Experimental study on the side load transfer of model H piles and sheet piles

Etude expérimentale sur transmission de charge latérale de pieux H et de palplanches modèles

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ABSTRACT: Frictional capacities of model H piles and sheet piles under compression loads and pullout loads were determined experimentally in sands. Measured load capacities are compared to predicted capacities based on semi-empirical approaches. The differences between measured and predicted frictional capacities may be attributed to partial soil plug. Experiments show that, for the same density of soil, load transfer and soil plug is related to the height-to-width ratio of H piles and degree of opening for sheet piles.

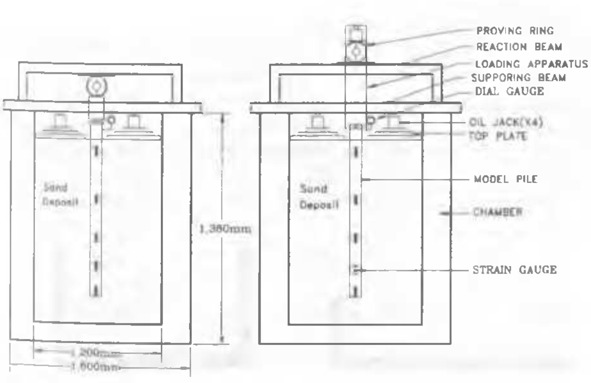
RESUME: Les capacités frottants de modèle des pieux H, les palplanche sous les charges de la compression et les charges de l'arrachement se sont determinés expérimentalement dans le sable. Les capacités des chargesmeasurés se comparent aux capacités prévus bosés sur les approches semi expérimentales. Les dêfferénces entre les capacités frottants mesurés et prévus se peuvent s'attribuer au encastrement partiel. Pour la meme densité des sols, les expériences montrent que le transfert des charges et l'encastrement partiel. Pour la même densite des sols. les expériences montrent que le transfert des charges et l'encastrement se rapportent au longeur à largeur des pieux H et au degré ouvert pour les palplanches.

1 INTRODUCTION

The bearing capacity of non-displacement piles such as H pile and sheet pile will be different from pipe pile which has closed perimeter surface. Futhermore the soil plug between flanges depends upon relative density, confining pressure, soil condition and loading direction etc.

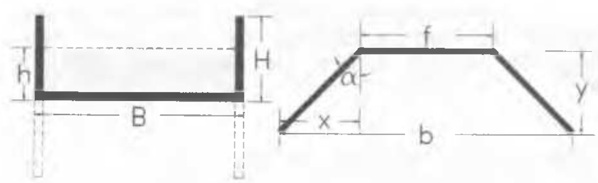
During last decades many researches were performed on the soil plug and skin friction of pipe piles. However there are a few research on the H pile and sheet pile(Busmante & Gianeselli 1991, Hegedus & Khosla 1984). In this research pile loading tests were carried out for model H piles and sheet piles in a calibration chamber.

4 H piles with different ratios of flange to web length and 5 sheet piles with different angle of flanges were tested under different confining pressure.



(a) compression test (b) pullout test

Fig. 1 Setup for model pile test



(a) (b)

Fig. 2 Model pile (a) H pile (b) Sheet pile

2 TEST EQUIPMENT AND MATERIALS

2.1 Calibration chamber

A chamber is consisted of prestressed concrete which has rigid boundaries. Diameter and height of the chamber are 1,200 mm and 1,380 mm, respectively. The overburden pressure is given by means of 4 oil jacks through 3 layers of steel plates as shown in Fig. 1. The influence of boundary condition was checked by using cavity expansion theory and the influence was negligible.

2.2 Model pile

4 model steel H piles and 5 sheet piles were prepared in this research. The shapes and sizes are given in Fig. 2 and Table 1. It should be noted that the sectional areas of all the model piles are the same.

2.3 Sand

A marine sand near Inchon has been used for all the tests. Index properties are given in Table 2. The sand was dried in the air beforehand and the measured water content was about 0.1 %. Sand deposit was made by adopting the undercompaction concept (Ladd, 1978) and the internal angle of friction for the same density was obtained from direct shear test. The sand deposit is completed in 10 layered tamping procedures and the procedure can be

Table 1 Section of model H pile and sheet pile

(a) H pile

H/B	2H+B=150mm	
	H(mm)	B(mm)
0.2	21.4	107.2
0.3	28.1	93.8
0.4	33.3	83.4
0.5	37.5	75

