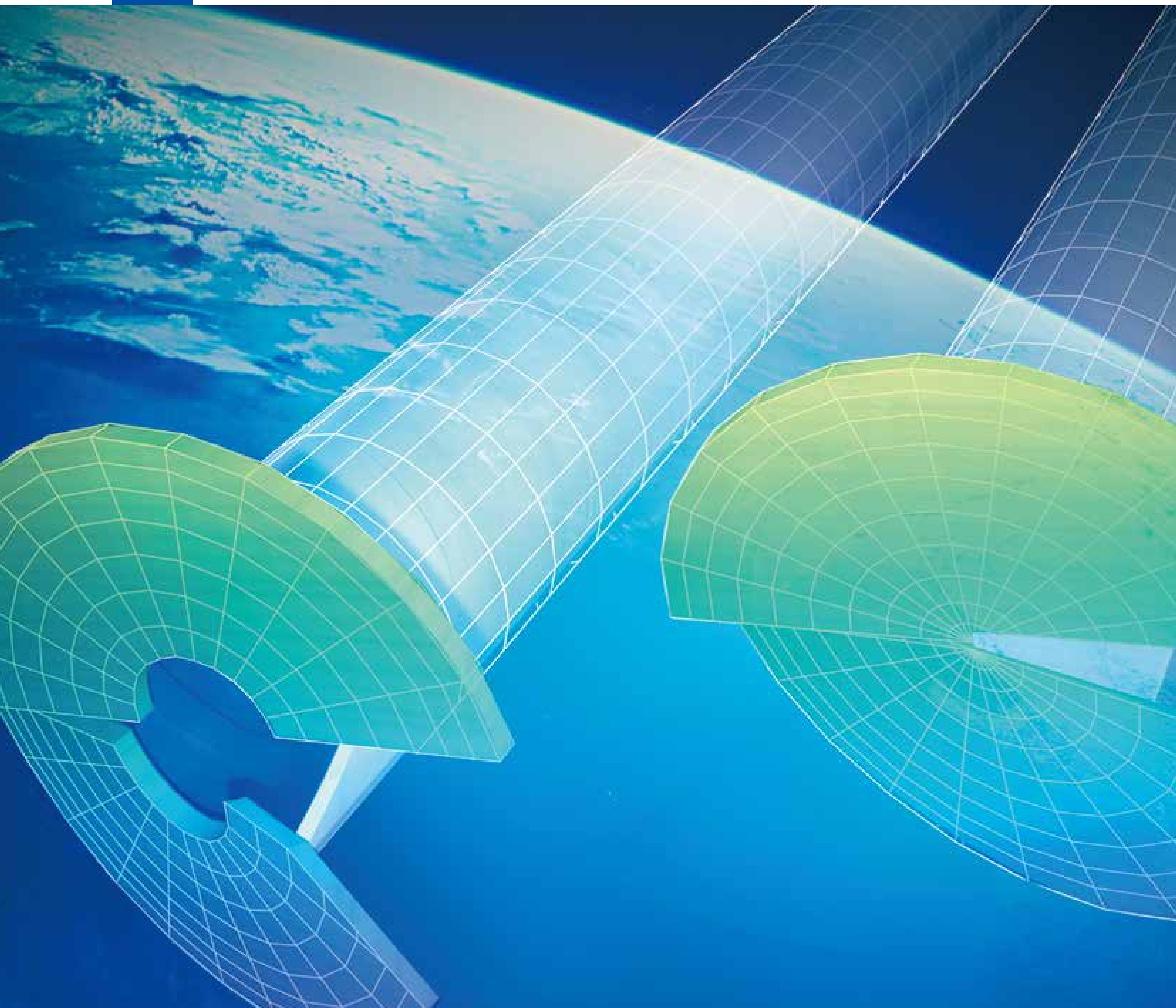
Based on

- TCCS 01/2017/ VJIAT-JFE
January 2018

TSUBASA (Wing) PILE™

Rotary Penetration Steel Pipe Pile with Toe Wing



JFE Steel Corporation

Introduction

In recent years, environmental impacts have been highlighted as an important issue in construction works.
In response to this matter, JFE Steel Corporation already developed a rotary penetration steel pipe pile with a toe wing called Tsubasa (Wing) pile™ in 1999.
Besides of its high bearing capacity, Tsubasa (Wing) pile™ has been highly appreciated for its environmental friendly functions such as:
Low noise; Low vibration; No waste soil during construction; No ground water contamination; rapid construction and reasonable cost.
There are two types of Tsubasa (Wing) pile™: an "Open-end" type and a "Closed-end" type.
The Tsubasa (Wing) pile™ has been widely designed and applied in Highways, Railways, Bridges and Building foundations in Japan. In order to contribute for the infrastructure development in the ASEAN region, the first technical standard TCCS01/2017/VJIAT-JFE (Vietnam) was made. This catalog describes the outline of the Tsubasa (Wing) pile™ design and construction method based on the TCCS 01/2017/VJIAT-JFE (Vietnam)
We would be grateful if you refer to this catalog for your eco-friendly foundation design & construction.

