III-380 SOIL STRUCTURE INTERACTION OF A LATERALLY LOADED MINIPILE

Toyohashi University of Technology member ○KOMATSU Hirokazu
Perak Water Supply Department, Malaysia WONG Mok Far
Toyohashi University of Technology member NIIRO Tadashi
Japan Minipile Association TUZUKI Tomio
Toyohashi University of Technology member KURIBAYASHI Eiichi

1.Introduction The objective of this paper is to study the behavior of a minipile being subjected to an external lateral load, applicability of the existing available solutions to predict the behavior, and derived a solution that better suit characteristics of the minipile. The minipile is confined to pile with embedded length less than three meters and diameter less than about twenty centimeters. The minipile generally fall under the category of finite length type of pile, and accordance to its embedment, it can be further divided into short pile and transition pile.

2.Literature Review The behavior of a pile can be evaluated either by loading test, existing available data, analytical method, or combination of the methods. Basically two group of analytical methods are currently available for evaluating behavior a pile in particular and minipile in general. The first group is the solution by stability analysis which is often adopted for short pile. The solution is generally independent of pile deflection and intermediate behavior cannot be predicted. The ultimate behavior can be estimated by taking forces equilibrium with an assumed predetermined shape of soil reaction. The second group of solution often adopt a differential equation for a beam resting on an elastic medium as a start. Closed form solution only available if simplification to pile and soil properties are made. The solution generally using horizontal subgrade reaction to replace the actual soil response which is experimental confirmed being influenced by diameter of pile, boundary condition, and deflection of pile or applied load level. The horizontal subgrade reaction has been found inversely proportion in a range between third square root and one pile diameter, and in a range between third square root and one pile deflection. The differential equation often give analytical difficulty for short length of pile.

3.Formulation and Derivation The main behavior that required for designing the minipile is the maximum lateral resistance, and in some cases deflection at ground surface and moment. This paper proposed a solution by idealizing a three dimensional behavior of soil with two parabolic equations which were solved by considering equilibrium of forces and continuity conditions. The solution adopting a linear elastic perfectly plastic soil behavior, with soil surface discontinuity had been replaced by a three dimensional failure wedge, and horizontal subgrade reaction was purposely avoided.

4.Comparation with test result The proposed solution was compared to some representative solutions, scale down test results published by the Port and Harbour Research Institute,(Table 1), and thirty one cases of field tests carried out by this University(Table 2). The results concluded that with proper value of passive resistance, the behavior can be estimated confidently for piles that fall under both the short and transition ranges.

The proposed solution may be used to predict increase of lateral resistance due to enlargement of pile diameter near ground surface, and pile group efficiency. The minimum longitudinal spacing estimated(Table 3) for unity efficiency coincide with experimental results obtained by other investigators(Figure 1). Due to nature of the proposed solution, the actual estimated minimum spacing would be less than the value in Table 3.

<u>5.Simulation by the finite element solution</u> The 2-D finite element solution was used as a research tool to study the progressive failure of soil. The result confirmed the assumptions made for the proposed solution, and behavior of the minipile is greatly influenced by yielding zone near the ground surface.

<u>6.Conclusions</u> A particular solution is required to estimate behavior of the minipile. A solution was proposed and compared with the existing representative solutions, existing published data and field tests carried out by Toyohashi University of Technology. Further, simulation by the 2-D finite element method also been carried out. This study concluded that the proposed solution estimated the behavior of the minipile close to the test results, and can be adopted for the minipile with embedment fall under both short and transition ranges.

Table 1. Comparative result witn model test(Takahashi.K,Kubo.K)

Total Length = 2.0(meters)				
Diameter = 0.508 (meters)				
Kp=8.3 ; ϕ= 40° γ=1.1g/cm³ ; δ= -15°				
L(meter)		1.83	0.85	1.95
Eccentricity		0.12	0.10	0.0
Test Result	Hy	1.4 (t)	1.5 (t)	1.6 (t)
Solution	H	1.49 (t)	1.54 (t)	1.81 (t)
Ratio H/Hy		1.06	1.03	1.13

Kp=50 ; ϕ = 45° ; γ = 1.78 g/cm³							
D (cm)	h (cm)	L (cm)	L / L_{m0}	Hy (kg)	H (kg)	H/Hy	% increase for 30 in resion I
7	15	31.5	0.68	20.3	20.0	0.99	40.
7	10	54.8	0.96	118.5	105.0	0.89	22.
7	10	44.8	0.76	59.5	59.0	0.99	29.
7	9	35.5	0.70	31.0	33.0	1.06	36.
7	38.5	36.5	0.83	25.2	19.0	0.75	42.
5.09	15	48.0	0.66	61.6	53.0	0.86	23.
10.5	10	60.0	0.56	245.9	246.0	1.0	

Note : Kp=passive coefficient
Hy=maximum lateral load by model test
H =maximum lateral load by the proposed solution

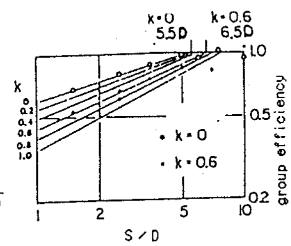

Fig.1. Minimum pile spacing by Tamaoki

Table 2. Results from the proposed solution and field tests

Kozakai site : for soil data Unit weigth of soil is taken as 1.8 t/m³							T.U.T site : boring data γ=1.5t/m³ ; C_u=5.38t/m²			T.U.T site : boring data γ=1.5t/m³ ; C_u=2.0t/m²		
D (cm)	L (cm)	solution ϕ=37°	solution ϕ=40°	Broms ϕ=40°	Engel ϕ=40°	Field tests	solution	Broms	Field tests	solution	Broms	Field tests
16.52	200.	1.5 t	2.0 t	'2.46t	*1.16t	2.0 t	4.27t	*3.0 t	2.0t	1.59t	*2.42t	2.0t
16.52	100.	0.45	0.5	0.39	**	1.0	2.3	0.79	2.0	0.85	0.29	1.8
13.98	200.	1.3	1.75	'1.66	*0.98	1.5·2.	3.39	*1.89	2.0	1.28	*1.43	1.7
13.98	100.	0.4	0.48	0.33	**	1.0	1.76	0.79	2.0	0.65	0.29	1.3
10.16	200.						2.22	*0.97	0.9			
10.16	100.	0.16	0.45	0.24	**	0.7	1.08	0.67	1.0	0.40	0.25	1.0
10.16	50.	0.0078	0.05	0.168	**	0.35	0.15	0.15	0.5	0.15	0.05	0.5

note : a)' value calculated based on σ=41kg/mm²
b)* value calculated by Engel solution.
c)** represents value cannot be estinated due to lialtation of Engel solution.
d) solution = the proposed solution

Table 3. Typical longitudinal spacing

	internal angle ofriction(°)					
	30.	32.	34.	36.	38.	40.
Spacing	6.9D	7.7D	8.5D	9.4D	10.4D	11.6D

nate : D is diameter of pile