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Lateral Soil Movement Due to Installation of a Single Pile using Jack-in Method

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Abstract. Lateral movement of soil due to the installation of a single pile using jack-in method was studied. The piles considered in this study were 15 piles of the diameter 800 mm. The lateral soil movement was predicted using Plaxis 2D, which incorporated cavity expansion theory as prescribed displacement. The results were compared to the recorded data from the field and those determined using several formulas. The comparison shows that the lateral movement of soil due to the installation of a single pile can be closely estimated using Plaxis 2D that employed a linear prescribed displacement of 0.42*r* at the pile head and zero at the pile tip. Lateral displacement of soil predicted using Plaxis 2D agrees well with data measured from the field both at the ground surface and along the depth of piles.

Keywords: cavity expansion, PLAXIS 2D, jack-in method, lateral soil movement

1. Introduction

Jack-in is an alternative method to install piles. The method is also called silent piling since there is no noise and no vibration during the pile installation so that it produces low pollutant [1]. Despite its advantages, the jack-in method requires a hard layer of fill to support its own weight. It is also unable to install piles with pile head elevation above the ground level, unable to install pile close to the wall, and unable to install piles around the corner that bordered by walls. In addition, like all displacement piles, this method still generates lateral soil movement around the installed piles. Song [2] stated that lateral movement affected by the number of installed piles, the thickness and depth of the soft soil layer.

Numerous formulas to predict the lateral displacement of ground surface due to pile installation have been published. Randolph et al. [3] derived theoretical formulation for lateral soil displacement on the ground surface based on the assumption of plane strain and purely radial deformation at constant volume. The radial displacement can be calculated by the following equation:

$$\delta/r \quad = \left[\left(R/r\ \ ^2\right)+1\right]^{1/2} - R/r \tag{1}$$

where δ = radial displacement (m); R = radial distance from pile (m); r = pile radius (m). It can be seen that Randolph et al. [3] do not consider the length of the pile in his formula.

In contrast to the formula derived by Randolph et al. [3], Sagaseta [4] considered the length of the pile to calculate the radial movement of soil on the ground surface due to the installation of a single pile. This formula is given as

$$\delta \ = \frac{r^2}{2} \cdot \frac{L}{R.\sqrt{R^2+L^2}} \tag{2}$$

where r = pile radius (m); L = pile length (m); R = radial distance from pile (m); δ = radial displacement (m).

Olsson and Holm [5] derived a formula for determining the lateral displacement of the ground surface subjected to the installation of a pile group. The lateral movement of soil (δ_h) on the ground surface is assumed the same to that vertical movement (heaving, δ_v). The lateral displacement of soil due to the pile installation may extend up to a distance as far as the depth of pile (Figure 1).

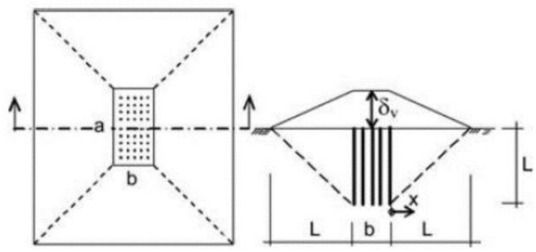

Figure. 1. Illustration of Horizontal and Vertical Displacement
Source: Olsson & Holm (1993) [5]

where L = pile length (m); a, b = length and width of pile group (m); x = distance from the pile group $(0 \leq x \leq L)$ (m).

Zhu [6] utilized the cavity expansion theory in semi-infinite space to calculate the lateral displacement of soil layer due to the installation of a pile. The soil is assumed to have Poisson's ration of 0.5. The radial displacement (u_r) of soil layer due to pile installation at any elevation along the depth pile is presented in Eqs. 3-6:

$$u_r = \frac{D^2.R}{16}\left(I_1(L)\right) + I_2(L) - 6.z.I_3(L)) \tag{3}$$

$$I_1(L) = -\frac{z-L}{R^2\sqrt{(z-L)^2+R^2}} + \frac{z}{R^2\sqrt{z^2+R^2}} \tag{4}$$

$$I_2(L) = \frac{z+L}{R^2\sqrt{(z+L)^2+R^2}} - \frac{z}{R^2\sqrt{z^2+R^2}} \tag{5}$$

$$I_3(L) = \frac{1}{3}\left[-\frac{1}{\sqrt{\left((z+L)^2+R^2\right)^3}} + \frac{z}{\sqrt{\left(z^2+R^2\right)^3}}\right] \tag{6}$$

where, D = pile diameter (m); L = pile length (m); R = radial coordinate (m); z = vertical coordinate (m).

