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Ground Screw Solution for Rapid Foundation Construction of Traffic Control Devices and Other Structures

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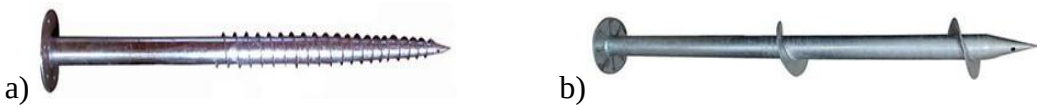
Abstract: Along with the development of the economy, the demand for transportation infrastructure is increasing. To ensure traffic safety, many traffic control devices, such as signage, signal light, sound wall, surveillance camera, bus shelter, etc., are needed along the roads. In our country, the foundations of these structures are usually cast-in-place reinforced concrete (RC) spread footings. Although the concrete volume of a footing is not much but there are many footings scattered along the road or intersections. To build a footing, we have to use many kinds of materials and execute many steps such as digging foundation pit, making formwork, placing reinforcement, pouring concrete. This takes long time and is not economically effective. At present, in some countries using small screw pile (mini screw pile, ground screw) can overcome these disadvantages and has lower costs, very potential in replacing cast-in-place RC spread footing mentioned above to make foundation for traffic control devices and other structures.

Keywords: Screw pile, spiral pile, helical pile, ground screw

I. OVERVIEW OF MINI SCREW-PILES AND CONSTRUCTION EQUIPMENT

Screw-pile is also known as spiral-pile or helical-pile, which has the pile shaft is the steel pipe on which spiral wings (continuous or interrupted) are lowered by rotating and pressing.

According to the shaft sizes (diameter of steel pipe, Dp), are divided into screw-pile types: large shaft type (D> 600mm); medium shaft type (300mm <D <600mm) and small shaft type (D <300mm)



a) b)

Fig.1: Small screw-pile *a) Continuous wing, b) Interrupted wing*

This article is mainly focused on analysis of small shaft screw-piles with continuous wing (mini screw-pile, ground screw).

Advantages of mini screw-piles: Fast preparation and application time, less manpower required; The piles have small cross section and light weight , which can be transported; executed by hand crafted machine or by specialized machine; Easy to connect; easy to link with steel columns of the upper structure; Easy to dismantle when used as temporary foundation; Can be installed in narrow space (such as under bridges); The piles may be vertical or oblique, can be installed on sloping terrain or vertical and inclined wall; Have less vibration and less noise in construction; less space, so it should not move near the ground; Be prepared piles, so it isn‘t affected by the weather; Have no waste land or waste material due to construction; Pile materials is reusable and recyclable; Can bear force immediately after lowering the piles; It is possible to predict the bearing capacity of the piles through the torque of the pile lowering equipment;

Disadvantages: Cross section of the pile shaft is small, so it is bad at horizontal force bearing and anti-flip; Foreign objects and hard ground can make it difficult to lower the piles; can be eroded in the land. However, these disadvantages can be overcome such as hot dip galvanized piles for anticorrosion; Horizontal poles can be used with multiple piles or with additional horizontal bearing ("+"wings or "+" wings combined with sleeves to increase the cross section of the pile) as shown in Figure 2 or use oblique piles; Working in hard ground or encountering a foreign object that can deflect the heart of the pile, it may overcome by a guiding frame or encountering foreign objects may be repaired by pulling up the piles to remove foreign objects (if the foreign object is small and located near the ground) or changing pile position.

a) b)

