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Bored Pile Behaviour under Lateral Load Testing in Stiff Clay Instrumented with Inclinometer

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Abstract— Pile under lateral load test is a soil-structure interaction where the deflection will depends on soil response. The purpose of this study is to see the behaviour of bored pile displacement and bending moment with 1% reinforcement. The study is carried out in a stiff clay soil. The bored pile with 30-cm diameter and 12-m length was cast underwater using tremie method. Pile was reinforced under 1% reinforcement area to the pile area using 4 bars of D 16 mm rebar. Pile is instrumented using inclinometer to the bottom of the pile. The test was conducted follow ASTM D3966 until 10 cm displacement reached. Analysis done by using finite difference method with LPile software developed by Reese et al. and the instrumentation result calculated following Ooi proposed. Result shows that degradation to lateral strength occur under cyclic lateral load and varies to the displacement. The experimental results confirmed the calculated displacement and maximum bending moment, therefore the parameter use in this study appropriate to reflect the behaviour of pile under lateral load test.From curvature of displacement and bending moment for both analytical and experimental, shows location of fixity point at about 6 times diameter.

Index Terms— Cyclic Lateral Load Test, displacement, bending moment, fixity point.

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1 Introduction

THE deep foundation might subjected to lateral load, thus it shall designed to be able to carry those lateral load. Reese, et al. (1993) stated that lateral load is a soil-structure interaction where the deflection will depends on soil response and vice versa. This paper presents the analysis of a single pile instrumented with inclinometer under lateral load. The pile is bored cast-in-situ with 30-cm diameter and 12-m depth. Pile was reinforcered with 4 bars D 16 mm main rebar and D13 spiral rebar with 150 mm spacing. The compression strength of the concrete equal to 30 MPa.The moment of inertia, I, was computed as 0.000397 m^4, pile modulus, E_p calculated as 25700000 kN/m^2, its bending stiffness, E_pI_p, was 10200 kN-m^2.

2 Project Data

2.1 Soil Investigation Data

The data on properties of stiff clay at the test site was obtained from Standard Penetration Test (SPT) as shown in Figure 1 with its properties presented in Table 1. The soil profile consisted of stiff silty clay with SPT N-value variated from 10-16. The clay has a total unit weight of 16 kN/m^2, and the undrained shear strength of 48 kPa. The water table was at depth of 1.0 m. a value of ε_{50} of 0.007 was selected according to Reese (2011)

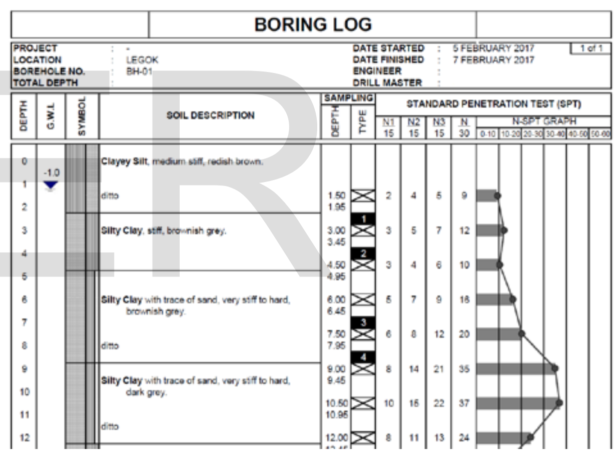

Fig. 1. Test pile and geotechnical investigation layout.

2.2 Test Pile Data

The 12-m bored pile was reinforced using 4 bars of D 16mm. The pile was installed together with 70-mm inclinometer pipe.

TABLE 1
PROPERTIES OF SOIL

Depth (m)	SPT (-)	Total Unit Weight (kN/m^3)	Undrained Shear Strength (kN/m2)	Soil Type
2.5	12	13	-	Silty Clay
4	10	15.6	48	Silty Clay
7	16	16.7	-	Silty Clay

Compressive strength of the concrete equal to 30 MPa. Area of steel was about 1% of area of the pile. Pile was grouted under

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water using a low-pressure pump and tremie pipe to the bottom of the shaft. Figure 2 shows the test pile loading configuration based on ASTM D3966 - 07.

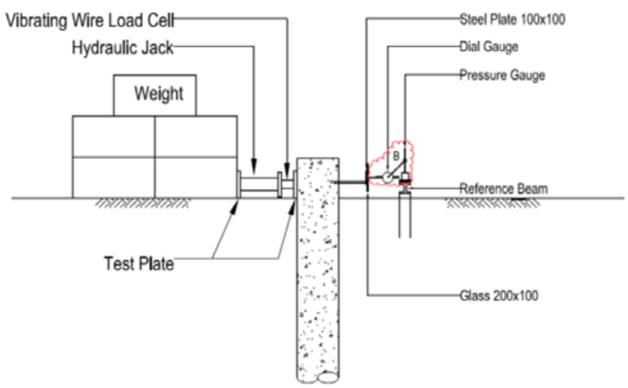

Fig. 2. Test pile loading configuration.

