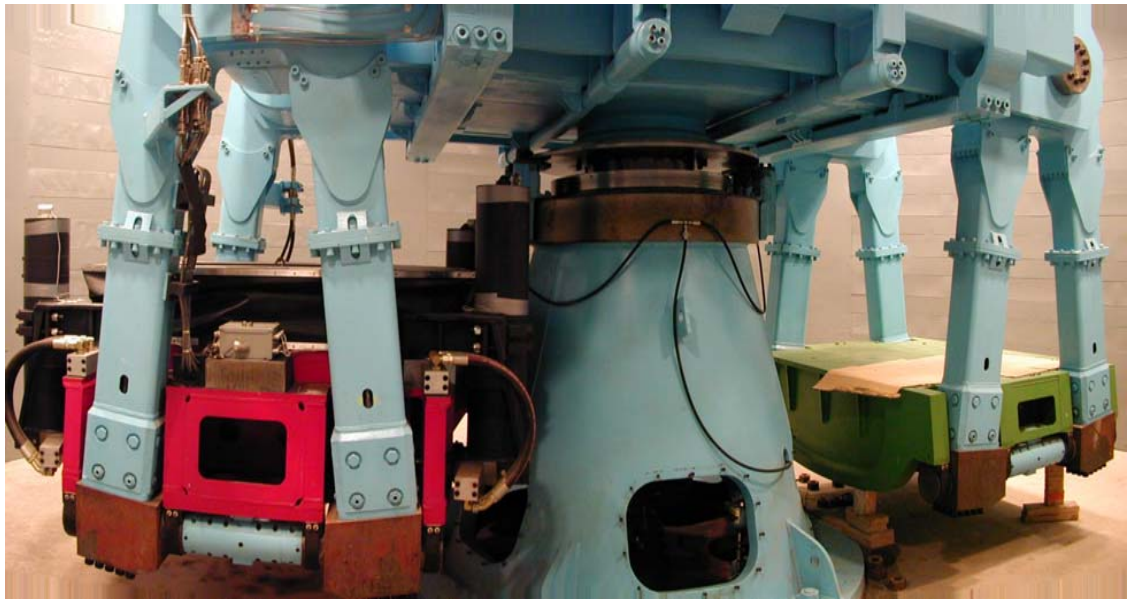


# Geotechnical Centrifuge
# at
# National University of Singapore



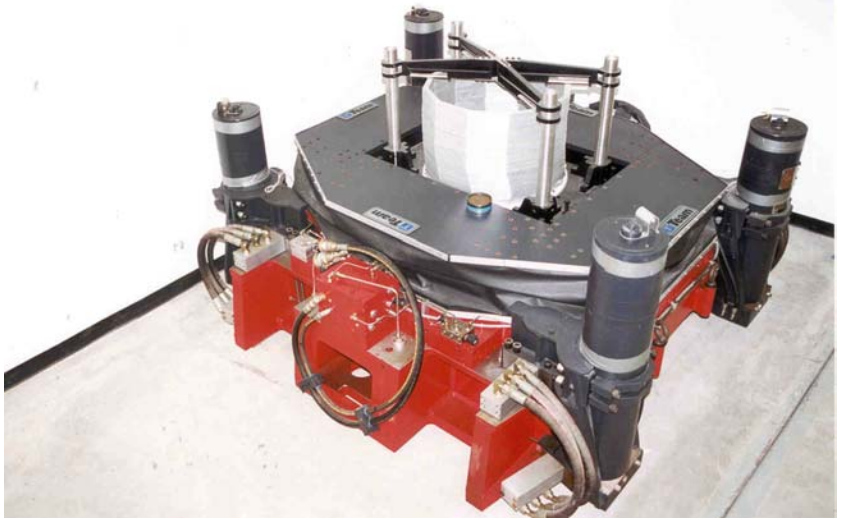

Effective dia. 3.64m; Maximum 200g; Maximum payload 40g-t

# The Geotechnical Centrifuge at Hong Kong University of Science and Technology

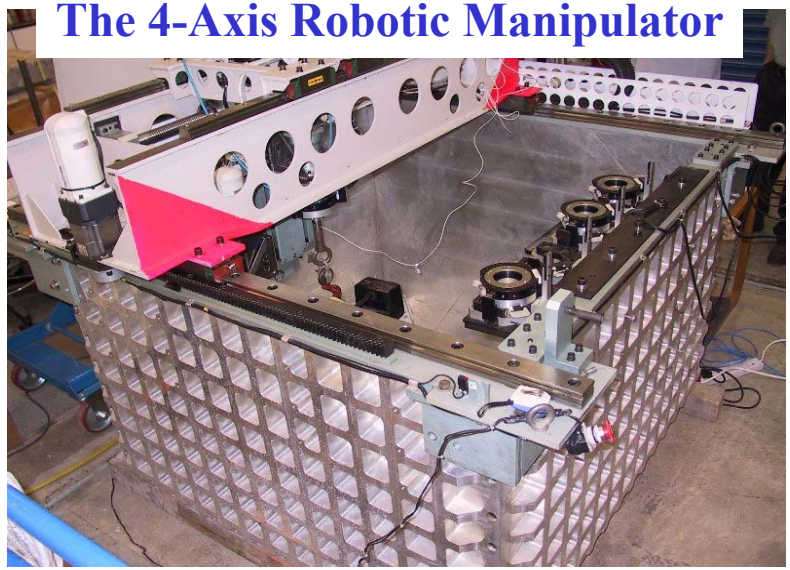


Diameter 8.4m
Maximum 100g
Maximum payload 300g-ton

## The 2D Hydraulic In-flight Shaking Table



## The 4-Axis Robotic Manipulator



# Projects Reviewed

- Slope stability – static liquefaction, earthquake effects, stabilisation method by micro-piles and soil nails
- Shallow foundations – minimising vibration effects from HS trains, correction of building tilt, improvement of composite foundation
- Deep foundations – negative skin friction, lateral soil movement on pile performance
- Tunnelling – multi-tunnel interaction (HKUST), tunnelling effects on piles (Dr C.F. Leung et al)
- Land reclamation (Dr C.F. Leung et al)
- Marine applications – gravity caissons, assessment of ship impact loading on bridge piers (Dr Daman Lee)

# Slope stability

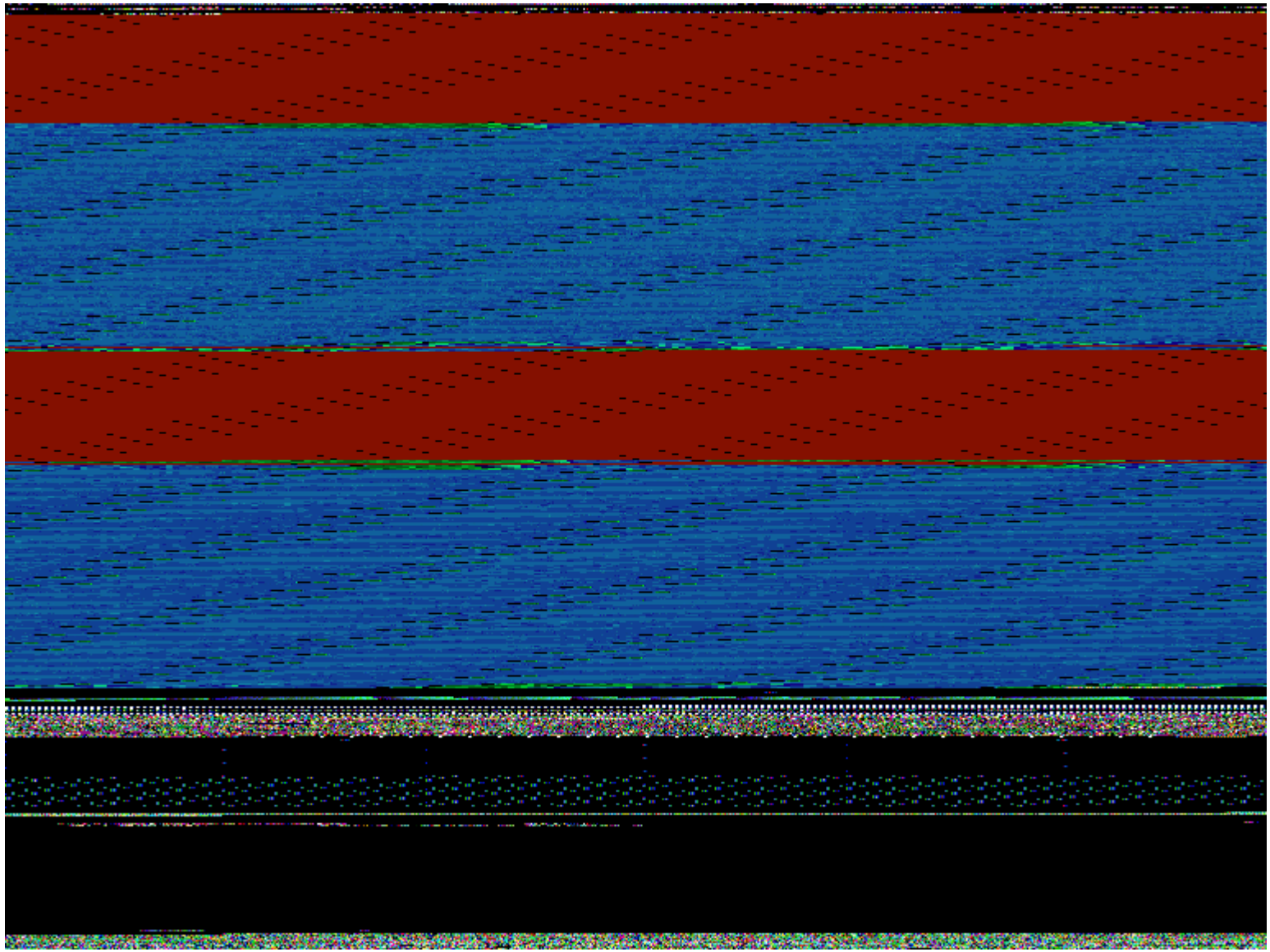
Possibility of static liquefaction of loose fill slopes and stablisation methods ?