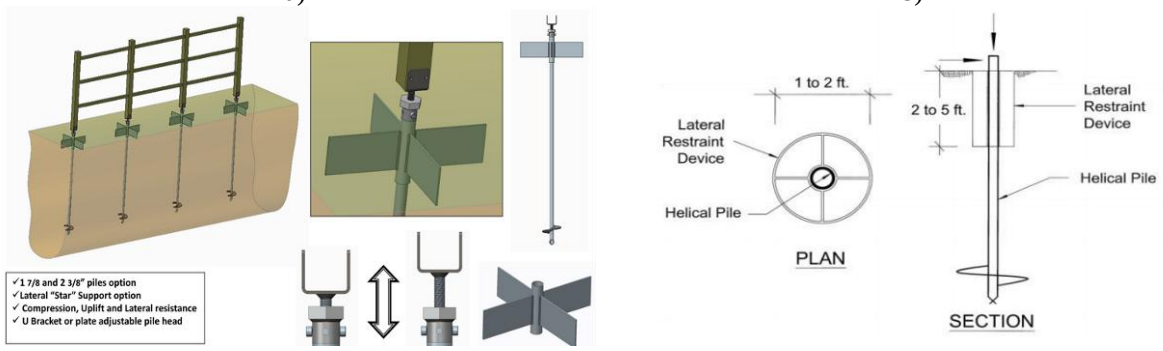


Fig.1: Part to increase horizontal bearing capacity for screw piles
a)"+"wing, b) sleeve type

Pile lowering method: Small screw-pile may be lowered by many various equipment such as: by hand and rotor; by handheld machine and shaped frame; by spiral pile drill attached to the self-operating vehicle; by spiral pile drill with instructions attached on the self-operating vehicle[1].

a) b) c) d)

Fig.2: Method of screwing

a) by hand and rotor b) by handheld machine and shaped frame c) by spiral pile drill attached to the self-operating vehicle, d) by spiral pile drill with instructions attached on the self-operating vehicle.

a)Spiral pile drill without guiding /YDS3000, *Unit price: 62,3 million VND (2769.23USD)*

b)Spiral pile drill with guiding / YDZJ3000, *Unit price: 132 million VND (5846USD)*

c)

Spiral pile drill parameter

Main parameter	unit	DTDL2000	DTDL3000	DTDL4000
Operation parameter				
Pile diameter	mm	⩽114	⩽114	⩽140
Pile depth	mm	1800	3000	4000
chassis				
Track base	mm	1640	1790	2100
Gauge	mm	1100	1350	1550
crawler width	mm	230	300	450
ground clearlance	mm	225	350	360
blade length	mm	1100	1700	1800
engine				
power/speed	KW/rpm	15.4/2400	33.1/2200	45.3 /2200
fuel tank	L	45	70	120
feed				
length of drilling	mm	2900	3200	4300
feed length	mm	1800	2000	3000
feed speed	m/min	2	3	3
travelling				
travel speed	km/h	0-4.5	0-4.5	0-4
max traction force	KN	17	33.8	55
climbing ability	°	25	30	30
rotary				
rotary speed	rpm	40	40	30
rotary torque	Nm	3000	6000	6000(or 9000)
dimension				
weight	kg	2300	4500	6200
dimension (L×W×H)	mm	4850×1330×2400	5250X1650X2560	6550×2000×2560

Fig. 4: Specification of some spiral pile drills of Goinjade New Energy Technology Company (China) [7]

Scope of application of mini screw-piles: With small size, lightweight, fast construction, environmental friendliness in countries, mini screw-piles are widely applied in construction of new works and reinforcement and repair of existing works.

Upon construction, screw-piles are less likely to affect pedestrians on the sidewalk and vehicles which are being circulated without having to excavate the ground, pouring concrete, which results in saving more time and costs. In addition, screw-piles are prefabricated steel piles (easily recyclable), which are environmentally friendly, suitable for sustainable development. It is able to use the screw-pile foundation for the structure of traffic safety signal and other structures such as: street lamp posts, signal lights, columns, signboards, surveillance cameras; bus stop foundation, fence pillar foundation, sound insulation wall foundation, ...

Fig.3: Application of mini screw-piles

II. THEORETICAL BASIS FOR CALCULATION OF MINI SCREW PILE FOUNDATION

According to a study by Zhang D. (1999) [1,2] and Narasimha Rao (1989) [1,2], ... the operation of piles depends on the diameter (D) and the distance between screw wings (S). Narasimha Rao et al. (1999) [2] have also determined that when the S/D < 2, screw-piles are working according to the cylindrical surface model surrounding the screw wings and when S/D >2, the model is used for the load bearing capacity of each screw wing (Figure 6).