(b) sheet pile

α(°)	y(mm)	x(mm)	b(mm)	f/b
10	36.93	6.51	88.02	0.85
20	35.24	12.83	100.65	0.75
30	32.48	18.75	112.50	0.67
40	28.73	24.10	123.21	0.61
50	24.11	28.73	132.45	0.57

Table 2 Index properties of tested sand

Property	Value
Medium grain size, (mm)	0.38
Effective grain size, (mm)	0.23
Uniformity coefficient	1.74
Specific gravity	2.70
Maximum dry density, (kN/m^3)	15.83
Minimum dry density, (kN/m^3)	14.15
Internal friction angle, ϕ (deg) Dr=40%, Dr=70%	37, 40
Friction angle between pile surface and soil , δ (deg) Dr=40%, Dr=70%	9.5, 11.4

described as follows. 1)fix a pile at the center of the chamber, 2)weigh suitable amount of sand (the amount are determined by using undercompaction concept), 3)discharge the sands into the chamber carefully to make flat surface, 4)compact the layer by tamping rods with almost same energy. The relative densities are approximtely 40% and 70%.

3 TEST RESULTS AND ANALYSIS

Axial compression and pullout loading tests were carried out and the ultimate loading capacities were estimated by logP-logS (or De Beer) method. For the test results in this research, logP-logS method was the most suitable as shown in Fig. 3. The pile head is forced to settle at 0.4 mm/min by constant rate of penetration test method (CRP test).

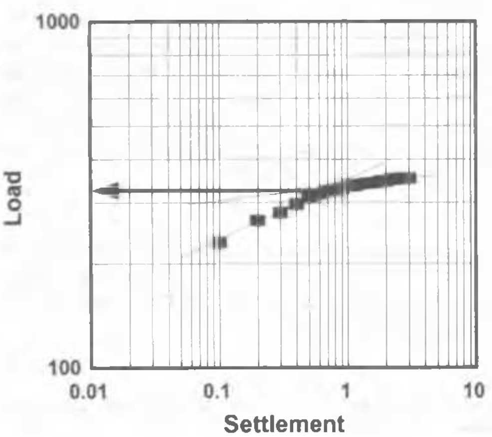


Fig. 3 Load-settlement response and evaluation of ultimate pile capacity.

Table 3 Settlement at ultimate bearing capacity

Pile type	Con. press. (kPa)	Sect-ion	Displ., S(mm)		S/Ds* (%)		S/Deq** (%)	
			Dr 40%	Dr 70%	Dr 40%	Dr 70%	Dr 40%	Dr 70%
H pile (com.)	49.1	0.2	0.3	-	1.5	-	0.6	-
		0.3	0.3	-	1.5	-	0.5	-
		0.4	0.3	-	1.5	-	0.5	-
		0.5	0.2	-	1.0	-	0.3	-
	98.1	0.2	1.4	1.5	7.2	7.7	2.6	2.8
		0.3	1.4	0.9	7.2	4.6	2.4	1.6
		0.4	0.8	0.8	4.1	4.1	1.3	1.3
		0.5	1.0	1.1	5.1	5.6	1.7	1.8
Sheet pile (com.)	98.1	10°	1.0	1.2	5.0	6.2	1.6	1.9
		20°	0.9	1.2	4.6	6.2	1.5	1.9
		30°	0.9	1.1	4.6	5.6	1.5	1.8
		40°	1.0	1.0	5.0	5.0	1.6	1.6
		50°	1.0	0.9	5.0	4.6	1.6	1.5
H pile (pullout)	49.1	0.2	1.2	-	6.2	-	2.2	-
		0.3	1.4	-	7.2	-	2.4	-
		0.4	1.3	-	6.7	-	2.2	-
		0.5	0.5	-	2.6	-	0.8	-
	98.1	0.2	1.9	4.2	9.7	20.5	3.5	7.4
		0.3	2	4	10.3	21.5	3.5	7.3
		0.4	1.8	3	9.2	15.4	3.0	5.0
		0.5	1.6	3	8.2	15.4	2.7	5.0
Sheet pile (pullout)	98.1	10°	2.2	2.6	11.3	13.3	3.6	4.2
		20°	2.2	3.0	11.3	15.4	3.6	4.9
		30°	2.2	2.6	11.3	13.3	3.6	4.2
		40°	2.2	2.8	10.3	14.4	3.2	4.5
		50°	2.0	-	-	-	-	-

* : equivalent diameter corresponding to sectional area

**: equivalent diameter corresponding to area of perfect soil plug

3.1 Load settlement response

Settlements at ultimate capacity from compression and pullout load test are summarized in Table 3. The settlement are normalized by equivalent diameter corresponding to its net sectional area and equilvalent diameter to perfect plug under assumption as shown in Fig. 4. The settlement mobilizing maximum frictional capacity is ranged 1 to 2 mm. Assuming perfect soil plug between flanges, the settlements are about 2% of equivalent diameter. This value is far lower than the settlement mobilizing maximum end bearing capacity in both driven pile(10% of the diameter) and bored pile (25% of the diamater). These imply that soil plug does not takes place through line ad in Fig. 4 but takes place near the line ab'c'd.