2.3 Instrumentation and Measurement Setup

Figure 3 shows the actual loading setup under reciprocal test load. Kentledge load was loacated at (2) sides of the pile with three times of contra load used to make sure no movement occur during the test. Pile head was cleaned and the load was centric to the inclinometer pipe. Two hydraulic jack simultanous with 30 Tons capacity was used and read using a calibrated manometer with accuracy of 100 psi. A calibrated load cell with 25 Tons capacity also used to make sure the actual load during test. Two displacement transducer use to measure the pile movement under lateral load at each direction. All displacement transducer was put in an independent reference beam. The Inclinometer pipe located in the center of the setup.

Fig. 3. PDA continues monitoring result.

3 Pile Behaviour under Reciprocal Load Test

The pile was subjected to reciprocal cyclic with increasing to its lateral displacement until 10 cm planned displacement reached. The cyclic load history, later could influence the degradation of its lateral strength. This degradation will later varies with the displacement (Haselton et al. 2008).

4 Test Result

4.1 Load Displacement Result

The load was conducted in right-left direction. Measurement of load-displacement at pile head was done under maximum load of 4 tons with maximum displacement recorded was 78 mm and 114 mm.

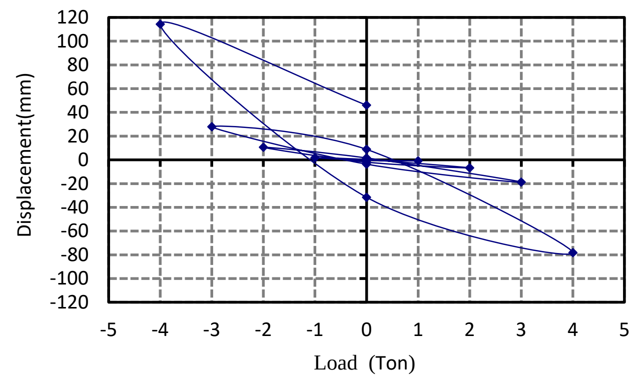

Fig. 4. Load – Displacement Curve.

Figure 4 shows measured load-displacement backbone curve. The displacement and load for each cycle are summarize in Table 2.

TABLE 2
DISPLACEMENT UNCER CYCLIC LOAD

Load (Ton)	Displacement Right (mm)	Displacement Left (mm)
1	0.85	1.71
2	6.75	10.59
3	18.76	27.92
4	78.28	114.32

4.2 Displacement and Bending Moment Curves from LPile (2005)

The free-head response simulated by using LPile to calculate the displacement and bending moment. The experimental p-y curves derived from bending moments along the pile depth and later integrated to obtain lateral displacement (y) and double integrated to obtain the soil resistance, p.

Fig. 5 presents the calculated displacement-depth under 3 Tons load. The analysis shows that nearly 20 mm displacement will occur when calculated using p-y curves for stiff clay with point of fixity located at about 1.8 m from ground level or approximately 6 times of pile diameter.

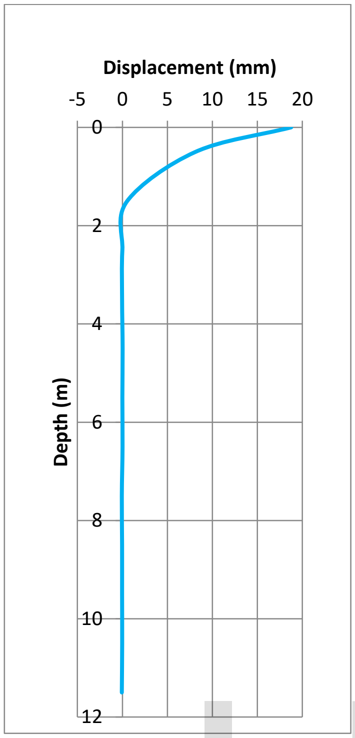

Fig. 5. Displacement vs Depth under 3 Tons Load

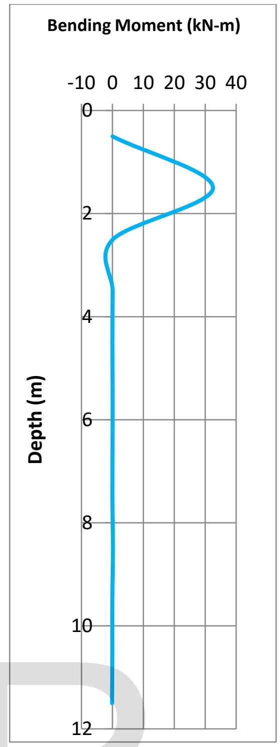

Fig. 6. Bending Moment vs Depth under 3 Tons Load.

