Future target to evaluate the skin friction of tapered piles in sands

Suman Manandhar, Noriyuki Yasufuku, Kiyoshi Omine and Taizo Kobayashi
Department of Civil and Structural Engineering, Kyushu University, Fukuoka, Japan

1 INTRODUCTION

The tapered piles have substantial advantage over straight pile with reference to bearing capacity and skin friction in the downward frictional mode. The load-carrying capacity of piles has widely been distinguished as an advantage of taper-shaped piles over straight cylindrical pile Based on the previous research references it makes keen interest on research of different piles from straight to tapered ones with especial attention to effects of skin friction and normalized unit skin friction. Consequently, the skin frictions of taper-shaped piles are larger than single cylindrical pile. The movement of soil mass around the pile during penetration in the model ground plays a vital role. Consequently, the skin frictions of tapered piles are larger than single cylindrical pile. The main objective of this paper is to brief the results of the skin friction and normalized unit skin friction of installing cast-in-place piles of different types on a defined model ground and explain the further targets of procedural experimental work to check the mobilized mechanism.

2 EXPERIMENTAL PROCEDURES

Two different types of air-dried silica sands were taken into consideration to observe the effect of different types of pile penetration. K-7 sand and Toyoura sand were used in different settling environment (Table 1). Three model steel piles were set up in the pile load equipment.

Laser Diffraction Particle Size Analyzer prepared by Shimadzu Company of Japan was used to carry out grain size analyses of K-7 sand and TO sands respectively. Both specimens are uniformly graded sand with various degrees of fines. K-7 sand contains more fines with compared to TO sand. Index properties of sands are shown in Table 1.

K-7 and TO sands were tested under relative densities of 60 % and 80 % at 50 kPa. The peak friction angles of K-7 and TO sands were 46.65° and 42.36°, and critical state friction angles were 40.79° and 36.90° respectively. These parameters were determined using advanced tri-axial apparatus. The chromium plated steel model piles with equal lengths of 500 mm and same tip diameters of 25 mm were used for pile penetration. Three different types of piles, one straight (S) and two tapered-shaped (T1 and T2) were used to perform test. The tapering angle of T1 and T2 piles were 2.5 % and 5.0 %. Dry sand was fallen freely through sieve with an average nozzle area of 493 mm^2 on determined height (K-7: 1400 mm and TO: 700 mm) to the pile chamber having 750 mm diameter. Soil was filled nearly 710 mm from the bottom of the chamber. Then, pile was set up at the centre of the chamber. From the center of the pile 4 earth pressure sensors were set up at intervals of 30 mm, 90 mm, 150 mm, and 210 mm respectively. Further, soil was poured up to 930 mm in the chamber and pneumatic air pressure of 50 kPa was furnished as the overburden pressure (σ_v) for driving pile to the depth of 100 mm at the constant rate of 5 mm per minute.

3 EXPERIMENTAL RESULTS

Figure 1 represents with increasing the angle of tapering the skin friction were become higher in a considerable amount at high normalized settlement ratio (S/D); where, S is the penetration depth and D is the pile tip diameter. The tapering effects were become higher than straight piles for both sands.

3.1 Normalized skin friction

Tapered piles have different radii at the pile head, so average area was considered to see the effects of normalized unit skin friction. The surface area affects the unit skin friction (f_s) during penetrating piles such that:

$$f_s = \frac{F}{A_s} \quad (1)$$

$$A_s = \pi D'(L_0 + \Delta S) \quad \text{and} \quad D' = \frac{D+d}{2} \quad (2)$$

Where, D' is the average diameter of pile head (D) and pile tip (d), L_0 is the effective length of pile and ΔS is the incremental depth of pile penetration measured in metric system. In Figure 2, the normalized skin frictions were gradually increased with increasing penetration depths in tapered piles.

3.2 Normalized skin friction at depth

Skin friction of a pile is the sum of pile to soil cohesion and friction components such that:

$$f_s = c'_\delta + \sigma'_h \tan \phi'_\delta \quad (3)$$

Where c'_δ and ϕ'_δ are adhesion and friction parameters

Table 1. Index properties of sands

Sample	ρ_s (g/cm^3)	ρ_{max} (g/cm^3)	ρ_{min} (g/cm^3)	ρ_{80} (g/cm^3)	ρ_{60} (g/cm^3)	e_{max}	e_{min}	e_{80}	e_{60}	D_{10} (mm)	D_{50} (mm)	U_c	U'_c	F_c %
K-7	2.622	1.597	1.19	1.516	1.431	1.202	0.641	0.728	0.831	0.050	0.18	4.0	1.21	14
TO	2.65	1.64	1.34	1.58	1.52	0.98	0.62	0.68	0.74	0.2	0.26	1.4	0.864	1.1

ρ_s: density of particles, ρ_{max}: maximum density, ρ_{min}: minimum density, ρ_{80}: density at D_r 80 %, ρ_{60}: density at D_r 60 %, e_{max}: maximum void ratio, e_{min}: minimum void ratio, e_{80}: void ratio at D_r 80 %, e_{60}: void ratio at D_r 60 %, D_{10}: effective grain size, D_{50}: mean grain size, U_c: uniformity coefficient, U'_c: coefficient of curvature, F_c: percent fines