* Tsubasa (Wing) Pile™ is a trademark of JFE Steel Corporation.

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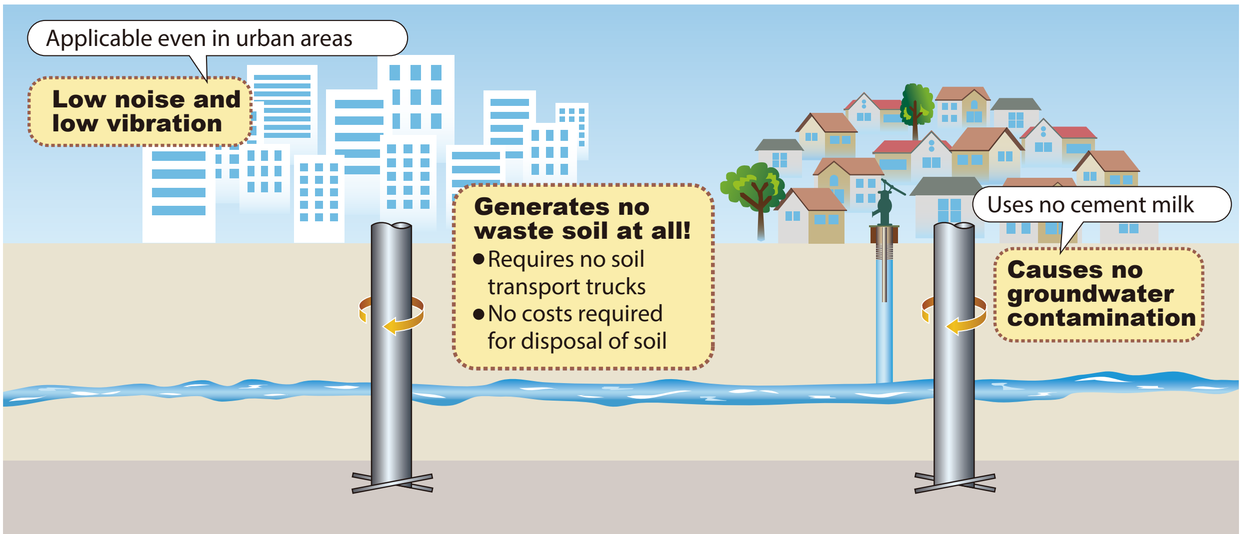
Closed-end Type

Features of Tsubasa (Wing) Pile™

The Tsubasa pile is a steel pipe pile with **toe wing**.
Toe wing is formed by installing two semicircular steel plates in a crosswise position to each other at the end of the steel pipe pile and has various features as shown below.

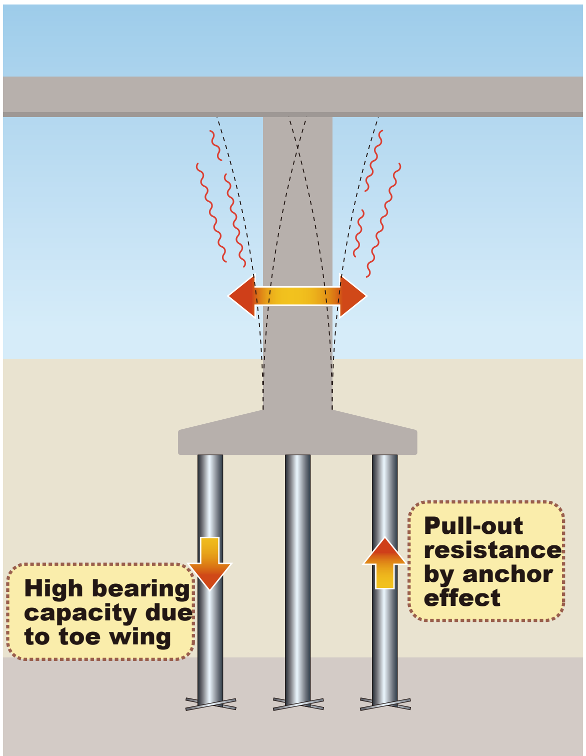
1 Environmentally Friendly

Environmentally-friendly construction by rotary penetration.