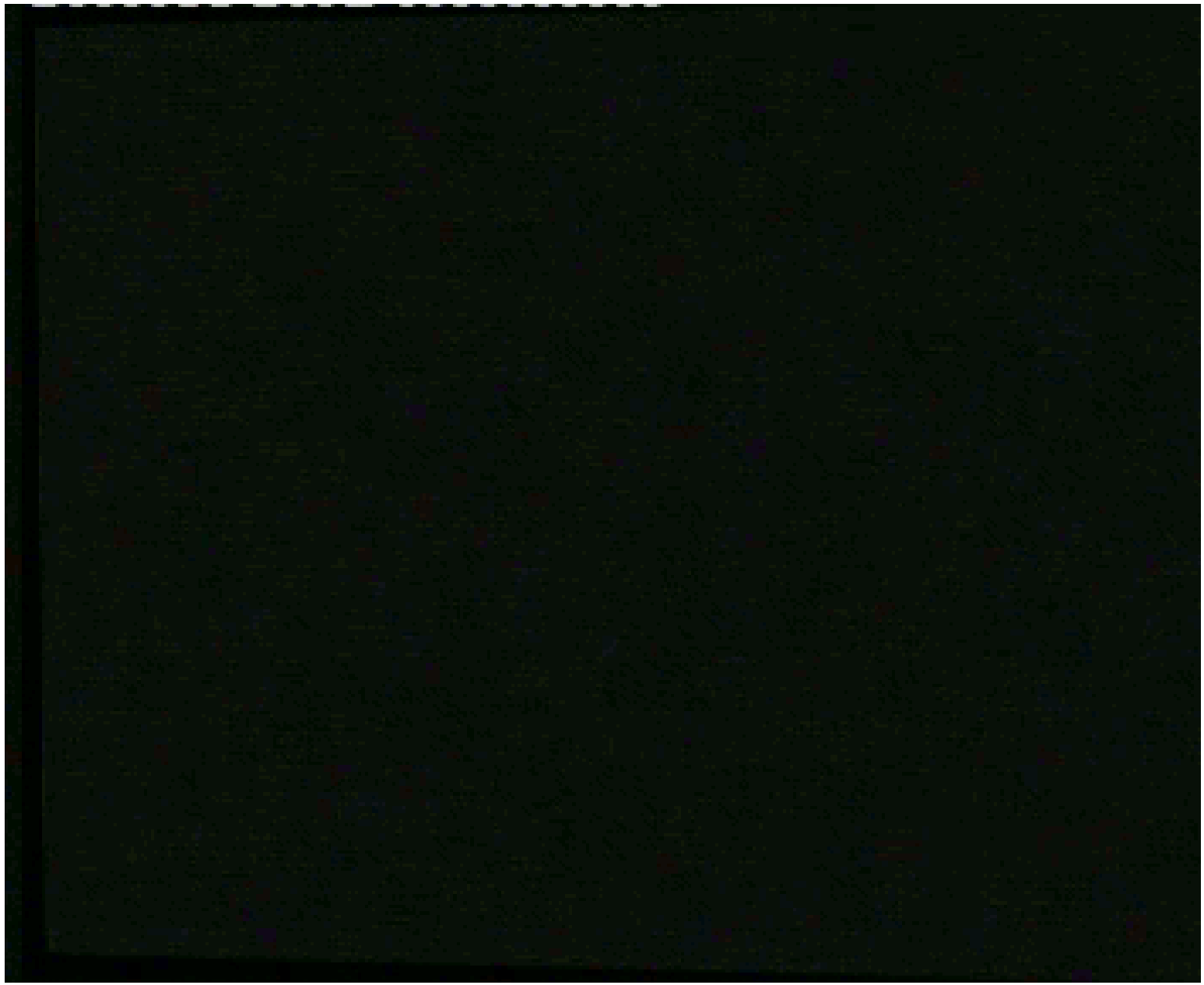
Client:

Geotechnical Engineering Office of HKSAR

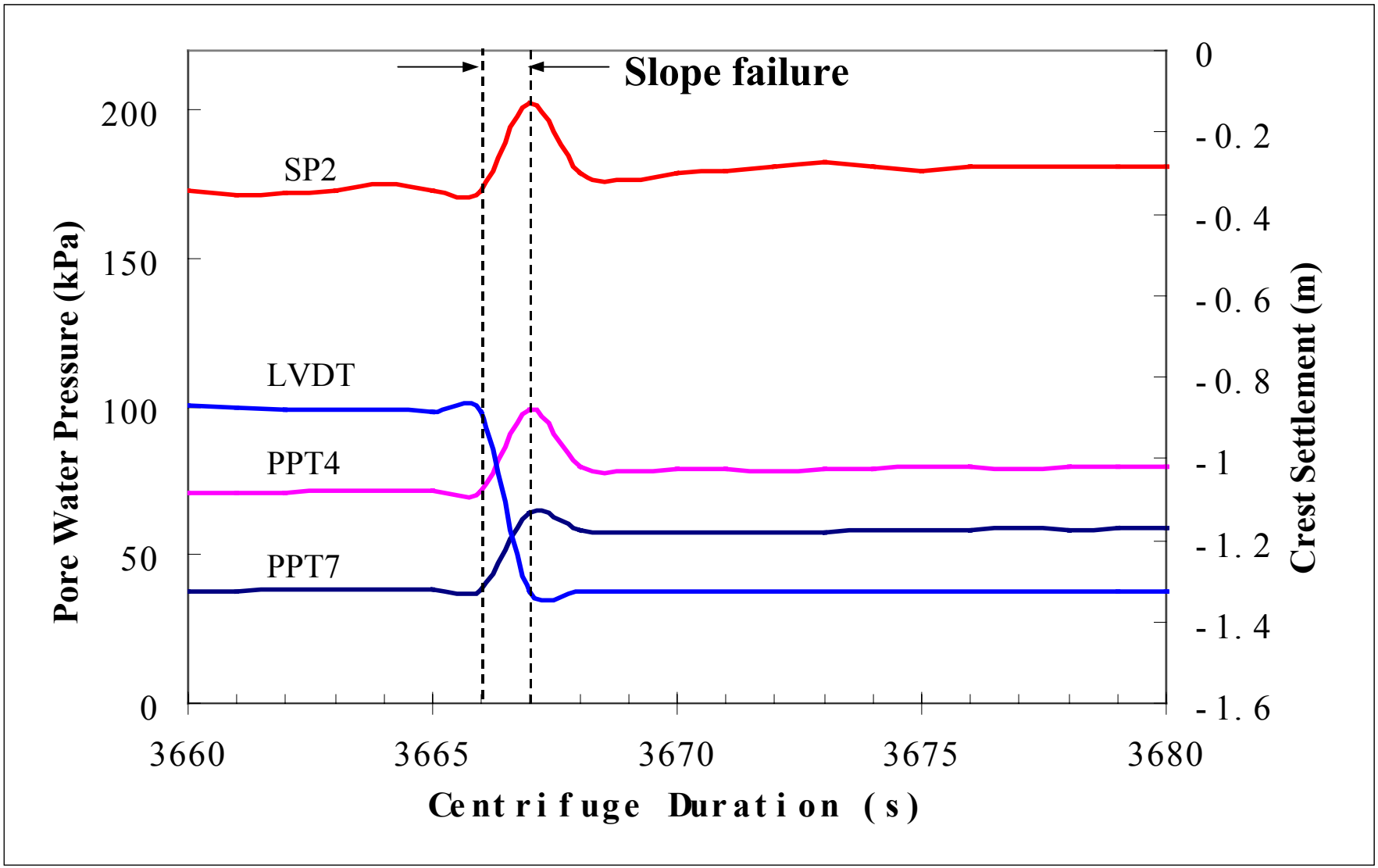
By

Hong Kong University of Science and Technology





# Centrifuge Test Results – SG30



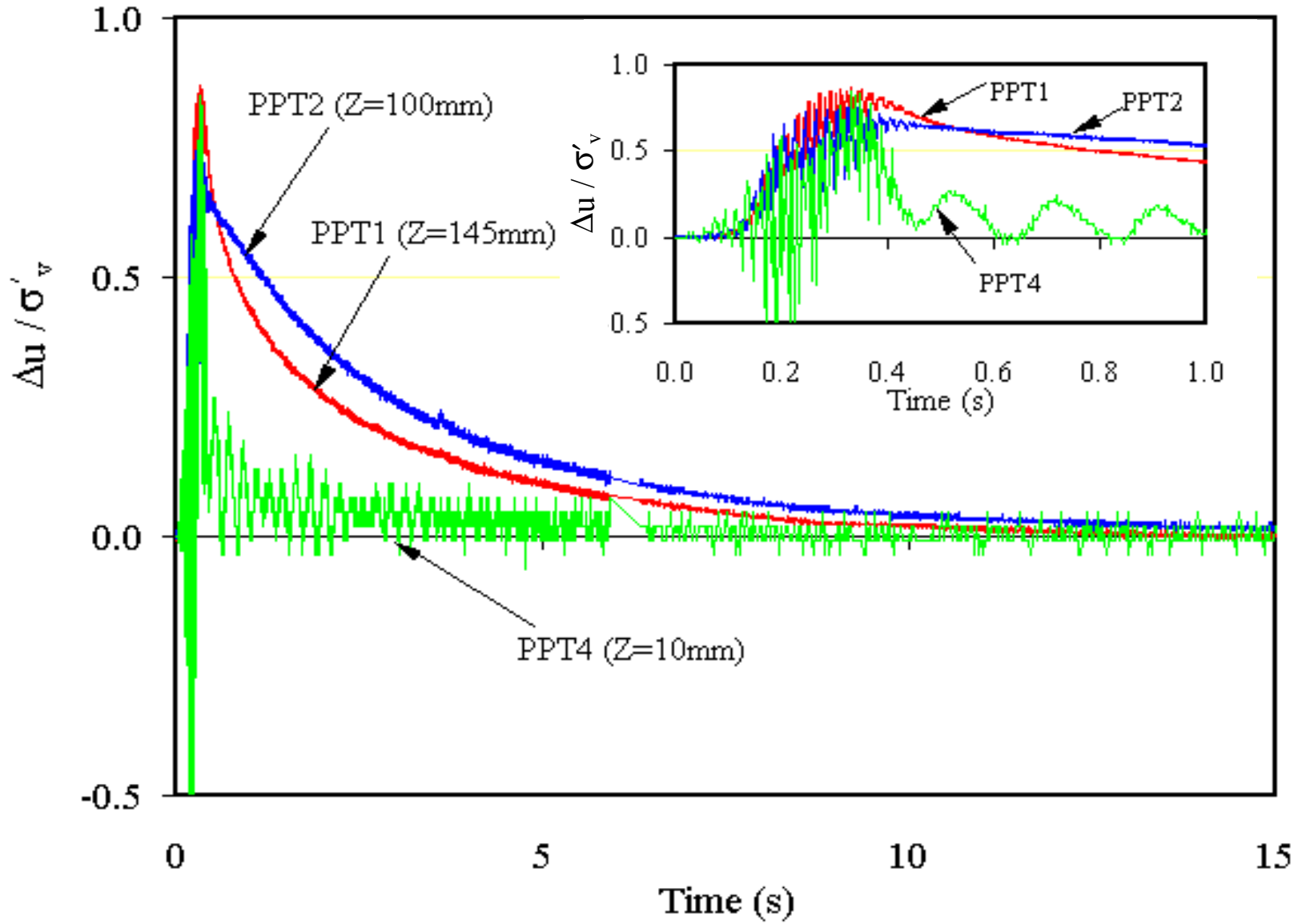
# Slope stability

## Behaviour of loose CDG fill slopes subjected to uni- and bi-axial earthquakes ?

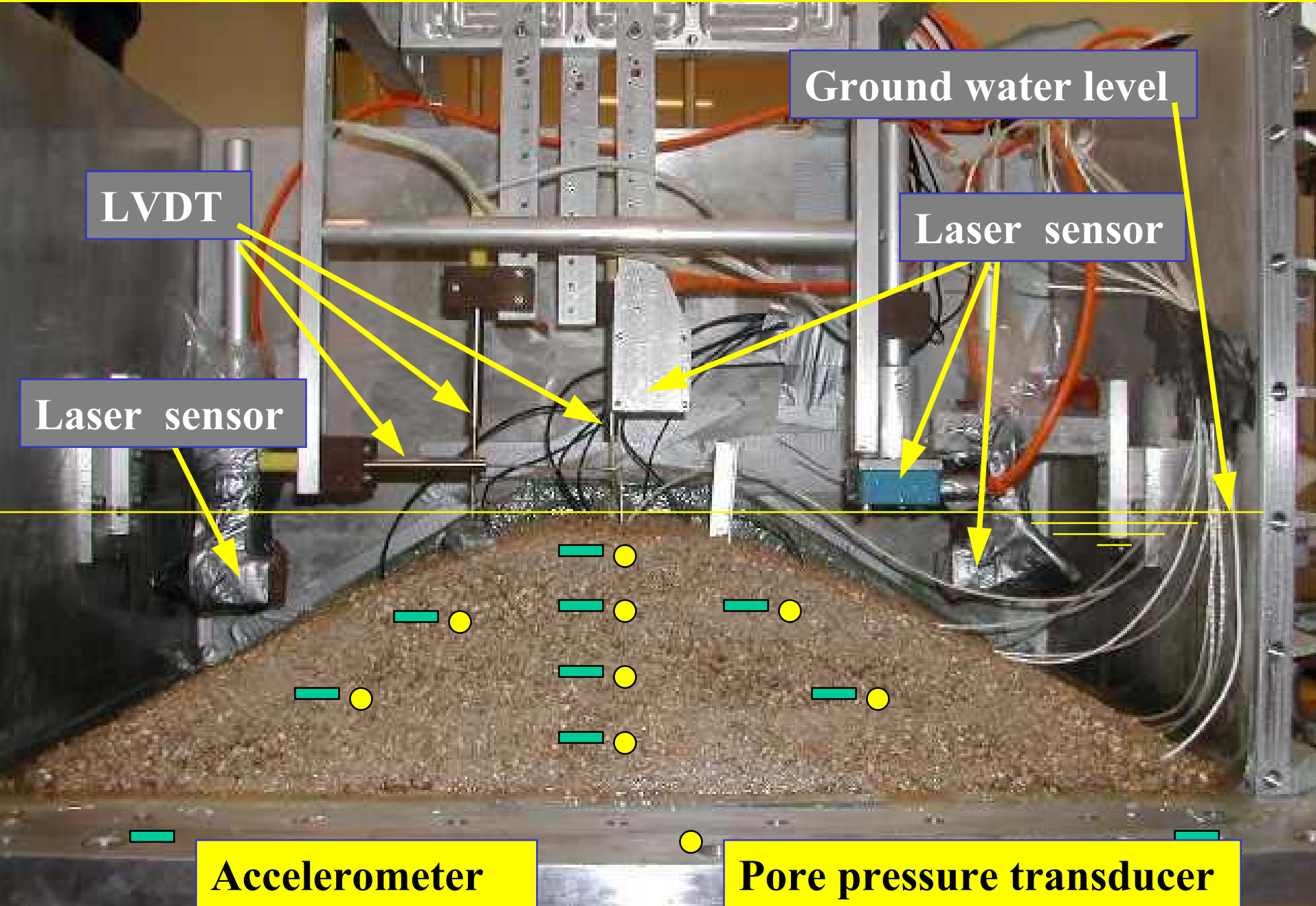
By

Hong Kong University of Science and Technology

