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Use of Short Piles for Stabilizing the Side Slope of the Road Embankment along the Canal

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***Abstract*—**This research presents the behavior of slope of the road along the canal stabilized by short piles. In this investigation, the centrifuge machine was used, modelling the condition of the water levels in the canal. The centrifuge tests were performed at 35 g. To observe the movement of the soil, visual analysis was performed to evaluate the failure behavior. Conclusively, the use of short piles to stabilize the canal slope proved to be an effective solution. However, the certain amount of settlement was found behind the short pile rows.

***Keywords*—**Centrifuge test, slope failure, embankment, stability of slope.

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I. Introduction

THAILAND is a country with various resources, and water is critical to Thai people. [1], [2] Pathumthani province, located in the north of Bangkok, has several small canals. During the dry season, the road embankment along the canal always failed leading to this research to study the embankment behavior along the canal using Canal no.13 (Klong 13) as case study.

Fig. 1 Road along the canal no.13 collapsed

On the 2nd of March 2016, the road embankment along Canal no.13 (Klong 13) collapsed (Fig. 1) for approximately 100 m long. The canal at the failure area was found to be nearly dry, and a large water pond was found to be located near the failure section (Fig. 2).

Soil investigation was performed to determine the subsoil properties. Triaxial tests and vane shear tests were completed with the result as shown in Tables I-IV

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TABLE I
NORMAL STRESS AND SHEAR STRESS FROM UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Sample	Depth (m)	Normal Stress (t/m²)	Shear Strength (t/m²)
1	4.00 – 4.50	4.33	1.41
2	4.00 – 4.50	6.56	1.80
3	4.00 – 4.50	9.86	1.57
1	7.00 – 7.50	6.16	1.96
2	7.00 – 7.50	10.04	1.92
3	7.00 – 7.50	14.30	1.92

TABLE II
EFFECTIVE STRESS AND TOTAL STRESS FROM TRIAXIAL TEST

Depth (m)	Effective Stress		Total stress	
	C'cu (kPa)	Φ'cu (kPa)	Ccu (kPa)	Φcu (kPa)
5.00 – 5.45	12.67	11.46	9.61	10.85
7.00 – 7.45	20.16	10.12	18.13	9.43

TABLE III
FIELD VANE SHEAR TEST (I))

Depth (m)	Undisturbed Condition			
	Reading (div)	Su (t/m²)	PI (%)	Adj. Su (t/m²)
1.00	-	-	-	-
2.00	29	1.67	42.80	1.42
3.00	19	1.05	74.67	0.73
4.00	37	2.13	74.67	1.49
5.00	42	2.46	74.67	1.72
6.00	37	2.13	74.67	1.49
7.00	38	2.2	74.67	1.53
8.00	39	2.26	74.67	1.58

TABLE IV
FIELD VANE SHEAR TEST (II)

Depth (m)	Remolded Condition				
	Reading (div)	Su (t/m²)	PI (%)	Adj. Su (t/m²)	Sensitivity
1.00	-	-	-	-	-
2.00	7	0.36	42.80	0.31	4.64
3.00	5	0.26	74.67	0.18	4.04
4.00	6	0.31	74.67	0.22	6.87
5.00	7	0.36	74.67	0.25	6.83
6.00	7	0.36	74.67	0.25	5.92
7.00	10	0.51	74.67	0.36	4.31
8.00	77	0.57	74.67	0.40	3.96

Fig. 2 a. The collapsed areas b. Shrimp ponds

II. Methodology

The experiment used a centrifuge machine at Hong Kong University of Science and Technology, and a simulation of two clay layers, soft and stiff, was prepared by using consolidated and compacted kaolinite clay respectively [3].

The water level in the model, both in the canal and under the road embankment, was fully controlled by water tank system. Two sets of experiment were ready to compare between unreinforced road and that with its slope being stabilized by short piles.

III. Centrifuge Test

A. Detail of Model Boxes

1. Material Modelling

(a) Stiff and Soft Clay Layers

60-mm of stiff clay layer was prepared by compaction method while 230-mm of soft clay layer was prepared by on-flight consolidation to 35 g.

(b) CDG layer

Re-compacted from Beacon Hill, Hong Kong, Completely Decomposed Granite (CDG) with particle sizes larger than 2 mm was used for modelling as a road embankment [5] and was sieved in order to minimize any particle size effects in centrifuge tests.