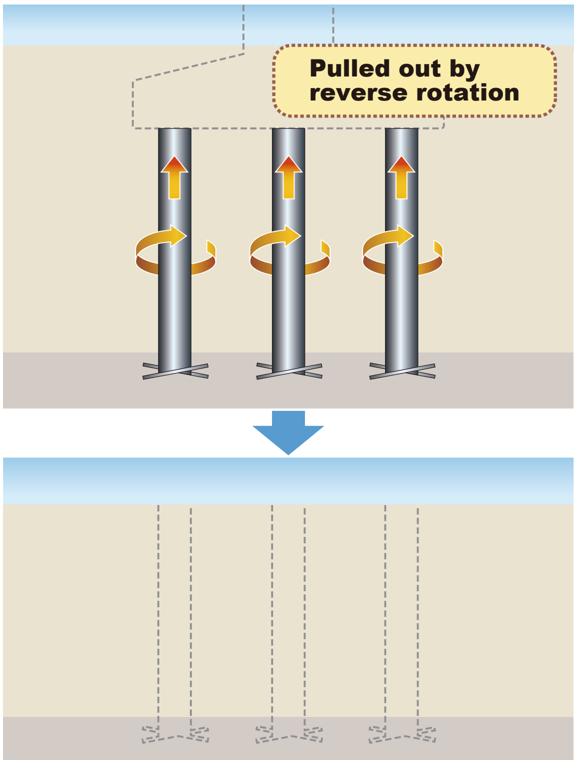
2 High Bearing Capacity

High end bearing capacity and pull-out resistance.



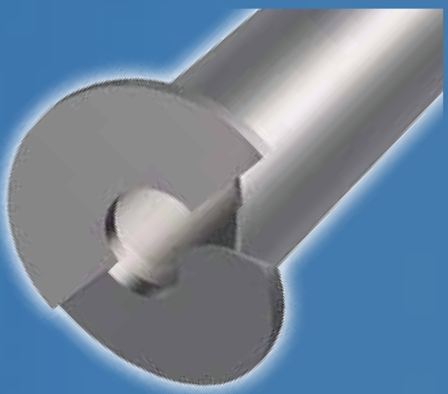
3 Possibility of pulling out

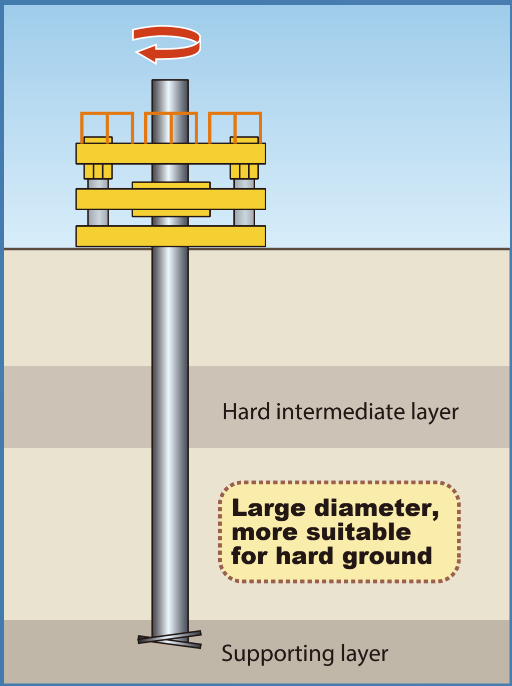
Removed by reverse rotation.



Open-end Type

Larger diameter (700 mm or larger) are more suitable for hard ground than the closed-end type.