# M2D-03: Pore pressure ratio at pga=0.3g



# Side view after seismic centrifuge test



# Slope Stabilization by Micro-piles

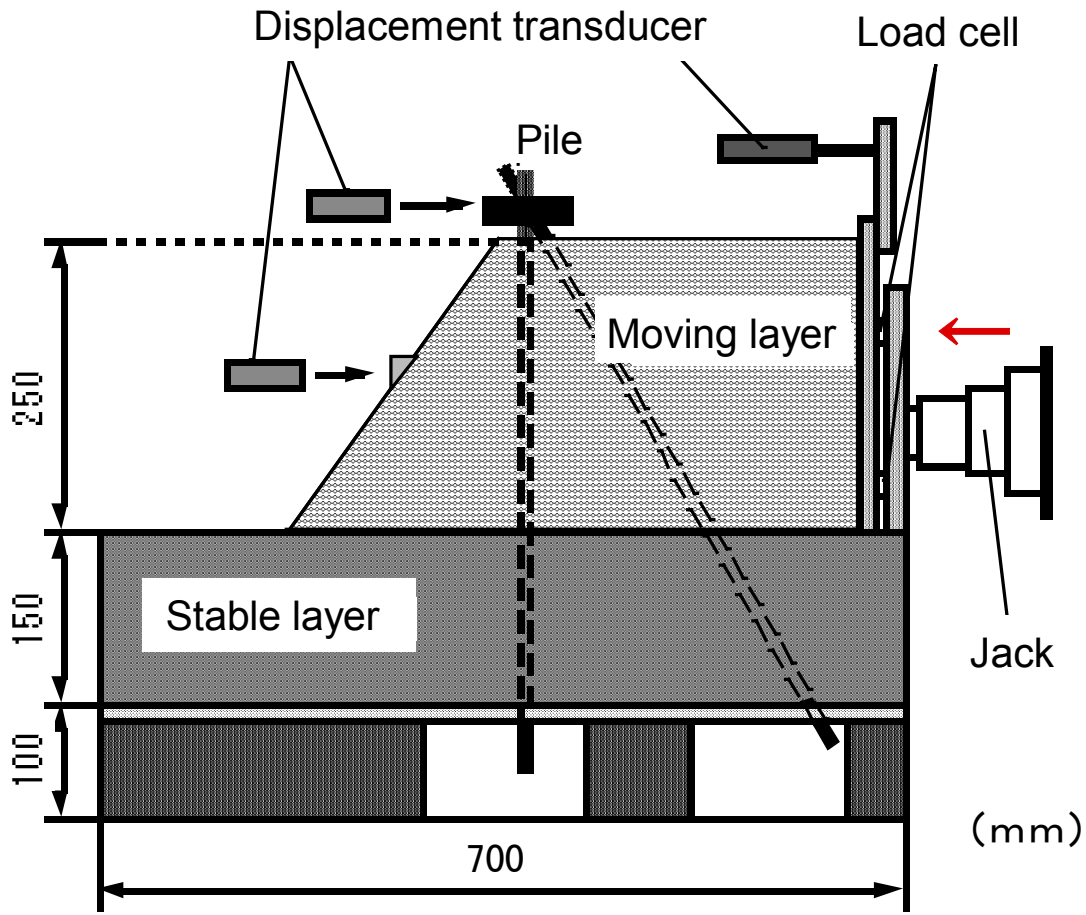
Jiro Kuwano et al of TIT

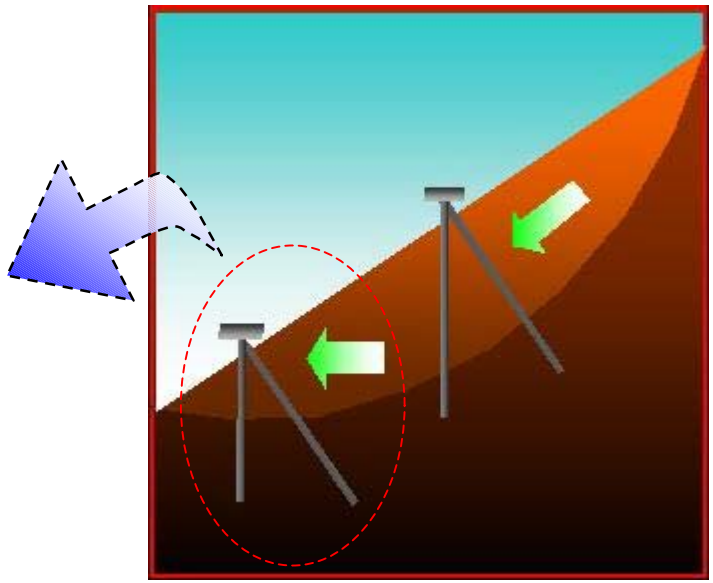
and

Masayuki Kido of Advanced Construction Technology Center

# TEST OUTLINE

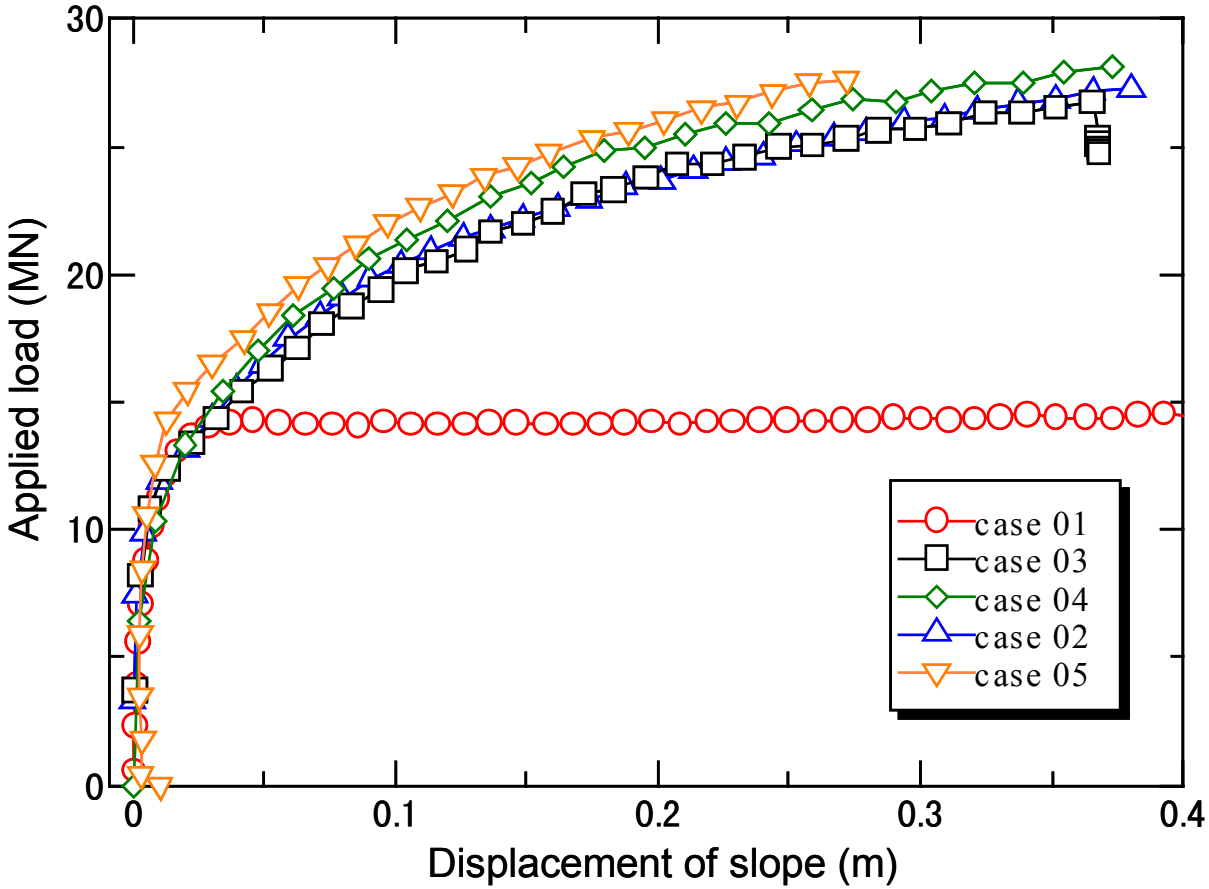
Centrifuge model tests were carried out in 30G to study the soil-pile interaction when subjected to lateral soil movement.