Maryono [7] performed a parametric study of modelling of 5000 square piles (L = 45 m) installation using Plaxis 2D to determine the lateral displacement of surrounding soils. The pile installation sequence was applied moving from back rows to the front with a prescribed displacement of 20 cm each pile row. It was assumed that surrounding soil affected by pilling activities was equal to the pile length. It was concluded that the radial movement of soil depends on the distance from the installed pile and the sequence of pile installation.

Triarso [8] carried out a research about lateral movement of clay due to pile group installation. Lateral displacements due to pile group installation, that was predicted using Plaxis 2D & 3D that incorporated cylindrical cavity expansion theory as prescribed displacement, were then compared to the inclinometer results. It was reported that by applying a prescribe displacement between 0.21*d* to 0.25*d*, the lateral movement of the surrounding soil was affected by the pile diameter, the volume of penetrated piles, and the sequence of pile installation.

The previous works mostly focused on lateral movement developed due to pile group installation. This paper presents the prediction of lateral soil movement due to the installation of a single pile using a jack-in machine. The study was conducted at two different piling areas, namely Project I and Project II.

2. Conditions of the Site

The soil profiles and standard penetration test (SPT) blow counts (N-SPT) for Project I and Project II is depicted in Figures 2 and 3, respectively. The soil layers in Project I are dominated by clay layers. The water level is at 1.8 m below the ground surface. While in the Project II, the first 10 meter of soil consists of soft clay which underlain by 5 m of sand. It is also underlain by stiffter layers of silt and sands. The water level is at the depth of about 2 m below the ground surface.