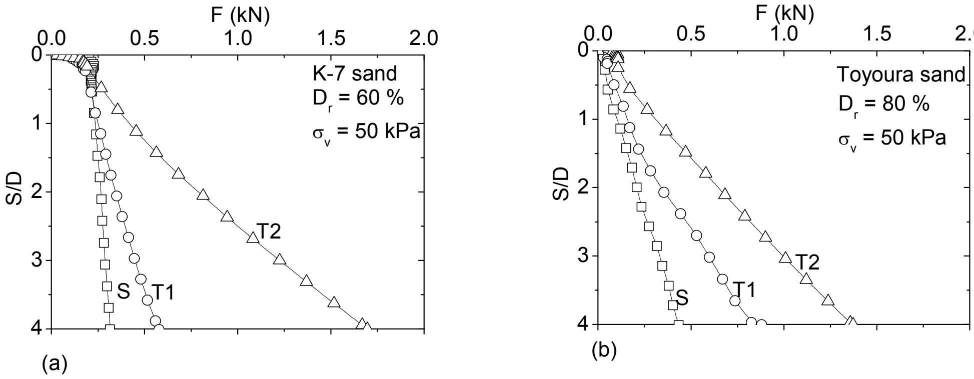

Figure 1. Skin friction of piles (a) K-7 sand and (b)

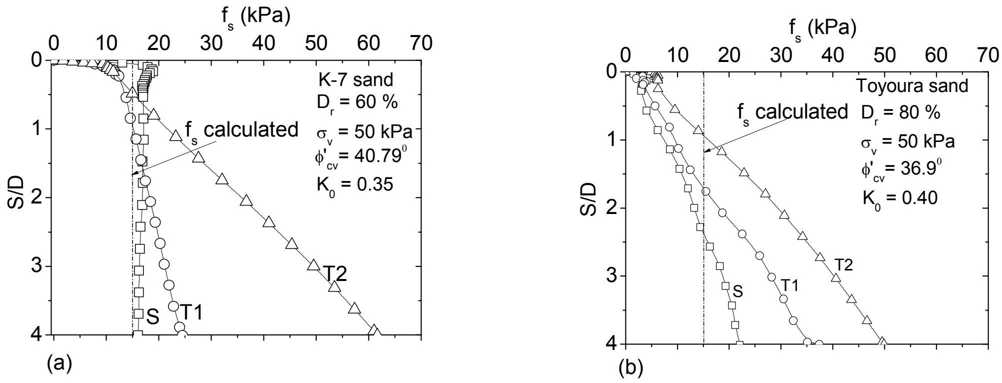

Figure 2. Unit normalized skin friction with calculated line

between pile and soil, and σ'_h is the horizontal effective stress acting on the pile. The settlement criterion for the drifting of the maximum f_s is exceeded such that:

$$c'_\delta = 0 \quad \text{and} \quad \phi'_\delta = \phi'_{cv} \tag{4}$$

Where, ϕ'_{cv} is a friction angle at the critical state, independent on density and overburden pressure and values of minimum strength. The horizontal effective stress σ'_h depends on overburden pressure σ'_v such that:

$$\sigma'_h = K\sigma'_v \tag{5}$$

Where, K is the coefficient of horizontal effective stress. For simplicity, modifying Equation (3) with aid to Equation (4), it can be represented as:

$$f_s = K_0\sigma'_v \tan\phi'_{cv} \quad \text{and} \quad K_0 = (1 - \sin\phi'_{cv}) \tag{6}$$

Where K_0 is coefficient of horizontal effective stress at rest. The calculated the normalized skin frictions of K-7 and TO sands of straight pile were 14.96 kPa and 15 kPa (Figure 2).

4 RESULTS AND FUTURE TARGET

Results confirm the skin friction, unit skin friction and normalized unit friction of tapered-shaped pile are greater than that of straight pile.

Since, the bearing mechanism of tapered pile governs high capacity when transferred to the soil with compared to single pile. It is imperative to find the type of pile so that it would become economically advantage and feasible. With regards to this, tapered piles are economically feasible in context to deep foundation. To observe the mobilized mechanism of pile and suggest the best and simple mathematical techniques to obtain the desired results, the model ground of silica sands having relative densities of 80 % and 60 % will be prepared. The confining pressure of 50 kPa will be used to perform the pile load test. Straight pile and tapered piles will be used to perform the experiment one after another. Colored layered silica sands were carefully installed on the model ground to observe the mobilized mechanism and geometry of material surrounding the pile during penetration. The obtainable results using different tapering angles will be analyzed and compared with cylindrical straight pile to support the above results.

5 REFERENCES

Manandhar S, Yasufuku N., and Shomura K., 2009, "Skin friction of taper-shaped piles in sands"; *Proceedings of the OMAE 2009 International Conference on Ocean, Offshore and Arctic Engineering, May 31-June 5, 2009, Honolulu, USA.*