Moving layer: compacted Inagi sand, 250 mm thick (7.5m in prototype)

Stable layer: soft PVC (polyvinyl chloride) with E=114Mpa (soft rock)



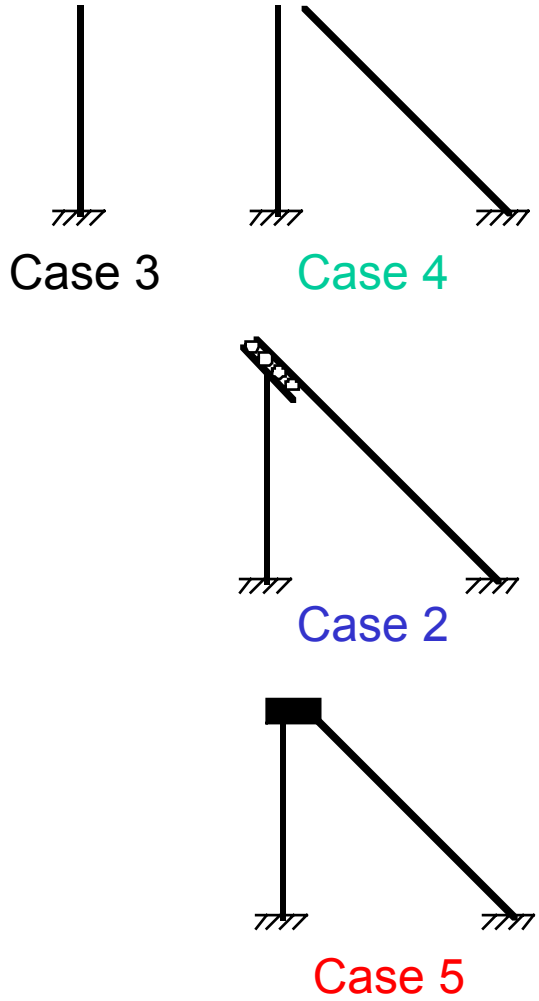




Fig. 5. Applied load ~ slope displacement

- The soil mass without pile started to move at 14MN.
- At early stage of loading:
  The slope displacements were almost same in Cases 2, 3 and 4.
  The slope displacement was smaller in Case 5 of rigid fixity.
- With the increase in the slope displacement,
  difference among the applied load became larger, and
  the displacement was largest in Case 3, then Cases 2, 4 and 5 in that order.

# Shallow Foundation

## Wave Propagation using a Multiple Moving Load System

**Kazuya ITOH, Akihiro TAKAHASHI, Osamu KUSAKABE**

*Department of Civil Engineering, Tokyo Institute of Technology, Japan*

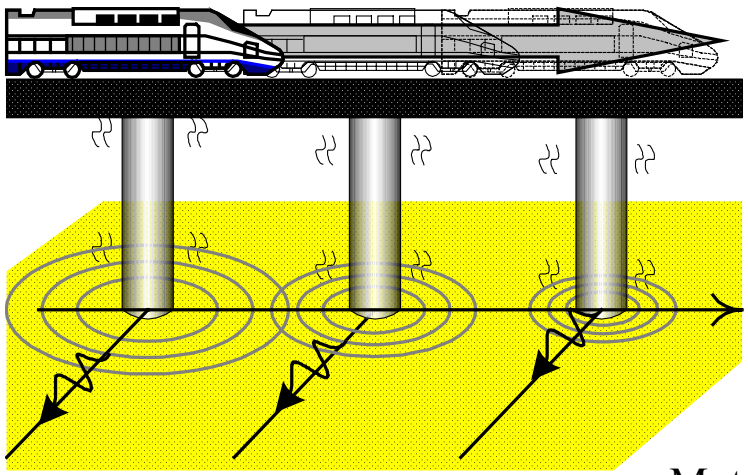
**Masayuki KODA, Osamu MURATA**

*Railway Technical Research Institute, Tokyo, Japan*

**Kang Il LEE**

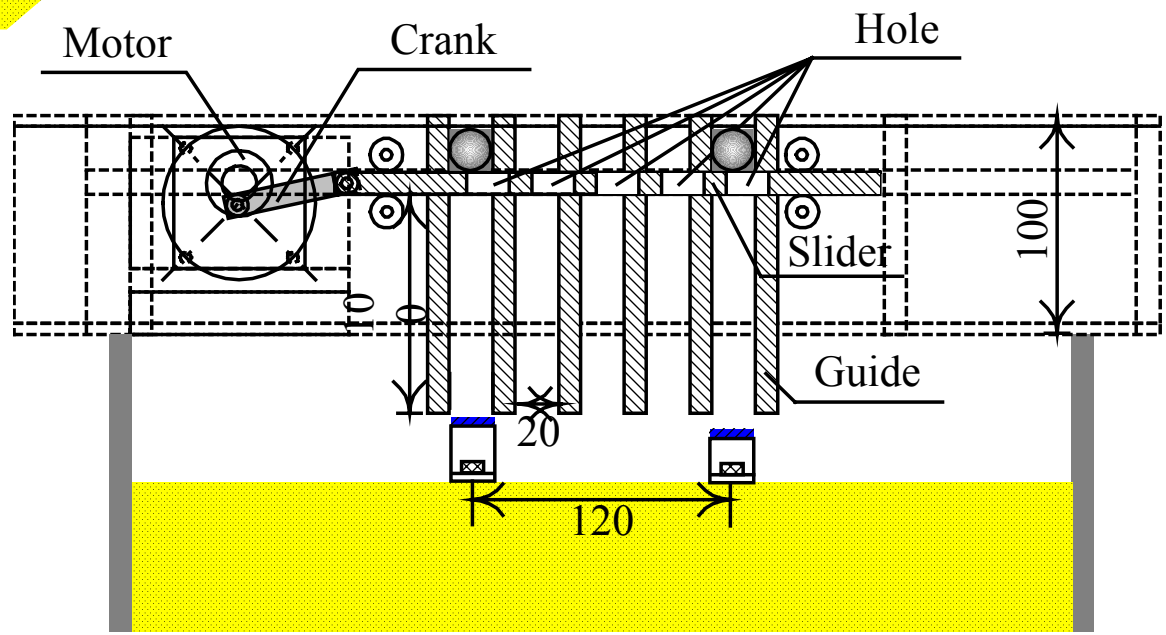
*Department of Civil Engineering, Daejin University, Kyungki-do, Korea*

# Multiple Ball-Dropping System

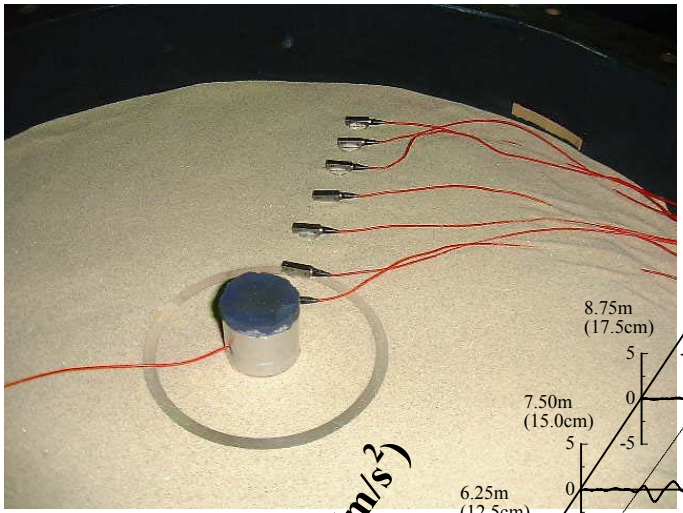


- Two balls drop and hit different model foundations
- There is a slight difference in height of the model foundations to provide a certain time lag