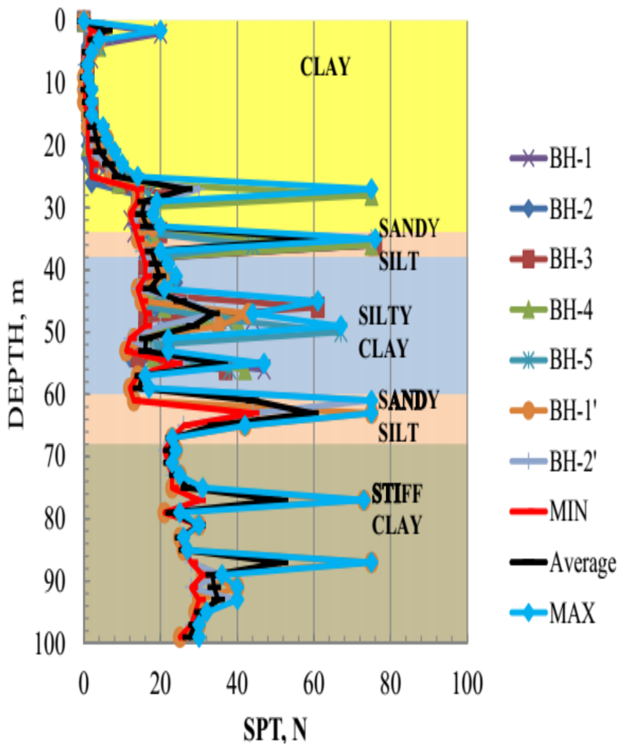

Figure. 2. N-SPT vs. Depth of Project I

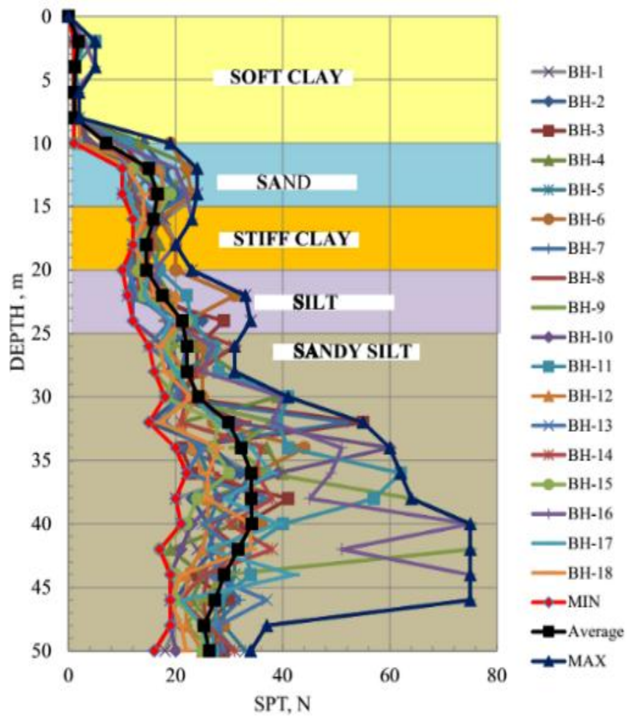

Figure. 3. N-SPT vs Depth of Project II

3. Measurement of Lateral Displacement of Soil

The lateral movement of surrounding soil due to single pile installation was recorded using inclinometer that embedded into the ground up to the depth of 50 m. The plan views of inclinometers and pile locations for both projects are presented in Figures 4 and 5.

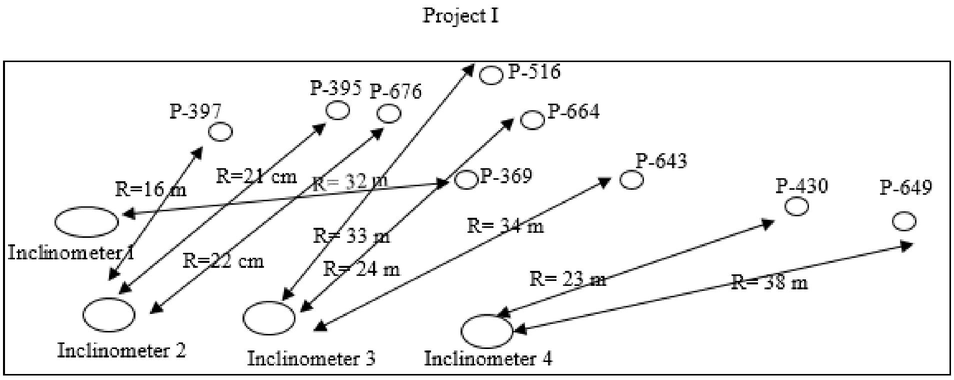

Figure. 4. Sketch of the Location of Inclinometer and Piles in Project I

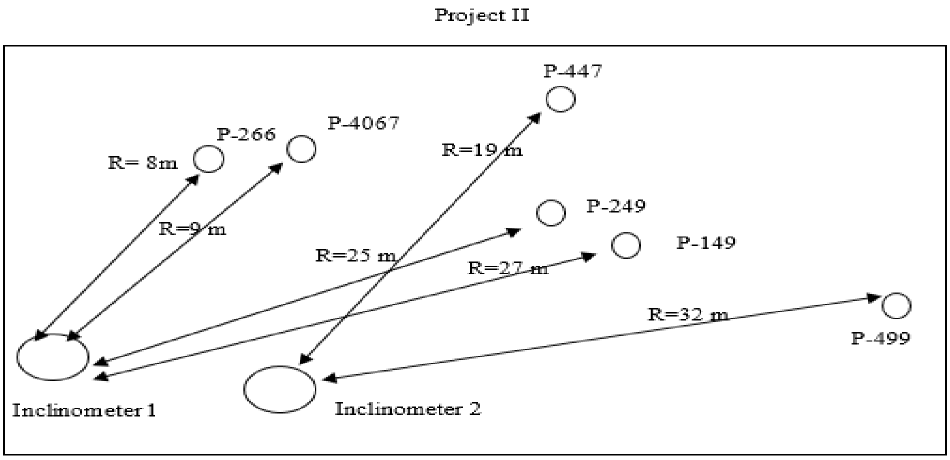

Figure. 5. Sketch of the Location of Inclinometer and Piles in Project II

The distance between pile (R) and the inclinomete varied from 8 m to 38 m. The data of lateral displacement were taken before and after installation of pile. The diameter of pile was Ø 800 mm and the depth of pile tips varied from 34 m to 47 m.