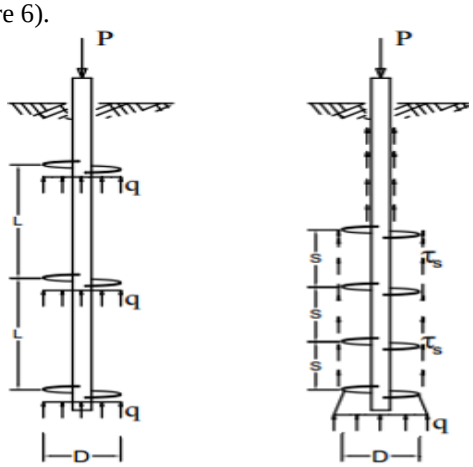


Fig.6: Model calculated according the load bearing capacity of each screw wing (left) and the cylindrical surface surrounding the screw wing (right) (Narasimha Rao 1991).

Fig. 7: Effects of distance between wings

From Figure 7, it can be seen that with the small distance of screw wings, the ground surrounding the pile limited by the screw wing side remains intact, the damage side of the pile is a cylindrical side surrounding the screw side. Considering the pile limited by two screw wings, as the screw wing distance increases, the total friction of the side wall of the pile section increases as the length increases, while the intensity of the ground

around the pile does not change, if exceeding any limit, the ground pillar around the steel pipe will be damaged. At this time, there is only friction between the steel pipe and the load bearing capacity of the screw wing [1,2].

The effect of distance and diameter of the screw wings shows that the operation of the screw-piles may be divided into two calculating models: cylindrical surface model surrounding the screw wings and load bearing capacity of each screw wing[2,3].

In 2016, Ministry of Science and Technology announces "TCVN 11520: 2016 [6] Screw-pile foundation with single wing at the head – Design requirements" for desining the screw-piles with single wing at the head. There is no standard for calculating the design of mini scew-piles with continuous wings. "TCVN 10304: 2014 Pile Foundation Design Standard" only briefly discusses the calculation of load bearing capacity of spiral-piles and does not specify how the spiral-piles are constructed.

Refer to the research results of Zhang D. (1999) [1,2] and Narasimha Rao (1989) [1,2], suggesting and applying a cylindrical surface model surrounding screw wings to calculate load bearing capacity along the axis of mini screw-piles in accordance with the foundation soil, apply the formula of Section 7.2.4 of TCVN 10304: 2014 [5]; The pile shaft of the upper of screw wings will be applied the formula calculated as steel pipe piles.

III. EXAMPLE OF MINI CREW-PILE FOUNDATION CALCULATION

Assuming the pile size of Figure 8 is lowered into medium sandy ground with the parameters as below:

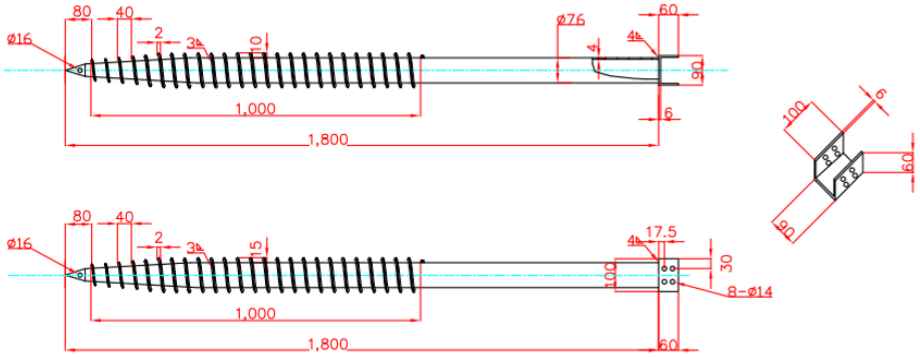


Fig.8: Example of structure and size of a mini screw-pile (uniy: mm)

Parameter of mini screw-pile: Pile length, L=1,800m; length of pile section with screw wings, L_b=1,000m; Pile diameter, D_p = 0.076m; Diameter of screw wing, D_p = 0.106m; Thickness of steel pipe of pile shaft, t_p = 4mm; Steel grade Q235MPa; Cross-sectional area of screw head, A_b = 0.0088mm^2; Cross-sectional area of the pile shaft, A_p=0,0045mm^2; Perimeter of screw wing, u_b = 0.3330m; Perimeter of pile shaft, u_p=0.2388m.

