Young Members

Introduction of Recent Initiatives and Bidirectional Cyclic Simple Shear Apparatus on Research of Liquefaction

Atsushi Mohri

Researcher, Port and Airport Research Institute
National Institute of Maritime, Port and Aviation Technology

I completed my doctoral program at the Department of Civil Engineering, Graduate School of Tokyo University of Science in March 2022. My research theme from the master's course onwards is about piles, and I had an opportunity to make a presentation at ICPE2018, Kochi, and ICPE2021, Kochi, while I was in school. In particular, since ICPE2018 was the first international conference for me, it was a memorable experience for me to get a real sense of overseas research situations.

As the theme of my doctoral program, I conducted model experiments on the behavior of ground reaction forces acting on passive piles, targeting the piles used in the steel pipe pile-type breakwater reinforcement method. In this construction method, by installing steel pipe piles in a row on the inner port side of the breakwater, it could be expected that the passive resistance received from the ground on the port side when the piles are displaced should have a reinforcing effect. Since various pile deformation modes could be considered depending on the distribution of the external force acting on the pile, it was necessary to investigate the behavior of the ground reaction force under different deformation modes. Based on the experimental results, I attempted to show this behavior in terms of the magnitude and depth distribution of ground reaction coefficients. However, I thought that the analysis method that examines the differences in ground shear modes (simple shear, compression/extension, rotation) at the ground element level might be more appropriate for such phenomena, so I am currently preparing to implement this theme.

I joined the Port and Airport Research Institute last year. The research themes so far have focused on: (1) the effect of seismic reinforcement of existing coastal parapet levees using high-stiffness sheet pile walls by means of a three-dimensional underwater shaking table, and, (2) the liquefaction test focusing on the effects of shear direction and shear history by using a Bidirectional cyclic simple shear testing apparatus.

In the first research on the seismic reinforcement effect of seawalls, as shown in the Fig. 1, I focus on a structure where a high-stiffness sheet pile wall is to be newly installed on the front side of the parapet, which is a coastal protection facility, and the front side of the ground is to be improved. In this structure, the lower end of the newly installed sheet pile wall is located in the liquefaction layer. Therefore, I am conducting model experiments and a validity check of the analysis model to confirm its subsidence behavior.

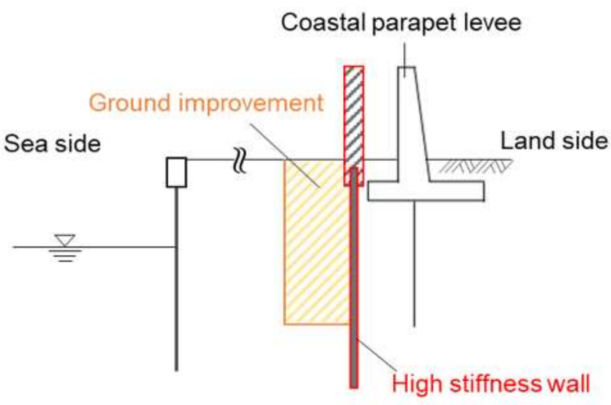

Fig. 1. Cross section of the seawall seismic reinforcement

In the second study on liquefaction, I am using a bidirectional cyclic simple shear apparatus, developed by Dr. Yudai Aoyagi (currently affiliated with the Public Works Research Institute) shown in Photo 1. This test equipment is designed so that the bottom cap under the specimen can move freely in the horizontal plane under back pressure and confining pressure. Moreover, instead of using conventional methods such as wire-reinforced membrane or stacked rigid rings for the K0 condition of the specimen, it adopts a cell pressure-controlled method, which enables detailed examination of the stress state of the specimen. By using the test equipment with these characteristics, I am investigating the effects of multi-directional and irregular seismic motions on liquefaction and re-liquefaction strength. In addition, by further improving this test equipment, I would like to utilize it for my research on the resistance behavior of the ground around piles subjected to horizontal forces at the ground element level.

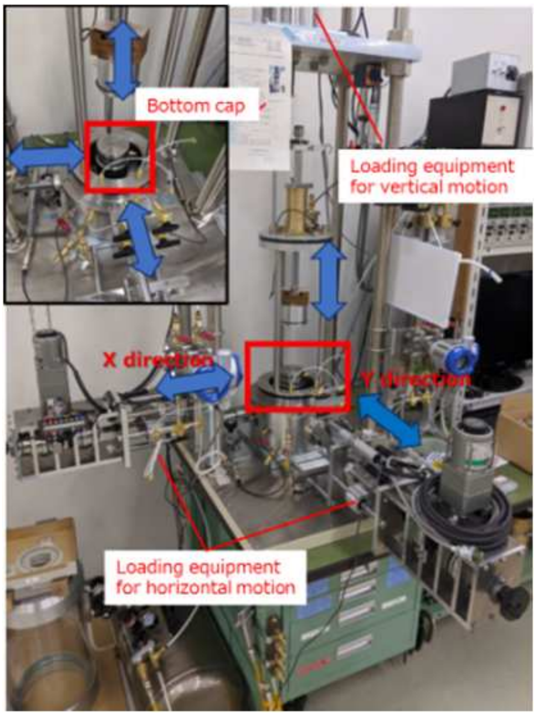

Photo 1. Bidirectional cyclic simple shear apparatus

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Revised Empirical Method for Predicting the Ultimate Bearing Capacity of Concrete Driven Piles Based on the PDA Results

Kong Sotheara

Instructor, Faculty of Georesources and Geotechnical Engineering
Institute of Technology of Cambodia (ITC)