Fig. 6 presents the curvature of bending moment occurred under the same 3 Tons load where the maximum moment occur at depth of 1.8 m where the displacement nearly zero. This is also the main objectives of the experiment, where not only displacement and maximum bending moment occur on pile top, but also the distribution of moment along pile depth. The curve in Fig. 6 clearly shows that no significant bending moment still occur up to depth of 1.8 m – 2.0 m.

4.3 Displacement and Bending Moment Curves from Inclinometer Measurements

The analysis later compare with the measurement by inclinometer during test pile. The displacement measured using Geokon Inclinometer type 6000 and recorded every 0.5 m depth interval. The displacement obtain from inclinometer can be use to calculate the slope. Ooi and Ramsey (2003), proposed Eq. 1 to calculate the slope.

$$Slope(\kappa) = \frac{\psi_A - (2 * \psi_B) + \psi_C}{L^2} \quad (1)$$

And bending moment were calculated from the slope value as shown in Eq. 2.

$$M = EI \times \kappa \quad (2)$$

Where κ is the slope (1/m), ψ is the cummulative deviation, L is the inclinometers reading interval and EI is the flexural rigidity of pile. Figure 7 shows the result of inclinometer displacement reading under 3 Tons load compared to LPile result and Figure 8 shows the calculated bending moment. The resulting of displacement and bending moment, shows a good trend compared to the calculated LPile results.

By using the finite difference method, the soil reaction clearly shows a good correlation from LPile and experimental result. The maximum bending moment occur at location of 6 times diameter as well as the maximum displacement

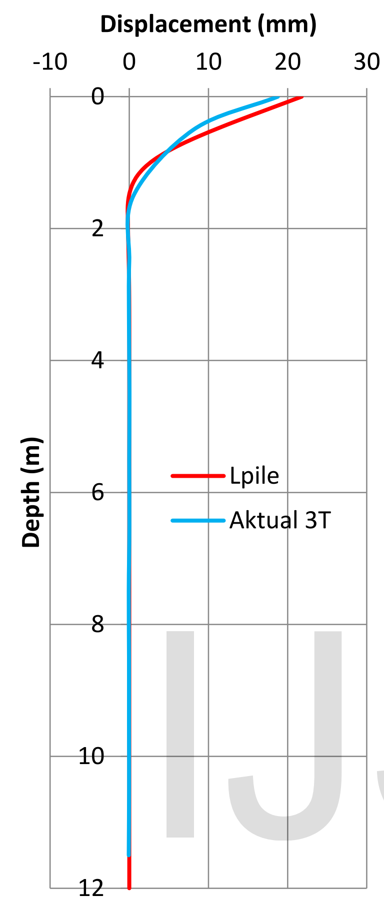

Fig. 7. Comparison of Displacement Distribution for LPile and Inclinometer Measurement.

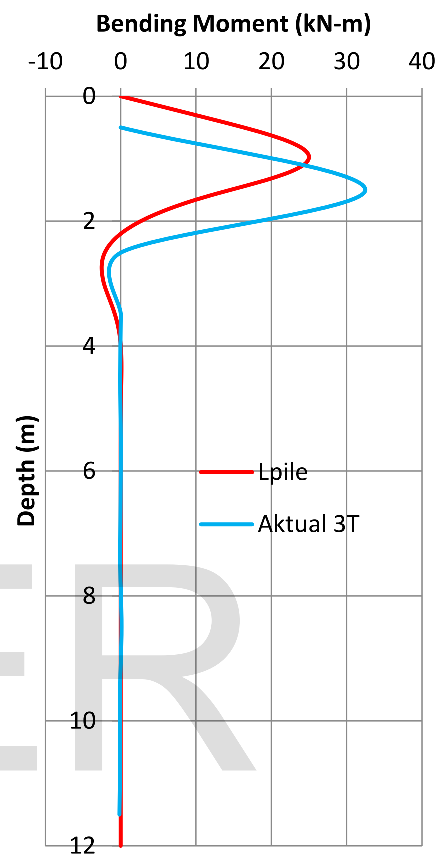

Fig. 8. Comparison of Calculated Bending Moment Distribution for LPile and Inclinometer Measurement.

7 Conclusion

The study shows that degradation to lateral strength occur under cyclic lateral load and varies to the displacement. The experimental results confirmed the calculated displacement and maximum bending moment, therefore the parameter use in this study appropriate to reflect the behaviour of pile under lateral load test

From curvature of displacement and bending moment for both analytical and experimental, shows location of fixity point at about 6 times diameter.

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