3.2 Ultimate bearing capacity

3.2.1 Compression loading test

Compression loading capacities of H piles are shown in Fig. 5. As shown, the bearing capacity increases with increasing relative density and increases with increasing confining pressure for the same H/B ratio. For the same relative density and the same confining pressure, the bearing capacities increase with decreasing H/B ratio for dense sand while the bearing capacities is more or less the same

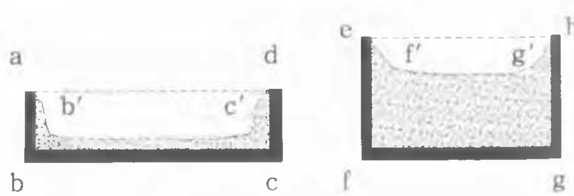


Fig. 4 Soil plug inside the pile

irrespecive of H/B ratio for loose sand. These can be explained that failure takes place near the perimeter abcd but not at the surface of pile.

For model sheet piles, test results from compression tests are shown in Fig. 6. In the figure we can easily notice that the bearing capacity of model sheet pile varies with the degree of open angle. For relative density 40% of sand, ultimate capacity of model sheet pile with lager than 30° angle gives more than 20% higher bearing capacity irrespective of the density. In sandy soil, soil to pile material friction takes place when the actual embeded pile surface is considered as the probable failure plane. Should a soil plug develop between the flanges in sandy soils, then a combination of soil to pile and soil to soil friction should be considered as some researchers analysed(Hegedus & Khosla 1984). The most probable failure zone will be the one that the least resistance against compression or pullout. Therefore in the case of this test for the same sectional area, maximum ultimate bearing capacity arises by the combination of soil to pile friction and soil to soil friction at the open angle around 20° to 30° .

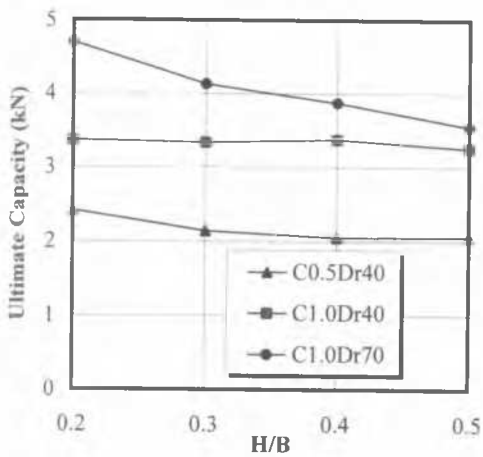


Fig. 5 Ultimate bearing capacity with different ratio of H/B in model H plie

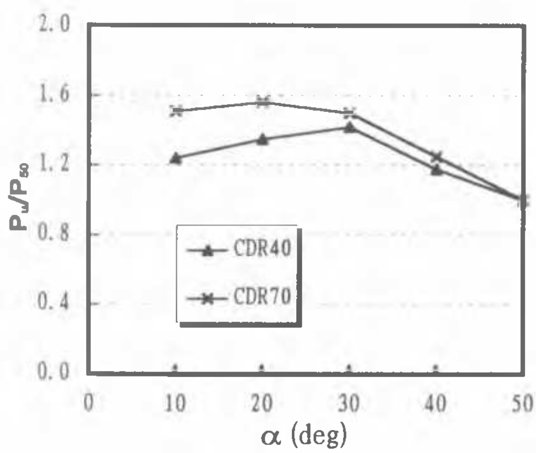


Fig. 6 Ultimate bearing capacity with different angle of opening in model sheet pile

3.2.2 Pullout loading test

In Fig. 7, test results from pullout loading for various ratios of H/B in model H pile are shown. The pullout resistance at lower H/B ratio is slight higher than that of higher H/B ratio. Considering the net sectional areas are the same each other, failure surface take places near the interface. Therefore the summation of frictional resistance of inside the model pile following broken line ab'c'd seems higher than that of broken line ef'g'h for higher H/B ratios as shown in Fig. 4.