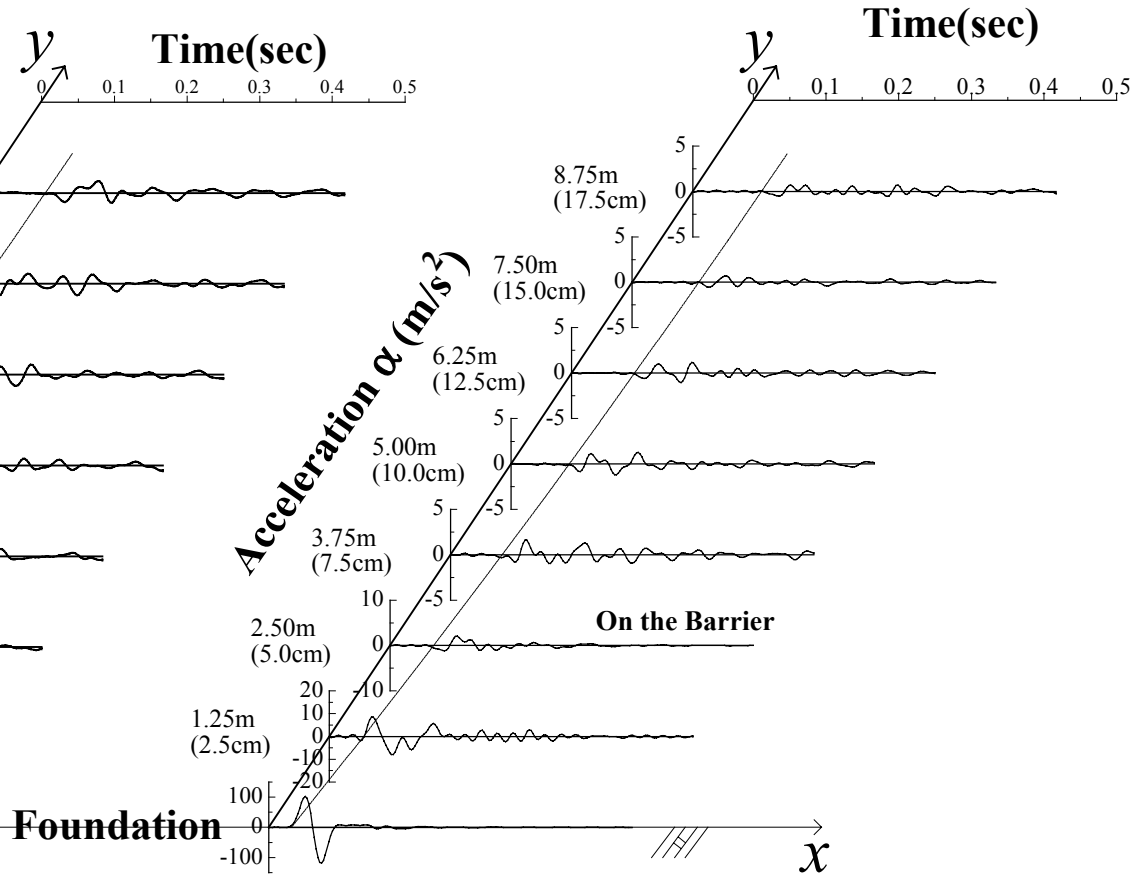
*Modelling*




unit : mm





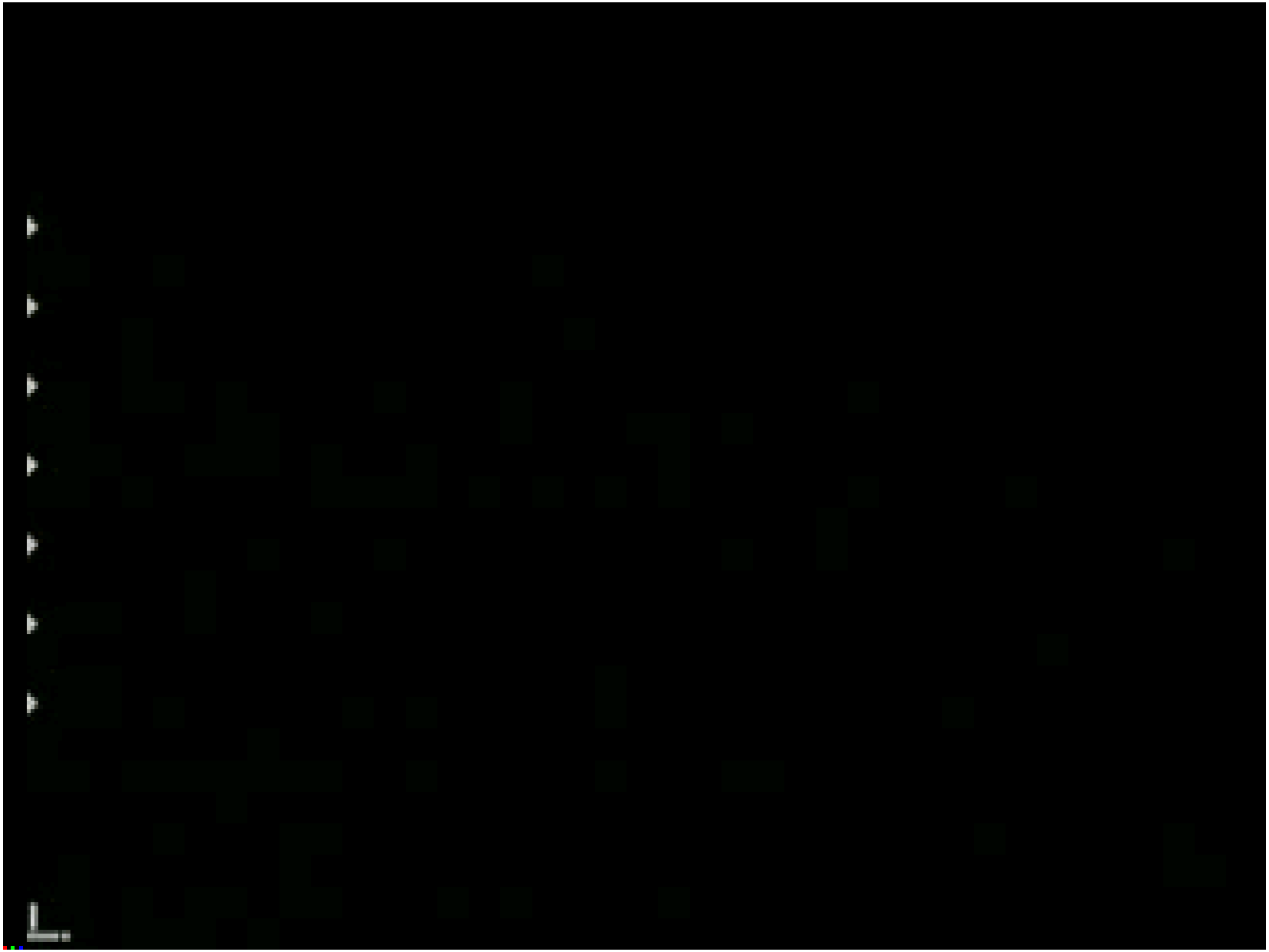



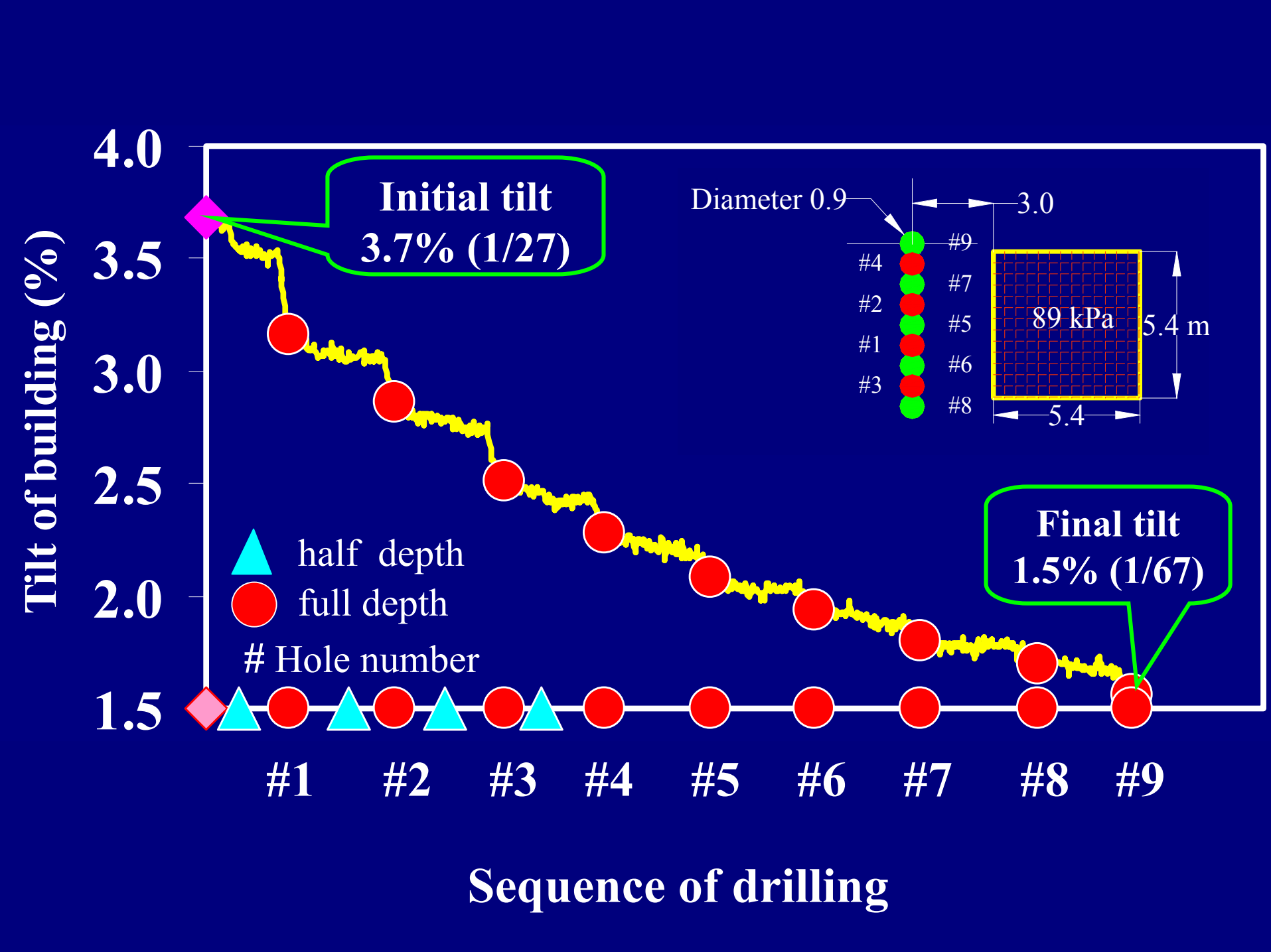

Without Barrier

With Aluminum Barrier(D=17m)

# In-flight Correction of Building Tilt using 4-Axis Robotic Manipulator

By
Hong Kong University of Science and Technology




Initial tilt
3.7% (1/27)
Final tilt
1.5% (1/67)
Diameter 0.9
3.0
#4
#2
#1
#3
#9
#7
#5
#6
#8
89 kPa
5.4 m
5.4
half depth
full depth
# Hole number
Tilt of building (%)
4.0
3.5
3.0
2.5
2.0
1.5
#1
#2
#3
#4
#5
#6
#7
#8
#9
Sequence of drilling



Tokyo Institute of Technology

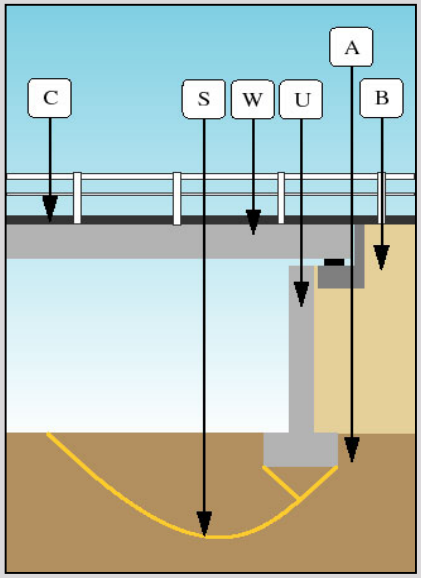
Railway Technical Research Institute

# Capacity of Skirted Sheet Pile Composite Foundation on Sand from Centrifuge Test

Kusakabe and Murata Laboratory

P. Punrattanansin, H. Nishioka, O. Murata & O. Kusakabe

# Statement of the Problem

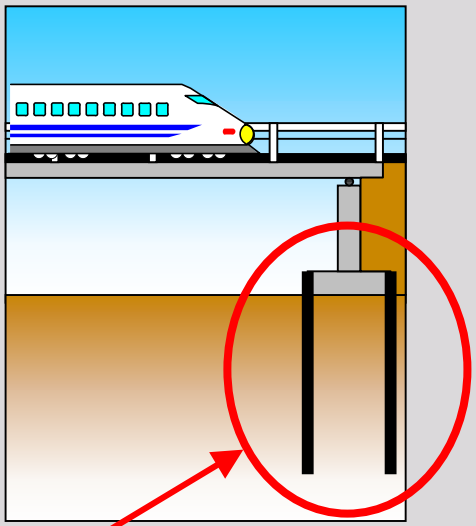



Spread footing

"Inappropriate spread footing design"
"Improve the performance of existing footing"

## What is Sheet Pile Foundation?

Composite structure: Shallow foundation with skirts (sheet piles) extending into the soil: exhibit both higher bearing resistance in compression, and also significant pullout capacity.