4. Parametric Study

Plaxis 2D was used to simulate the effect of a single pile installation to the movement of surrounding soil on both projects. Input datal for Plaxis 2D, such as c (cohesion) and ϕ (internal friction angle), γ (soil unit weight), E (Young modulus), and v (Poisson ratio) were determined based on the N-SPT correlations. The value of prescribed displacement was calculated by assuming that the volume of penetrated pile equals to the volume of displaced soil. Therefore the prescribed displacement used for input data was $0.42r$ and that at the pile tip was zero. The soil was modelled as an axisymmetric mesh having Mohr-Coulomb material model. The soil condition was assumed as undrained and drained for clay and sand layer, respectively.

5. Results and Discussions

5.1 The Lateral Displacement on The Ground Level

Figures 6 and 7 show the measured and computed lateral soil movement with the distance from the installed piles, in Project I and Project II, respectively.

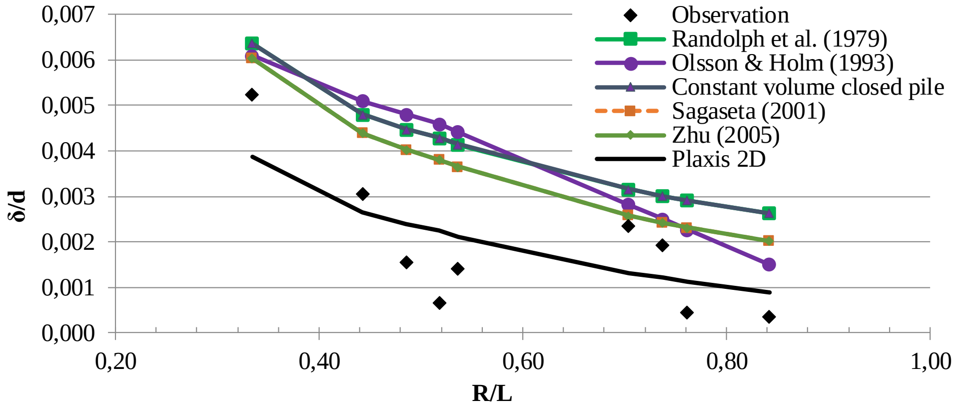

Figure. 6. Lateral Displacement of Soils in Project I

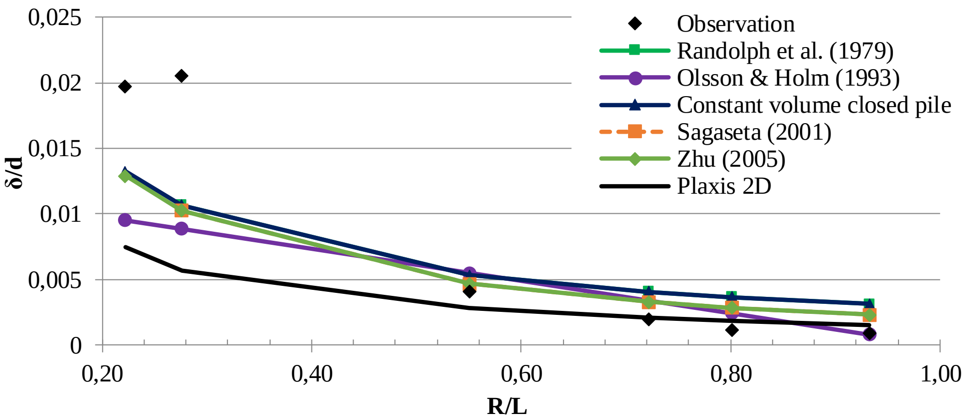

Figure. 7. Lateral Displacement of Soils in Project II

Figure 6 shows that the recorded lateral movement soil in Project I, that was dominated by clay layers is lower that those predicted using several formulas. While the prediction of lateral movement of soil in Project II that consists of clay at the upper layer and sandy layer at the lower layers agrees well to the recorded lateral soil movement. The lateral displacement of soils predicted using Plaxis 2D exhibits similar trend to those calculated using formulas and recorded in the fields.

5.2 The lateral displacement of soil along the depth of piles

Figures 8 and 9 show the lateral displacement of surrounding soil along the depth of pile in Project I and Project II, respectively. It can be seen that the lateral displacement of soil predicted using Plaxis 2D agrees relatively well to the recorded data.