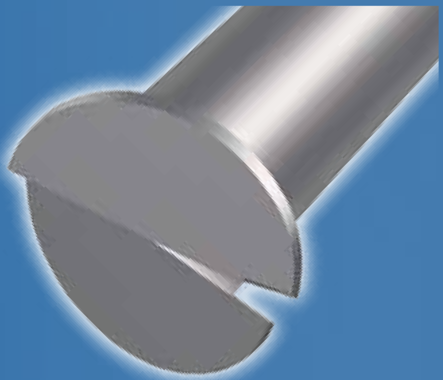


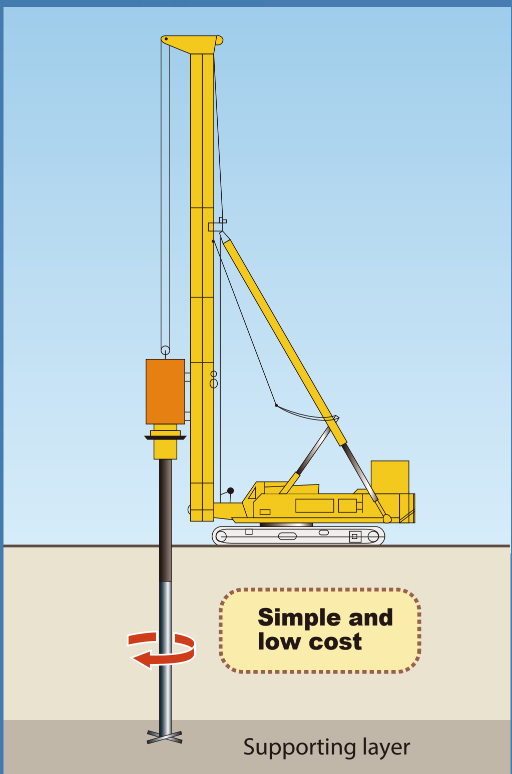


Closed-end Type

Compare to the open type, closed-end type has simple structure and lower cost

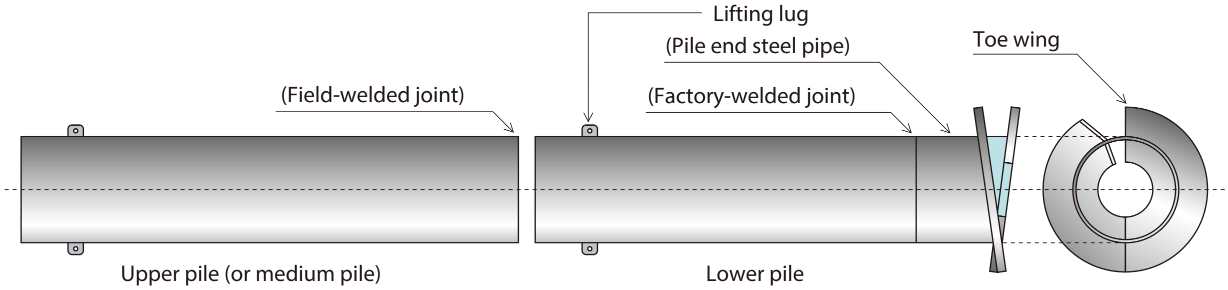
Hundreds of construction results centering on small and medium diameters (up to ϕ600mm).





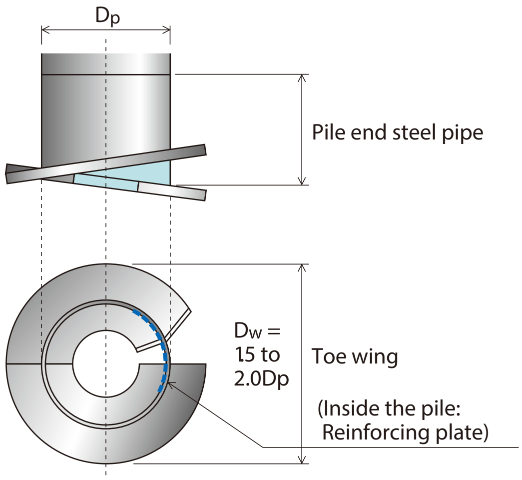
Open-end Type

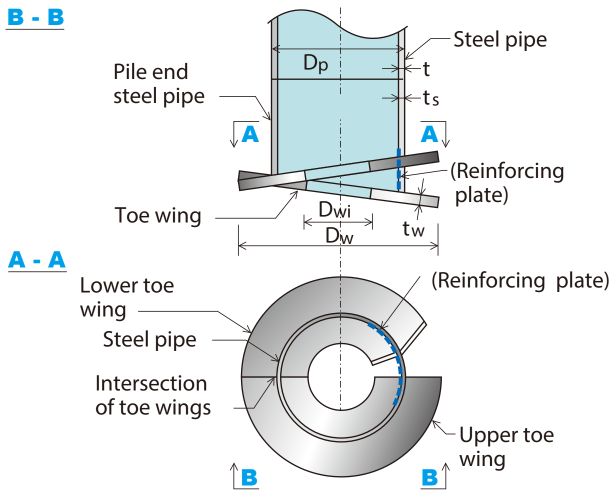
Pile Structure



Pile End Structure

A standard wall thickness is determined for each pile end steel pipe depending on the pile diameter. Reinforcing plates may be added to the inside of the pile end for convenience of construction.