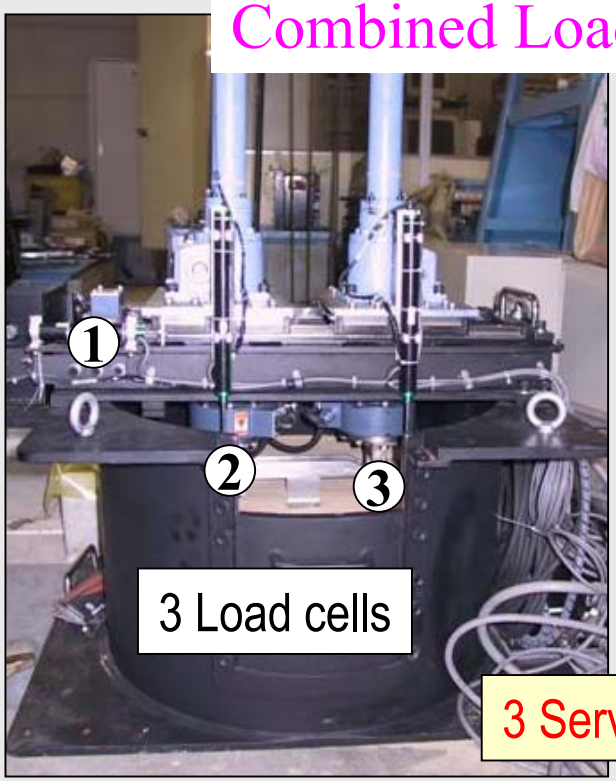


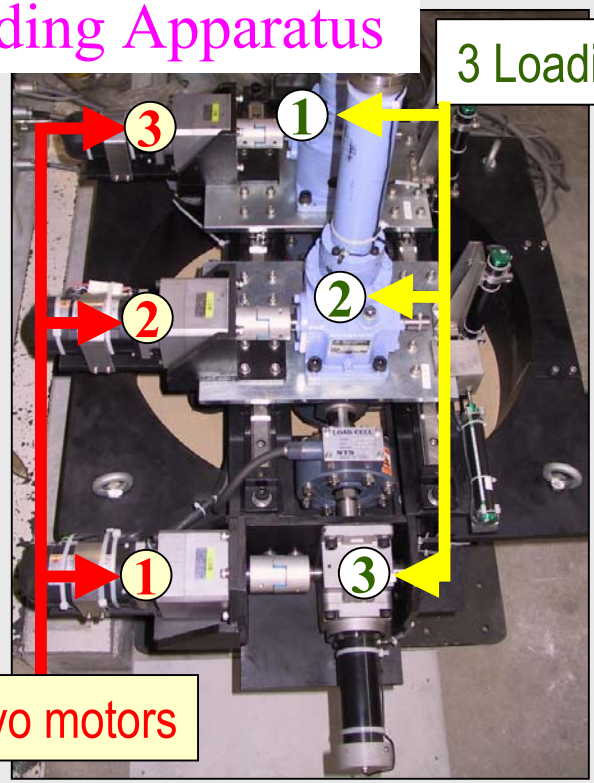
Skirted sheet pile composite foundation

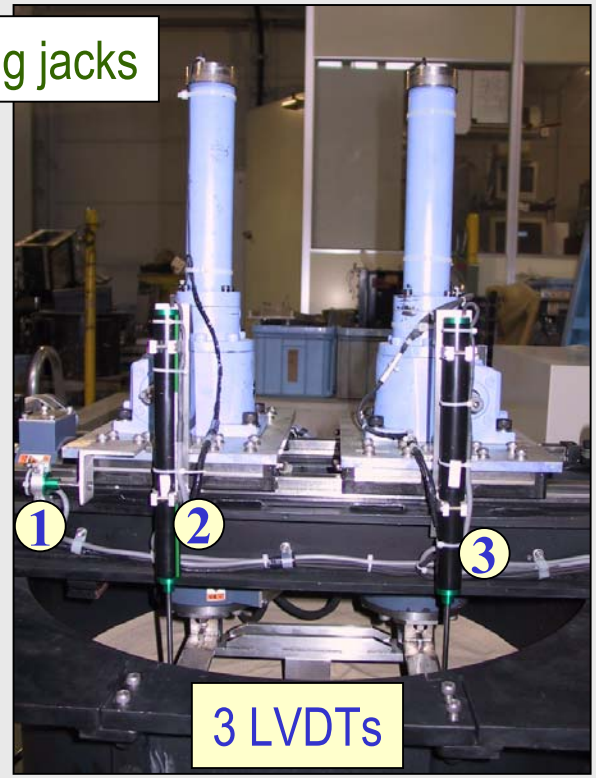


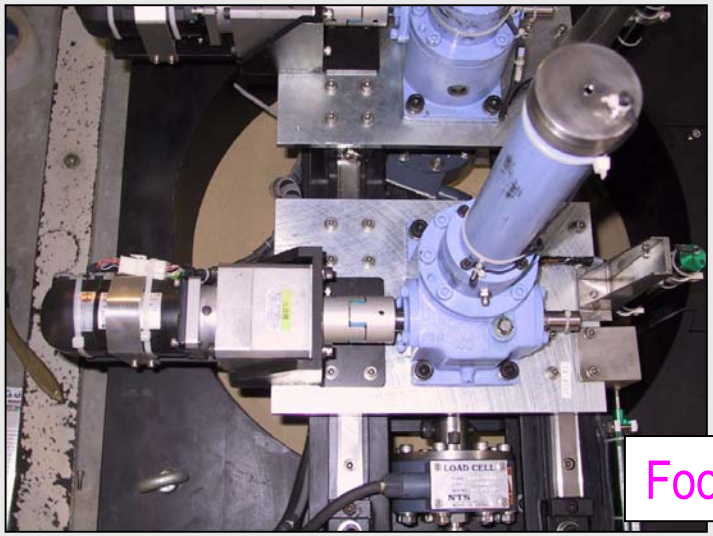


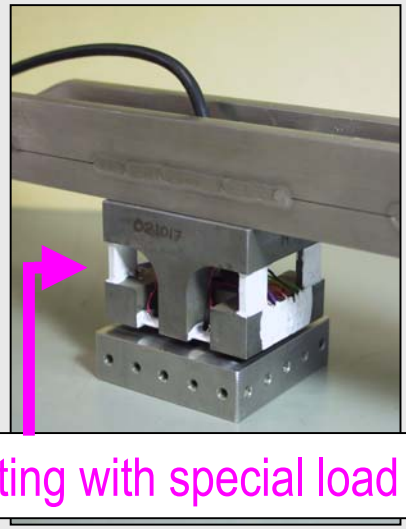
# Combined Loading Apparatus

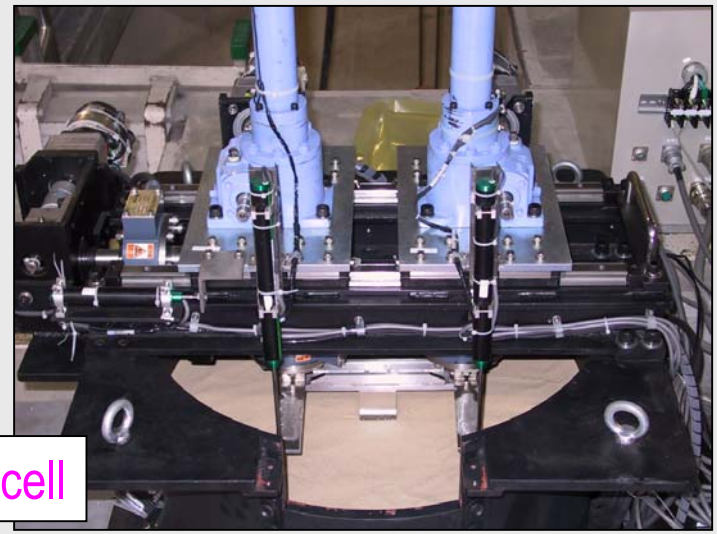


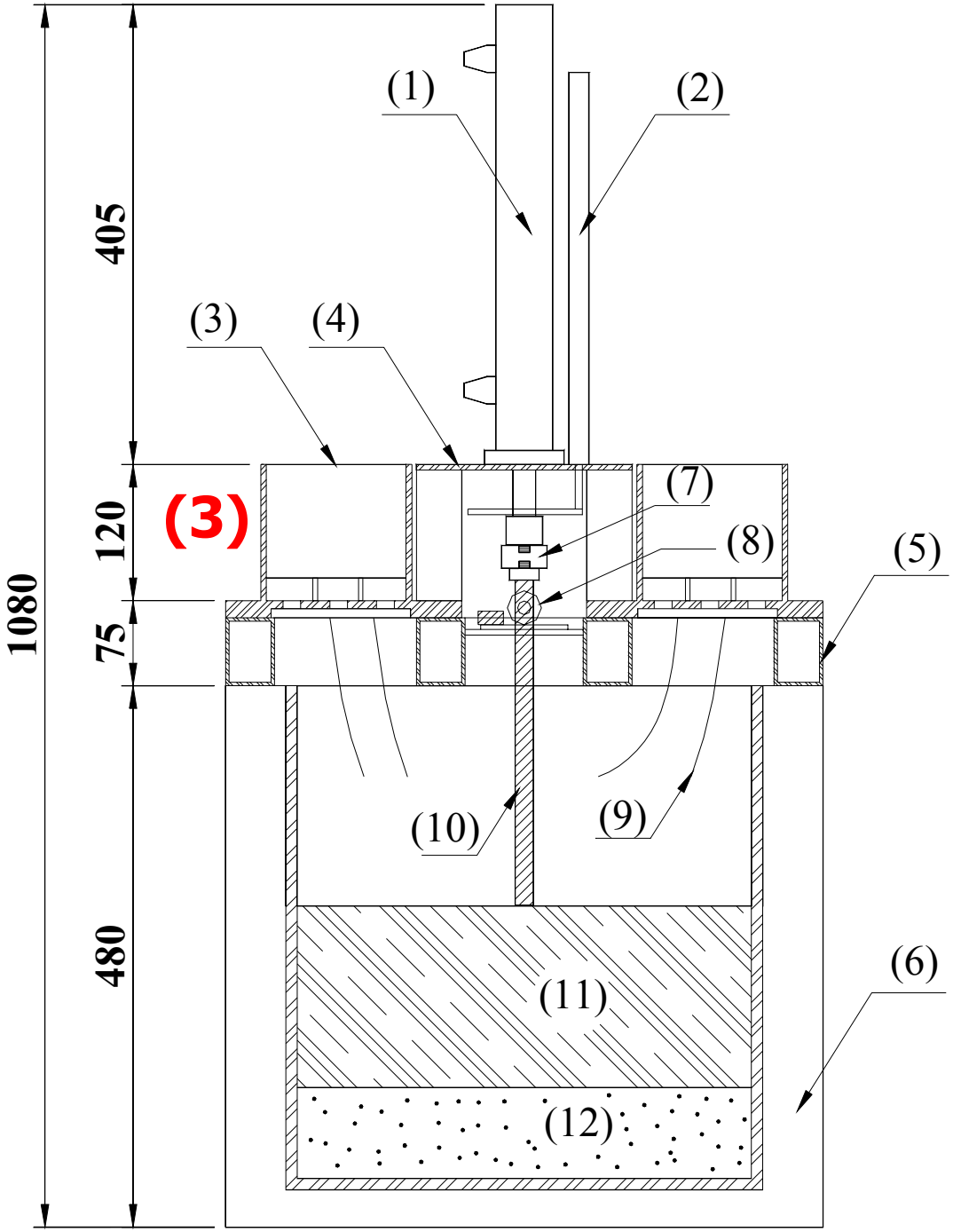


# Deep Foundations

# Pile subject to negative skin friction and vertical load

By C.F. Leung et al of NUS

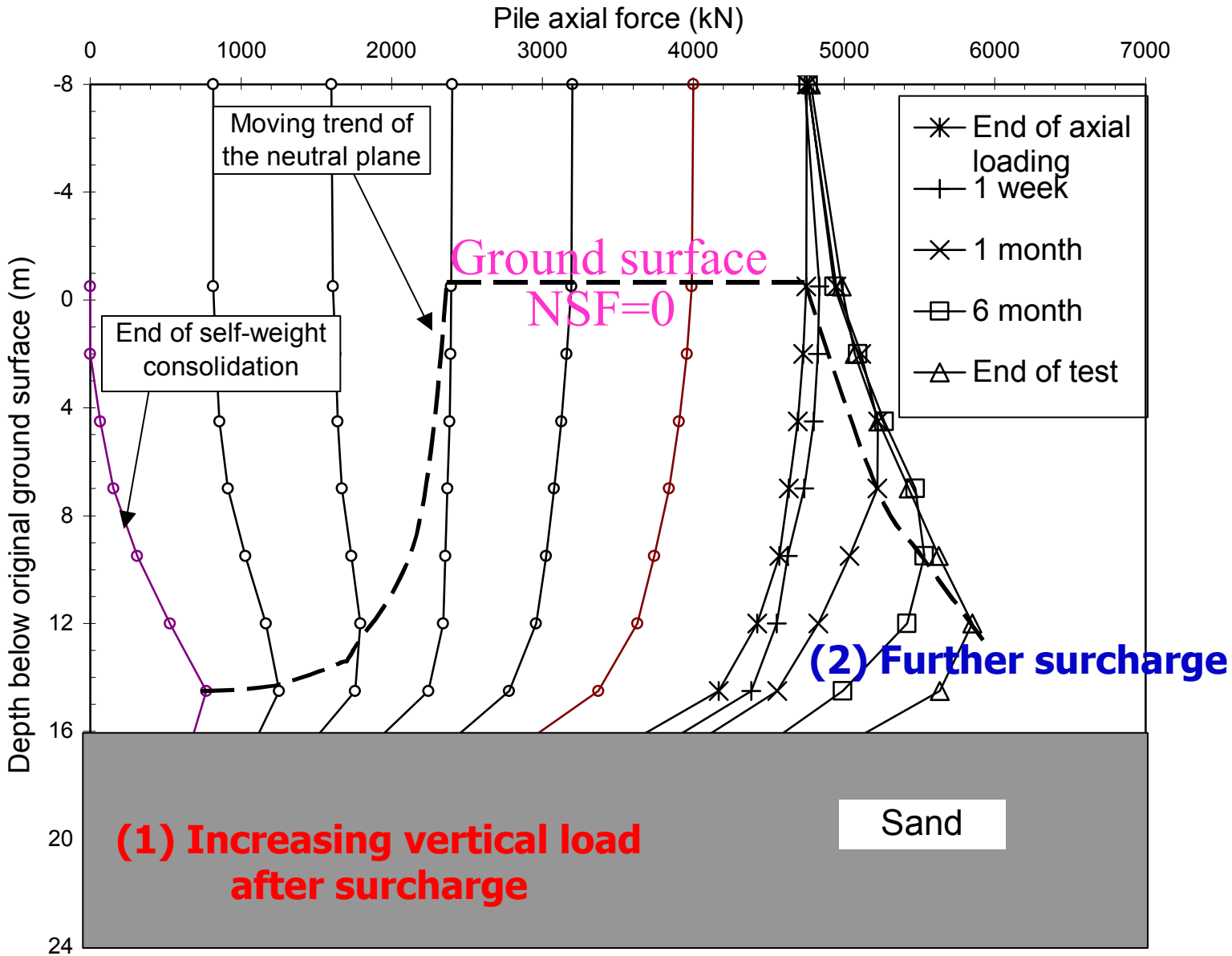



# Experimental setup

## (3) Sand hopper to induce placement of surcharge during centrifuge flight

(1) Vertical actuator
(2) Long LVDT
(3) Sand hopper
(4) Loading frame
(5) Supporting frame
(6) Soil container
(7) Load cell
(8) Horizontal actuator
(9) Guiding flaps
(10) Model pile
(11) Clay sample
(12) Sand layer

(Unit in mm)




**Pile axial load transfer profiles under vertical loading and sand surcharge.**

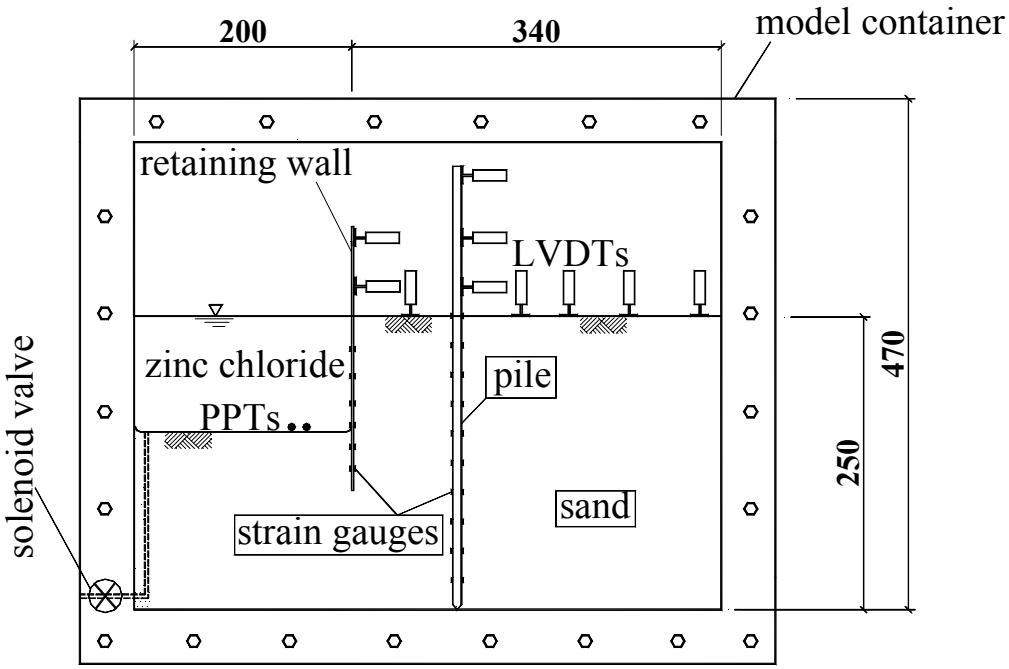
**The conventional design practice of adding negative skin friction to vertical load is likely to be conservative.**