Refer to quotation of Goinjade New Energy Technology Company (China) 2018 (in China): Pile 1800 * 76 * 4mm, Q235 (hot dip galvanized): 460,000 VND / pile, pile 1400 * 60 * 3mm , Q235 (hot dip galvanized): 240,000 VND / pile

Foundation ground parameters: sandy ground, moderate density: thickness of 3.00 m; is the calculated density of ground, □=18kN/m^3; friction angle, □=30^o; adhesive force, c=0,01 kN/m^3;

Calculation of load bearing capacity along the axis of the spiral-pile

$$\mathbf{R_{c,u} = \gamma_c [R_q + R_f] = 15,703\ kN}$$ (Formula 16, TCVN 10304:2014)

Of which:

- γ_c is the working condition factor, depending on type of load affecting on the pile and condition of foundation ground according to Table 8 TCVN 10304:2014, □$_c$ = 0,8.
- R_q is the resistance of ground under the screw head
- R_f is the resistance of ground on the pile shaft

Resistance of ground under the screw head

$$\mathbf{R_q = (\alpha_1 c_I + \alpha_2 \gamma_I h_I) A_v = 1,288\ kN}$$ (Formula 17, TCVN 10304:2014)

Of which:

- α_1, α_2 used according to Table 9 TCVN 10304:2014, depending on friction angle value in calculating $\varphi_I$of the ground at the working area (the ground surrounding the screw head with thickness D_b), α_1 = 10,2; α_2 = 4,5.

c_l is the adhesive force of the adhesive ground or the linear parameter of the sandy ground at the working area, $c_l = 0{,}01 kN/m^2$

γ_l is the density of average efficiency of the ground on the screw head, $\gamma_l = 18{,}00 kN/m^3$

A_v is the cross-sectional area of the screw head, $A_v = 0{,}0088 mm^2$

h_l is the depth of the screw head from the natural face of the earth or from the design face of the earth, $h_l = 1{,}8m$.

Resistance of the screw-pile shaft

$$\mathbf{R_f = \Sigma\ u_i f_i l_i = 18{,}341\ kN}$$ (Formula 18, TCVN 10304:2014)

Of which:

f_i is the strength of average resistance of the i^{th} ground bed on the pile shaft taken according to Table 3 TCVN 10304:2014. Resistance f_i on the pile section with length D_b at the screw head used as 0.

u is the perimeter of the pile shaft in the i^{th} ground bed

l_i is the length of pile section in the i^{th} ground bed

Ground bed	l_i (m)	f_i (kN/m^2)	u_i (m)	$u.f_i.l_i$ (kN)
Pile section without screw wing	0,80	35	0,2388	6,685
Pile section with screw wing	1,00	35	0,3330	11,655
			$\Sigma\ u_i f_i l_i =$	**18,341**

The load bearing capacity of the 1.8m mini screw-pile as shown above is 1.5 tons. This load bearing capacity can be applied when applying for the foundation of big signs, signal light posts, etc. In case of applying as foundation of pickets, small signposts, the shorter piles can be used. In case of larger foot load, more piles can be used.

Therefore, if only one initial investment was required for a pile drill to install for multiple piles with a signpost that required only a pile of 1800 * 76 * 4mm to be connected directly to the steel pipe of signpost without pile-work. The aforementioned cost is cheaper than the cost of materials and manpower of digging foundation, formwork, pouring concrete, returning pavement/sidewalk.

IV. CONCLUSION

From the requirements of the technology of mini screw-pile foundation construction in urban traffic works, the current technical standards, based on the analysis of construction equipment in the world, the authors have selecting equipment Screw-type pivoting machine Screw-type head mounted on the base machine available is the crawler excavator hydraulic as the construction equipment synchronous piles for pile foundation works for transportation projects In Vietnam, it is suitable with actual construction conditions and calculates the basic parameters of the equipment with appropriate technical features, which is the basis for the complete design and That is the basis for the complete design and manufacture equipment in water.

With low cost, simple and fast construction, mini screw-pile overcomes the disadvantages of single reinforced concrete foundation poured in place, is very suitable for fast construction of foundation for traffic signposts and other structures

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