2. Model Scaling

The actual dimensions of Klong 13 measurement are as:

- The width of road embankment is 5 m.
- The collapsed length is approximately 100 m.
- The canal is 4-m deep and 20-m wide.
- The side slope ratio is 1:2.
- The water level was found at the bottom of Klong 13 [4].

The modelling scale is shown in Table V.

TABLE V
THE SCALING DATA

Parameter	Prototype (m)	Modelling at 35 g (mm)	Material in Model
Height of stiff clay layer	2	60	Kaolin
Height of soft clay layer	8	230	Kaolin
Height of embankment layer	0.7	20	CDG
Depth of canal	4	115	-
Wide of slope	8	230	-
Wide of canal	5.425	155	-
Wide of embankment	2.975	85	-

3. Instrumentations

- PIV Camera: Located in front of the box to record the direction of soil movement.
- Laser: Record the settlement data.
- Pore Pressure water (PPT): Record the changes of water pressure.
- Water Tanks with flow control valve: Control the head of water while testing and the flow rate.

Fig. 3 illustrates the setup of instrumentations of both boxes.

B. Detail of Short Piles

When the piles were placed alternately, the soil between these piles were virtually not moving because of soil arching, expectedly that the two pile rows will acted as a retaining wall (Figs. 4 and 5).

- Pile length: 8 m (230 mm)
- Material: Aluminium
- Amount: 24 pieces

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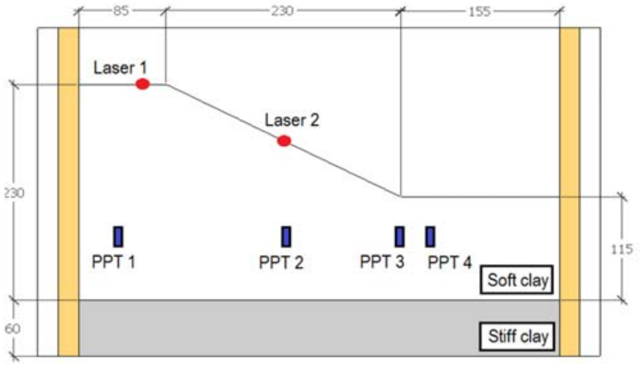
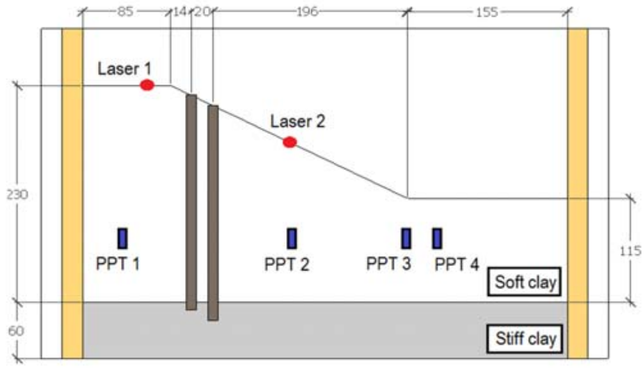


(a)



(b)

Fig. 3 The setup of instrumentations in both boxes (a) The box <u>without</u> reinforced piles (b) The box <u>with</u> reinforced piles

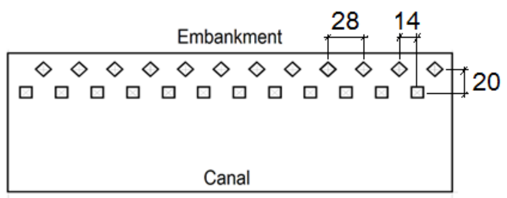


Fig. 4 Pattern of piles group

Fig. 5 Top view of piles group box

C. Test Procedures

1. After preparation of a soil sample and installation of the instruments, the model was spinned up to 35 g and then the water level was increased for 6 m to the bottom level of canal (6 m elevation).
2. The water level was then increased to 7 m elevation.
3. Only the water level in the canal was slowly decreased to the bottom of the canal (reduced to 6 m elevation). The reduction rate had to be slow enough not to cause a sudden drawdown failure.
4. Finally, the water level under the road embankment was slowly increased to the top level (about 9 m elevation) in order to represent the delay flow from the nearby pond.