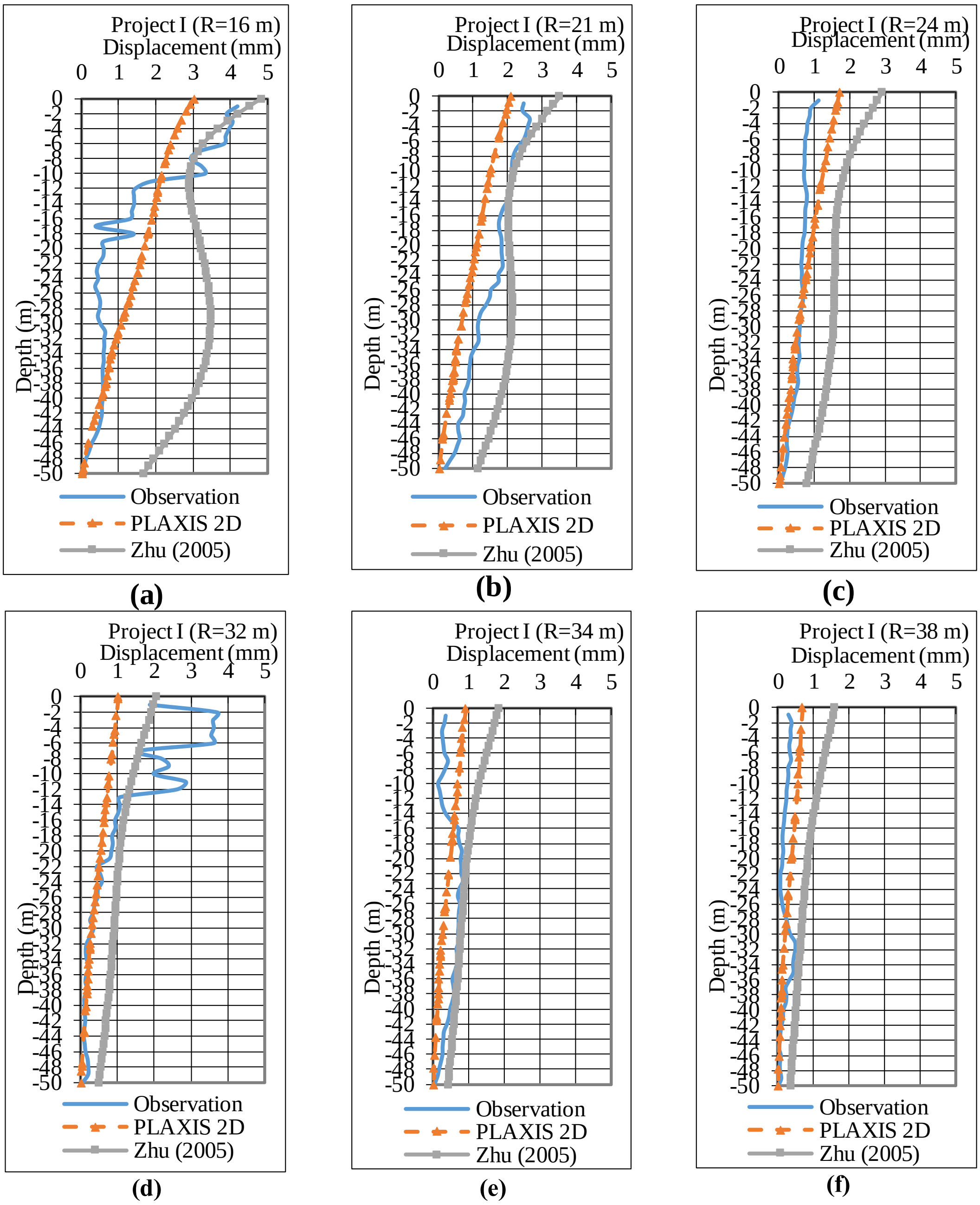

Figure. 8. Lateral Movement Results Obtained from Inclinometer, Zhu (2005), and PLAXIS 2D due to the 800-mm-Diameter Pile Installation in The Project I