In Fig. 8, both compression and pullout loading test results are given in the same figure for comparison. Assuming the pullout test are corresponding to frictional resistance, it can be noticed that the portion of end bearing capacity from the figure. For the test results the ratio of pullout to compression is about 0.8 and the results is similar to the results from others. For the same relative density of 40%, the portion of frictional capacity increases slightly with decreasing the ratio of H/B. And for the same confining pressure of 98.1kPa(1kg/cm^2), the trend of the ratio is conflicting.

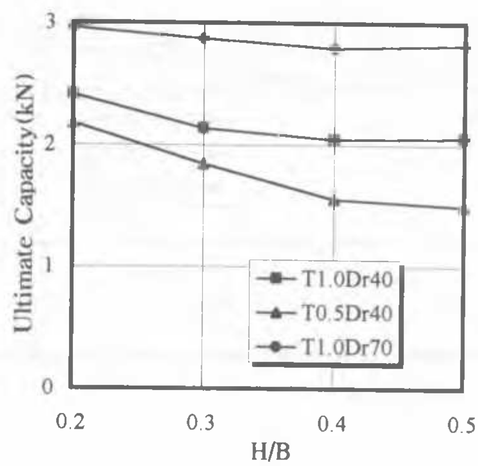


Fig. 7 Ultimate bearing capacity from pullout test in model H pile

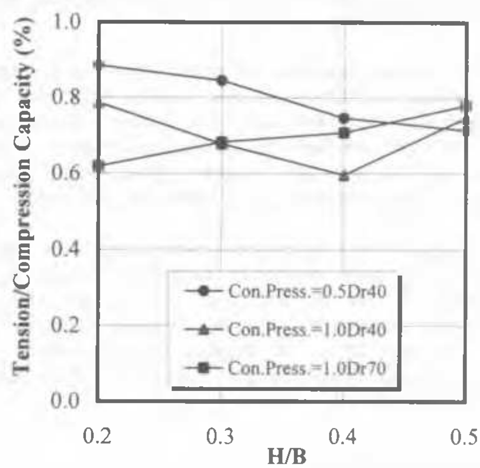


Fig. 8 Ratio of pullout to compression ultimate bearing capacity with H/B in model H pile

3.2.3 Variation of soil plug

In sands, the use of actual pile perimeter as the failure surface and soil to soil friction assumptions results in over estimation of pile capacities. Therefore in a comparative sense some assumptions were made. In this research frictional capacity was calculated by assuming perfect plugging following line ad or eh in Fig. 4 and by using the given angle of friction δ in Table 2. And the difference between measured ultimate capacity and calculated frictional capacity was considered as end bearing capacities. Thereafter the area satisfying the end bearing capcity was obtained. Fig. 9 shows the ratio of soil plug with variation of B/H ratios. In the figure $(h/B)_{0.2}$ denotes the relative depth from web to imaginary plug boundary. The lateral earth pressure coefficient was obtained by Jaky's expression, i.e. $k=1-\sin\phi$. FEM analysis with suitable boundary coitions shows a little difference from Jaky's expression. In Fig 9, it can be seen that soil plug increases with increasing H/B and confining pressure.

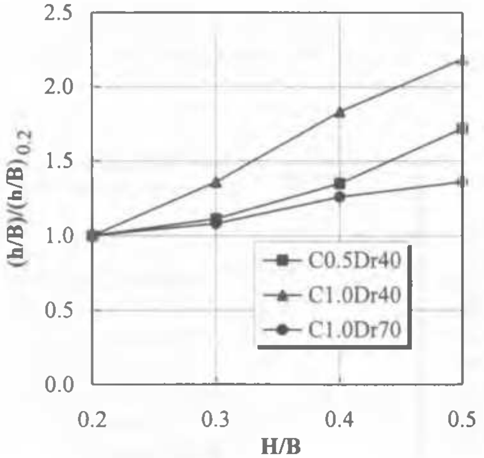


Fig. 9 Variation of soil plug with different ratio of H/B in model H pile

4 CONCLUSIONS

From model tests for H piles and sheet piles with the same sectional area and different shape in sand deposit, it may conclude the following.

(1) The bearing capacities of model piles vary with the sectional shape. In model H pile, lower H/B ratio gives higher bearing capacities and the failure surface seems arising near the interface. Assuming 'soil plug' develops between the flanges, the distance from inner side to plugging boundary increases with increasing H/B ratio.

(2) In model sheet piles the bearing capacities decrease with increasing open angle. It happens probably by the combination of soil to soil and soil to pile frictional capacity. The maximum ultimate bearing capacity takes place at between 20 to 30 degrees of open angle. The above conclusions should be conformed for further research in detail with installation of strain gauges.

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