IV. Research Result

The results of the centrifuge test can be classified into three states as (Fig. 6):

- State 1: Initial state, after soil preparation but before being spinned up to 35 g.
- State 2: Water level changes according to test plan but before CDG was added:

1. In the box <u>without</u> reinforced piles, the soil moved down the slope, and the failure plane was found.
2. In the box <u>with</u> reinforced piles, the soil behind short pile rows moved vertically, but no failure plane was observed.

- State 3: The final step, CDG was added to represent the embankment road:

1. In the box <u>without</u> reinforced pile, the slope failure was clearly shown (Fig. 7).
2. In the box <u>with</u> reinforced pile, the soil behind short pile rows moved vertically. Although, more settlement was found and the piles moved slightly, failure plane was not found (Fig. 8).

V. Conclusion

The results of the centrifuge test were summarized as:

1. The slope failure was found in the unreinforced slope when groundwater was raised up because of the delay flow.
2. Reinforced piles forced the road embankment to road embankment moved vertically instead of horizontally.
3. CDG weight exerted on the road embankment affected both horizontal and vertical movements.
4. The alternated piles presented the piles group behaved as a retaining wall.

Conclusively, the use of short piles for stabilizing the side slope of the road embankment along Klong 13 was successful.

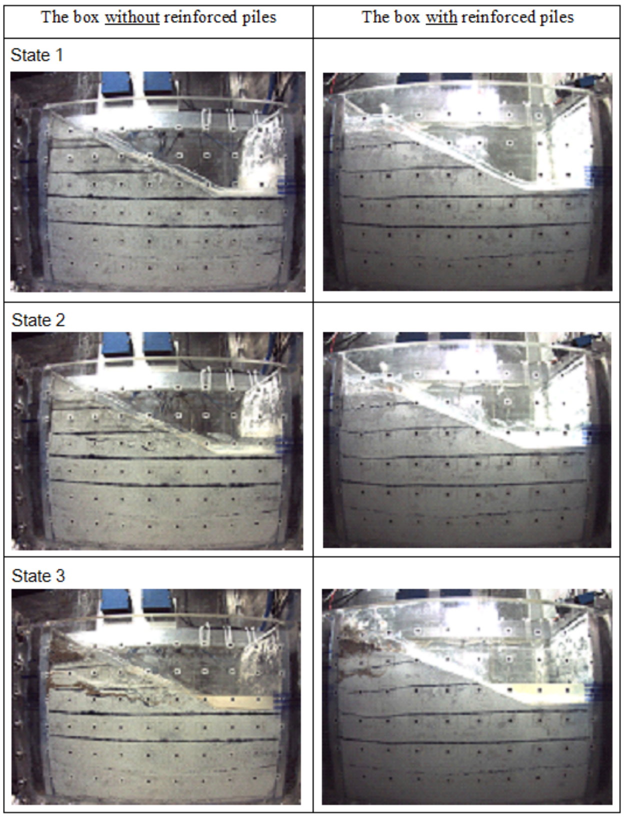


Fig. 6 The results of testing

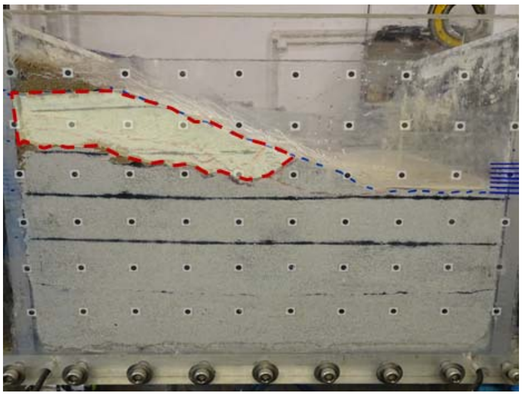


Fig. 7 Failure plane in the box without reinforced piles

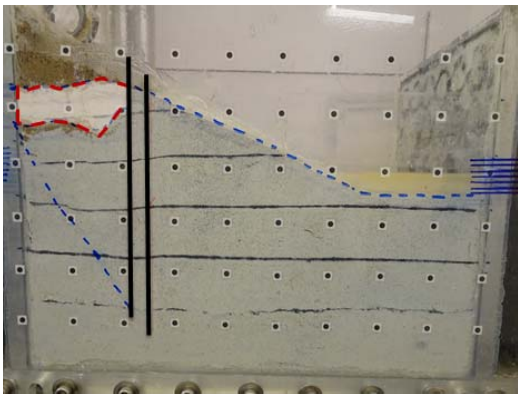


Fig. 8 The vertical settlement area in the box with reinforced piles

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