# Deep Foundations

## Behaviour of pile subject to excavation-induced soil movement

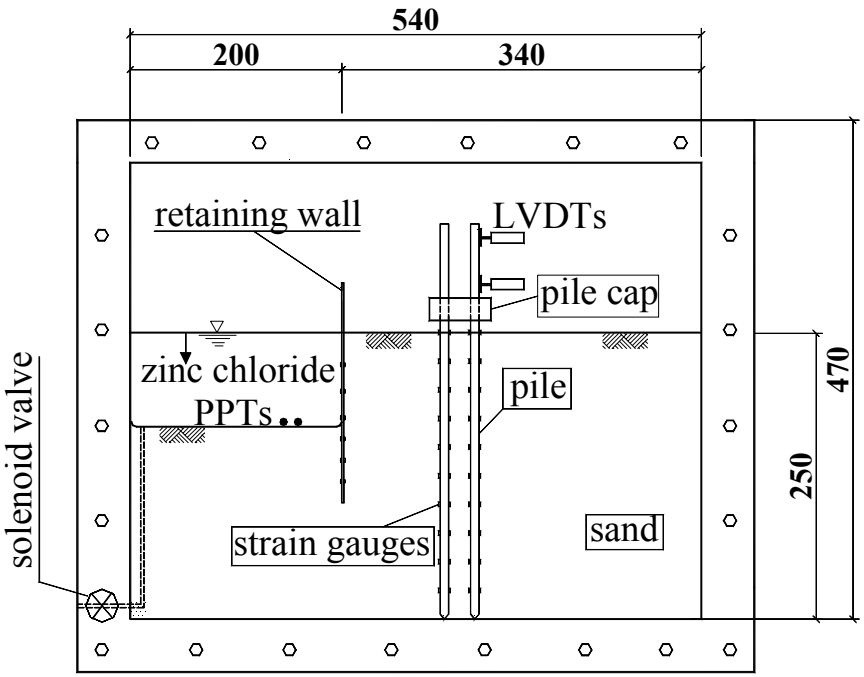
By

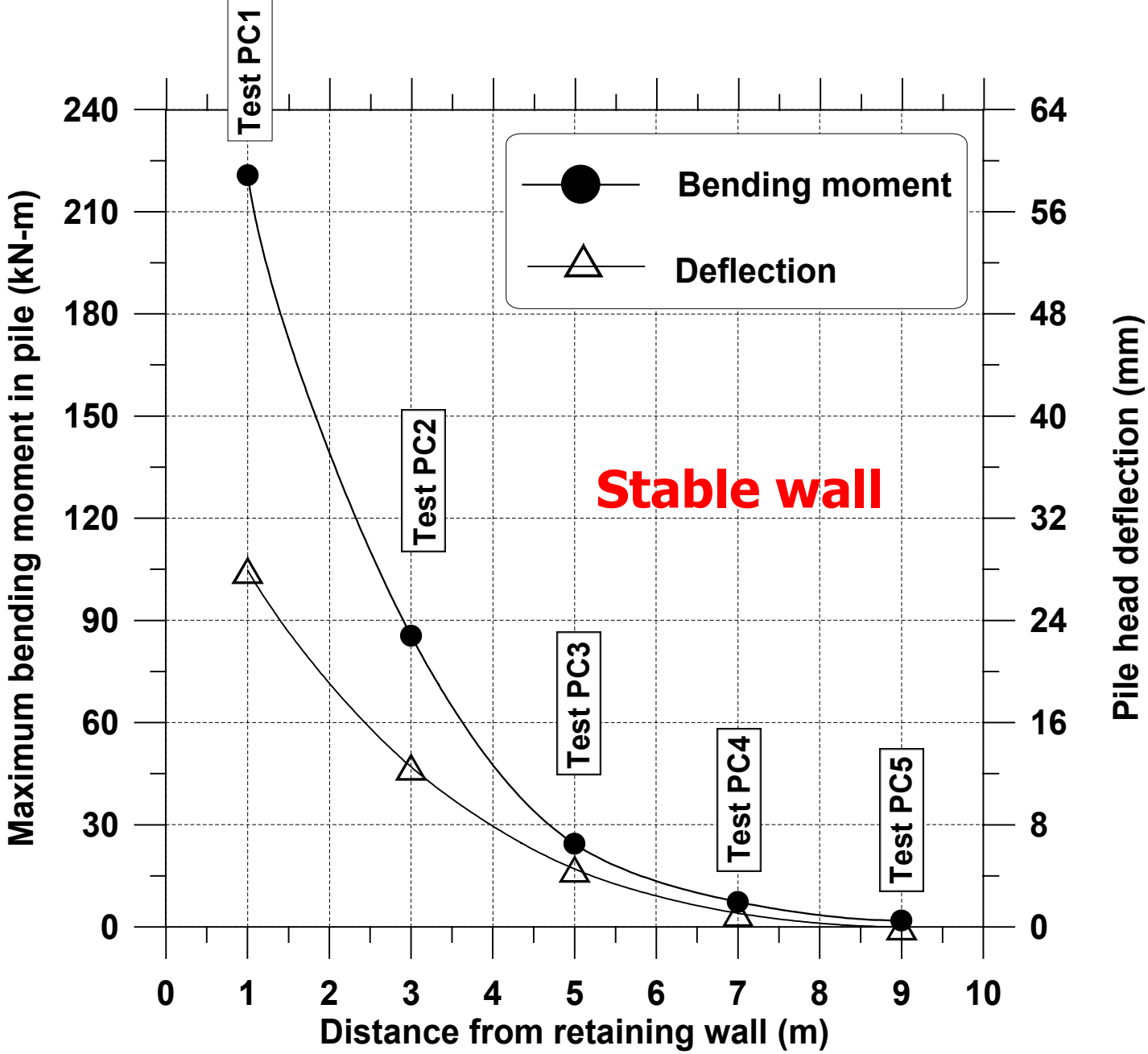
C.F. Leung et al of NUS




## Single pile in sand

## Pile groups in sand






Pile BM & deflection decrease with increasing distance of pile from wall

# Tunnelling

## NATM Multi-tunnel Interaction

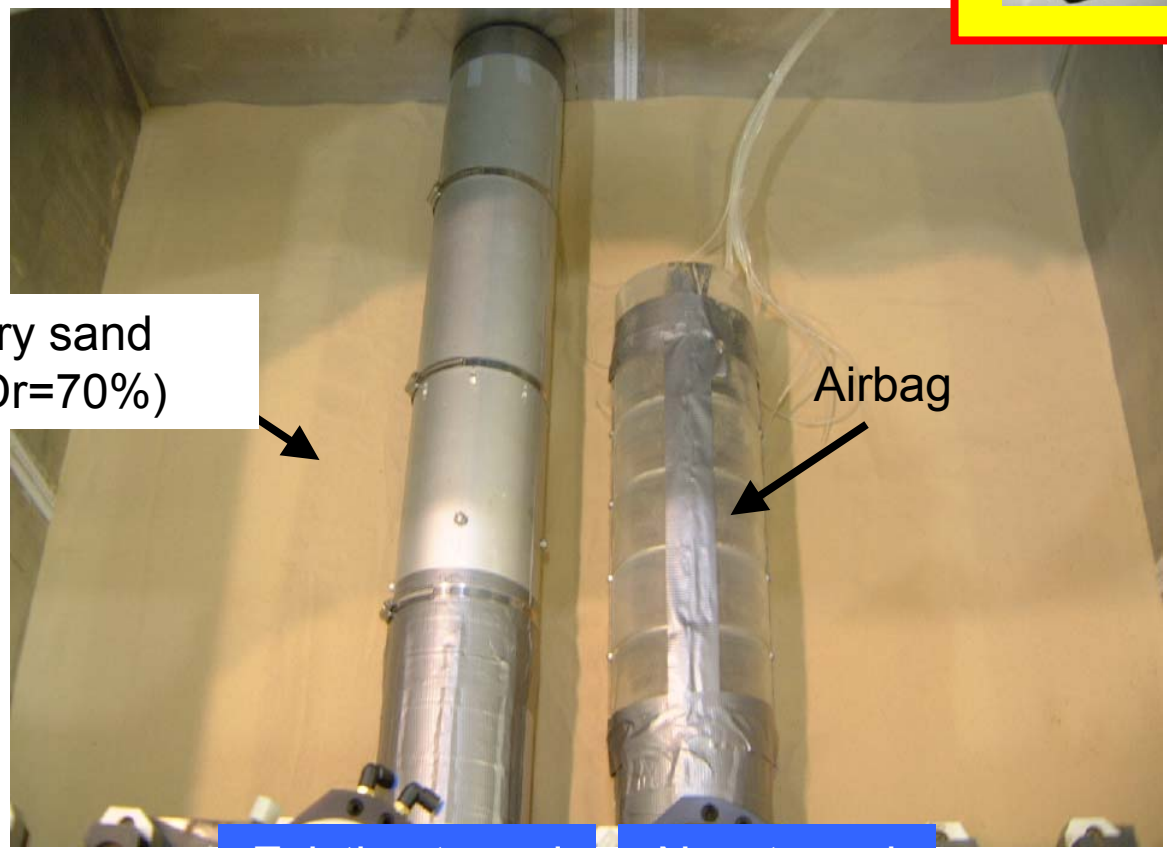
By

Hong Kong University of Science and Technology

# Model Package

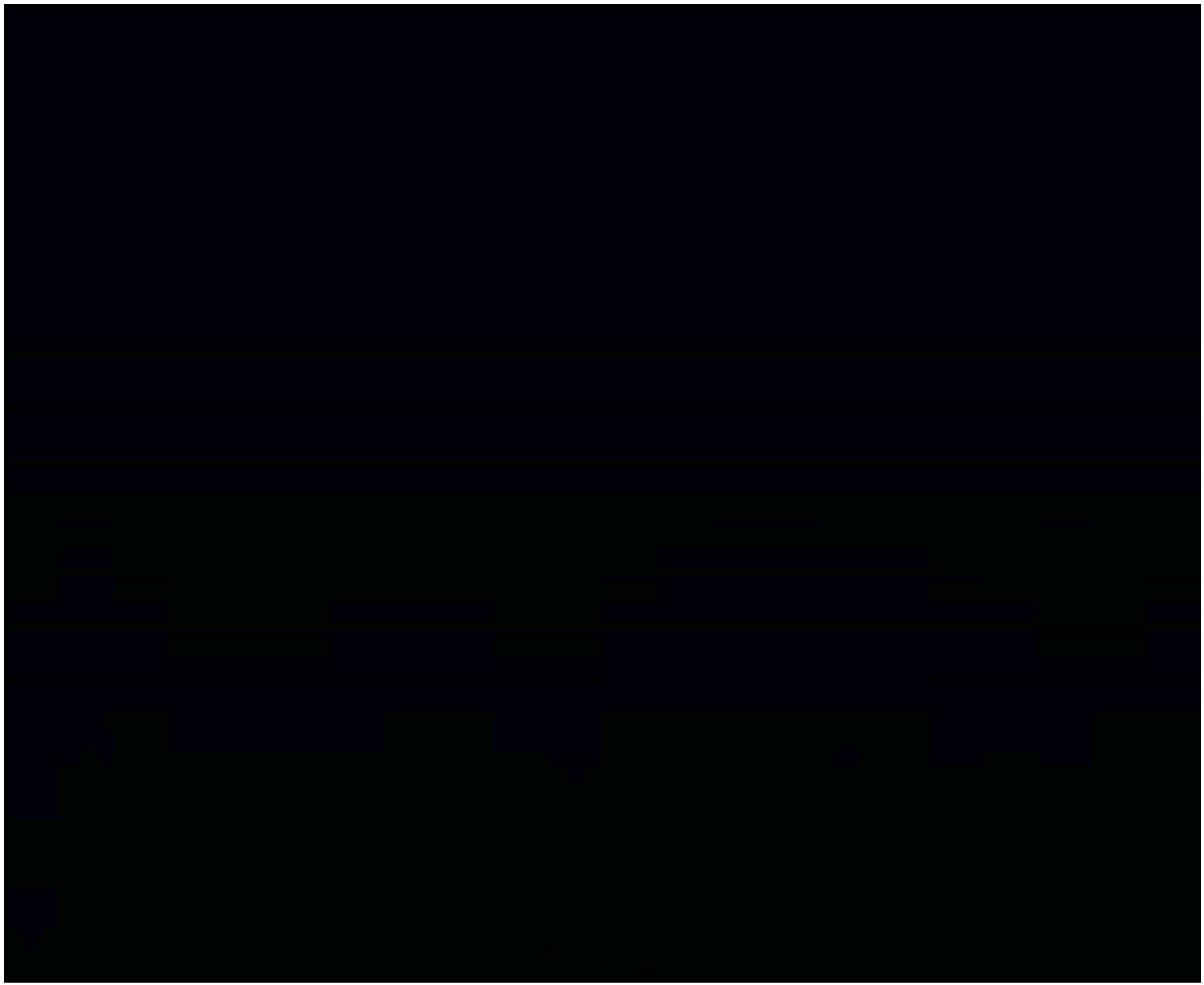
Airbag



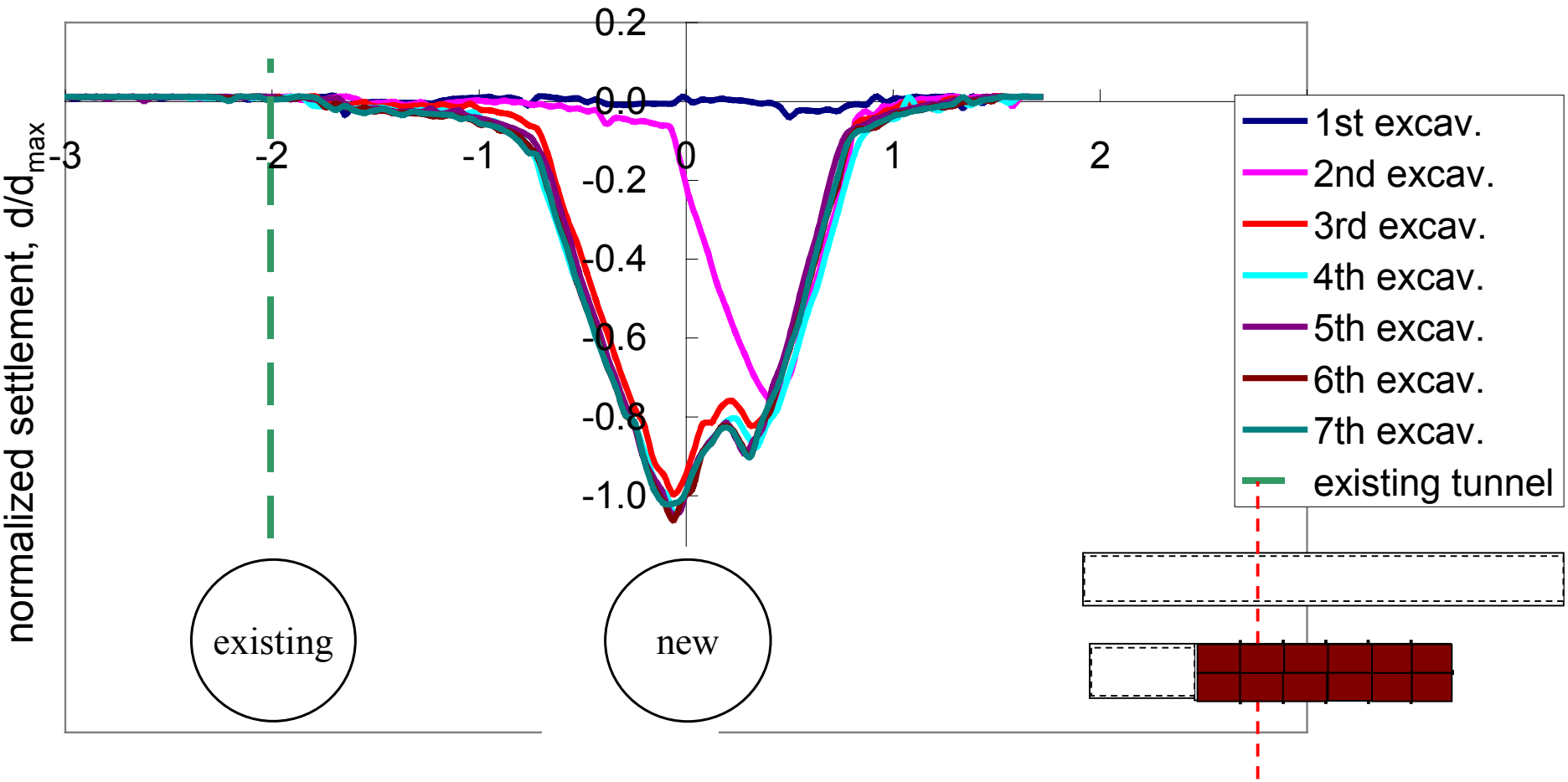



9m diameter
NATM tunnel

Spacing=9m



# Transverse Settlement



# Summary

- Innovative tools and modelling techniques such as multi-ball dropping system for vibration simulations, combined loading and displacement system (H, V & M), in-flight excavation and tunnelling techniques
- Use of 4-axis robotic system and biaxial shaking table
- Widening of geotechnical centrifuge applications such as static liquefaction of slopes, vibrations due to HS trains, correction of building tilt, ship impact on pier and land reclamation