Deep foundation systems consisting of precast concrete driven piles are commonly used in Cambodia due to the often-challenging geotechnical conditions underlying most project sites. Numerous searchers have proposed empirical methods to predict the ultimate bearing capacity of concrete driven piles based on correlations with in-situ tests such as the Standard Penetration Test (SPT), Cone Penetration Test (CPT), and Pressure Meter Test (PMT) and pile load test results. One of the most widely used empirical methods in Cambodia is that proposed by De Court (1982, 1995), which takes into account both the soil type and method of installation. In De Court's method, the shaft resistance for a pile with perimeter P_i in a soil layer with a SPT N-value of N_i and thickness of Δz_i is given by the relationship:

$$fs = (A_N + B_N \cdot N_i)\, P_i\, \Delta z_i$$

For displacement piles, $A_N = 10$ and $B_N = 2.8$, while for non-displacement piles, A_N ranges between 5 to 6 and B_N ranges between 1.4 to 1.7. The base resistance for a pile with a cross-sectional area of A_b in De Court's method is given by the relationship:

$$q_b = (C_N\, N_b)\, A_b$$

where N_b is the average SPT N-value within the effective depth of influence below the pile base which is often taken to be 3 pile diameters. Values of C_N for different soil types and methods of installation are summarized in the Table 1.

Table 1. C_N Factor for Base Resistance

Soil Type	Displacement Pile	Non-Displacement Piles
Sand	325	165
Sandy Silt	205	115
Clayey Silt	165	100
Clay	100	80

In this study, the correlation between the shaft and base resistance estimated using De Court's Method with estimates obtained from CAPWAP Analysis of High-strain Dynamic Pile PDA Tests performed on driven concrete piles in Cambodia and the Philippines investigated. The number of sites, piles and boreholes used in this is summarized in Table 2.

Table 2. Summary of Data Set

Data Source	Pile Type	Number		
		Sites	Piles	Boreholes
Cambodia	Regular Concrete Driven Pile (Dia. 0.3 x 0.3 & 0.4 x 0.4)	6	23	15
	Spun pile (Outside Dia. 0.35)	1	13	4
Philippine	Regular Concrete Driven Pile (Dia. 0.4 x 0.4, 0.45 x 0.45 & 0.5 x 0.5)	3	15	9

For De Court's Method, SPT N-values were normalized to an overburden of 1 ton/ft^2 and an efficiency 60%. The resulting adjusted SPT value $N_{1,60}$ was used in subsequent calculations used to estimate the side and end resistance using De Court's Method. The analysis of correlation used a linear regression with an assumed zero intercept. Table 3 summarizes the ratio of the estimate based on the PDA test results versus the theoretical estimates based on SPT N-values using De Court's Method, and the corresponding Coefficient of Correlation R^2.

Table 3. Summary of Ratios and Coefficients of Correlations

Data Source	Pile Type	Ratio and Coefficient of Correlation		
		$\frac{f_s\ (PDA)}{f_s\ (SPT)}$ R^2	$\frac{q_b\ (PDA)}{q_b\ (SPT)}$ R^2	$\frac{Q_{ult}\ (PDA)}{Q_{ult}\ (SPT)}$ R^2
Cambodia	Regular Concrete Driven Pile (Dia. 0.3 x 0.3 & 0.4 x 0.4)	2.0847 0.705	0.9846 0.7975	1.7607 0.8400
	Spun pile (Outside Dia. 0.35)	1.5404 0.9781	0.3231 0.8764	1.038 0.9796
Philippines	Regular Concrete Driven Pile (Dia. 0.4 x 0.4, 0.45 x 0.45 & 0.5 x 0.5)	1.141 0.9773	1.0093 0.8960	1.137 0.9773

The ratios summarized in the preceding table can be used to estimate the equivalent PDA side resistance, end resistance, and total axial capacity of driven piles. In all cases, the correlation coefficient was greater than 0.7. The regression model generally tended to slightly underpredict the equivalent PDA resistance based on the theoretical resistance estimated from De Court's Method. Based on the results of this study, it can be concluded that De Court's Method can be used to estimate the equivalent side resistance, end resistance, and total axial capacity of regular concrete piles driven in the Philippines. For Regular concrete piles driven in Cambodia, De Court's Method tended to accurately estimate the equivalent PDA end resistance while underestimating the side resistance by a factor of 0.5. For Spun piles driven in Cambodia, De Court's Method tended to overpredict the PDA end resistance by a factor of 3.0 while overestimating the side resistance by 0.67. The overprediction of the end resistance of spun piles can be attributed to the assumption that the pile tip is closed and thus treated as a displacement pile despite it being open at the start of driving. One explanation for the difference between piles driven in the Philippines and Cambodia concerning the factor for side resistance is that in the Philippines, the practice is to proof-test the pile to double the design load. In contrast, in Cambodia, piles are generally tested to three times the design load.

◆ A brief CV of Mr. Kong Sotheara

Kong Sotheara is an Instructor at the Faculty of Georesources and Geotechnical Engineering, Institute of Technology of Cambodia (ITC). He is also a student in the MS Civil Engineering (Geotechnical Engineering) Program of the University of the Philippines Diliman. His areas of expertise are in the general area of pile foundations and stability of MSE Walls. He graduated with an Engineer's degree in Georesources and Geotechnical Engineering, Faculty of Georesources and Geotechnical Engineering (GGE) from Institute of Technology of Cambodia (ITC).