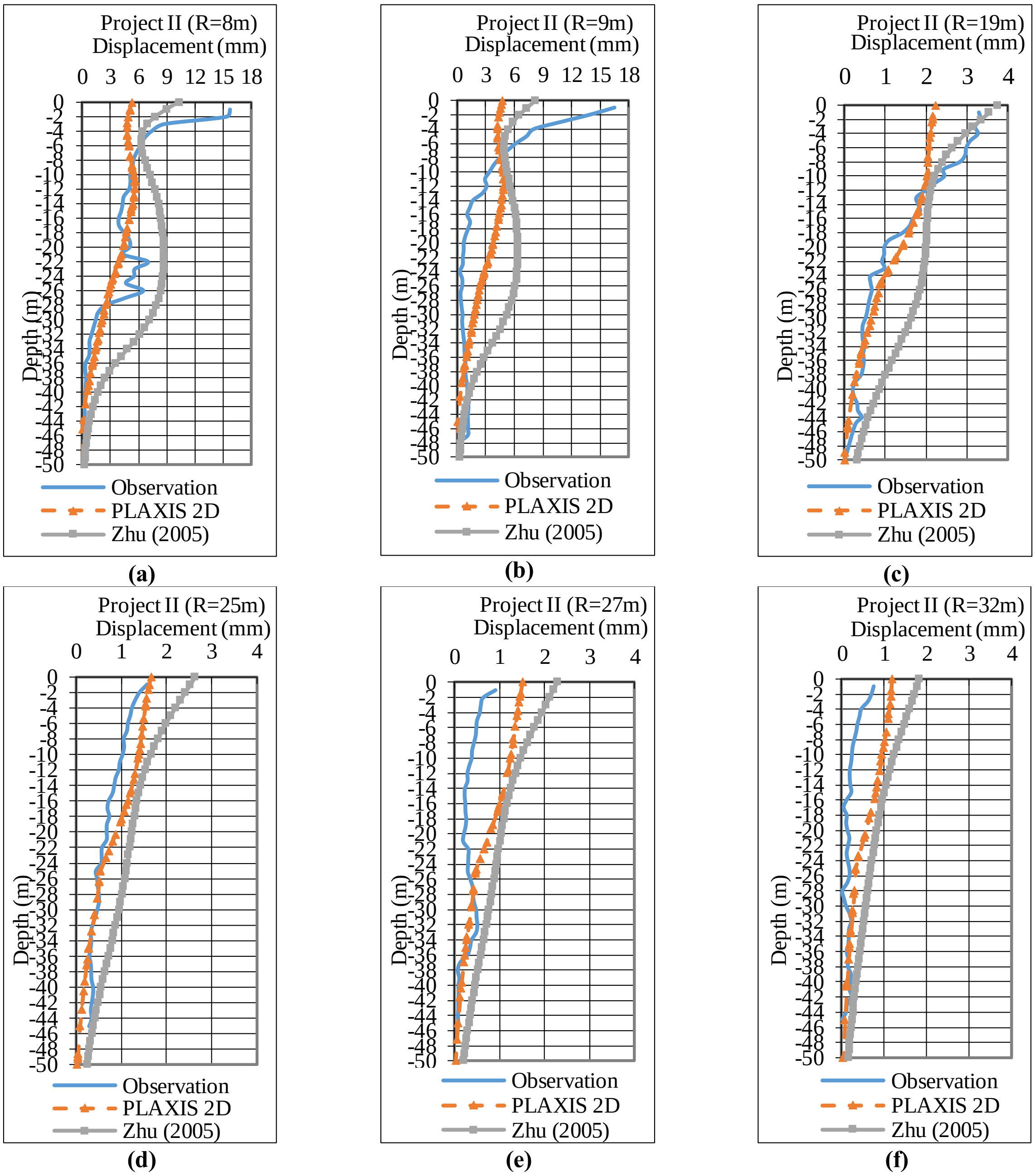

Figure 9. Lateral Movement Results Obtained from Inclinometer, Zhu (2005), and PLAXIS 2D due to the 800-mm-Diameter Pile Installation on the Project II

The discrepancy of the lateral soil movement is noticed mostly at the ground level. It might be caused by the effect of surcharge pressure from the weight of the injection machine. The lateral movement of surrounding soil along the depth of pile predicted using Zhu's formula is quite close to that recorded from the field, eventhough it does not consider the type of soil layers.

6. Conclusions

The lateral movement of soil along the depth of pile subjected to single pile installation can be predicted using Plaxis 2D that incorporated prescribed displacement of 0.42*r* at pile head and zero at the pile tip.

The recorded data of lateral soil movement at ground surface in the area that dominated by clays lower than those predicted using the lateral displacement formulas. While the lateral displacement in the area that consists of clay at the upper layer underline by sandy soils can be well predicted using theoretical formulas.

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