Scope of Application

The scope of application of the Tsubasa (Wing) Pile (open-end type) is as follows.
For the other applications, please consult us in advance.

Pile diameter (D_p)	ϕ318.5 to ϕ1600 mm
Wing diameter (D_w)	D_p = ϕ318.5 to ϕ1200 mm $D_w = D_p \times 1.5$ to 2.0 D_p = ϕ1300 to ϕ1600 mm $D_w = D_p \times 1.5$
Maximum penetration depth	77m
Supporting layer	Sandy soil, gravel
Pile inclination angle	Max. 15°

Open-end Type

Standard Pile Dimensions

The most standard dimensions of the Tsubasa (Wing) Pile (open-end type) are shown below for each pile diameter. For the application of other dimensions or specifications, please consult us in advance.

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Steel pipe		Toe wing			Pile end steel pipe
Outer diameter D_p (mm)	Wall thickness t (mm)	Outer diameter of wing D_w (mm)	Inner diameter of wing D_{wi} (mm)	Thickness t_w (mm)	Thickness t_s (mm)
318.5	9～12	477.8～637.0	159.3	19～28	9～15
355.6	9～13	533.4～711.2	177.8	19～32	9～15
400 / 406.4	9～15	600 ～812.8	200 / 203.2	19～32	9～15
450 / 457.2	9～17	675～914.4	225 / 228.7	22～40	10～16
500 / 508.0	9～18	750～1016	250 / 254.0	22～45	10～19
600 / 609.6	9～21	900～1219.2	300 / 304.8	22～55	12～23
700	10～25	1050～1400	350	25～65	14～27
800	11～25	1200～1600	400	28～75	16～30
900	12～25	1350～1800	450	32～80	18～31
1000	13～25	1500～2000	500	36～90	20～32
1100	15～25	1650～2200	550	40～95	22～32
1200	16～25	1800～2400	600	45～100	24～32
1300	17～25	1950	650	50～70	25～29
1400	19～25	2100	700	55～75	25～29
1500	20～25	2250	750	60～80	25～29
1600	21～25	2400	800	65～80	25～29

The thickness of the toe wing and pile end and steel pipe shall be selected based on the dimension and material specification of the steel pipe(lower pile)

※ Lower pile wall thickness of steel pipe : $t/D_p \geqq 1.3\%$ (9 mm or more)

Open-end Type

Standard Pile Dimensions

Combinations of pile end steel pipe thickness(ts) and toe wing thickness(tw) (diameter of 1.5 times)

Wall thickness of steel pipe (mm)	Pile diameter (mm)															
	318.5	355.6	400,406.4	450,457.2	500,508.0	600,609.6	700	800	900	1000	1100	1200	1300	1400	1500	1600
9	10-19	10-22	10-22	10-22	10-25	12-25	–	–	–	–	–	–	–	–	–	–
10	11-22	11-22	11-22	11-25	11-25	12-25	14-25	–	–	–	–	–	–	–	–	–
11	12-22	12-22	12-25	12-25	12-28	12-25	14-25	16-32	–	–	–	–	–	–	–	–
12	13-22	13-25	13-25	13-28	13-28	13-25	14-25	16-36	18-40	–	–	–	–	–	–	–
13	–	–	–	–	15-28	15-25	15-25	16-36	18-40	20-40	–	–	–	–	–	–
14	–	–	–	–	16-32	16-25	16-25	16-40	18-45	20-45	–	–	–	–	–	–
15	–	–	–	–	17-32	17-25	17-25	17-40	18-45	20-45	22-50	–	–	–	–	–
16	–	–	–	–	–	18-25	18-25	18-45	18-45	20-45	22-50	24-55	–	–	–	–
17	–	–	–	–	–	19-25	19-25	19-45	19-45	20-50	22-55	24-55	25-60	–	–	–
18	–	–	–	–	–	21-25	21-25	21-45	21-50	21-50	22-55	24-60	25-60	–	–	–
19	–	–	–	–	–	–	22-25	22-45	22-50	22-55	22-55	24-60	25-60	25-65	–	–
20	–	–	–	–	–	–	23-25	23-50	23-50	23-55	23-60	24-60	25-65	25-65	25-65	–
21	–	–	–	–	–	–	24-25	24-50	24-55	24-55	24-60	24-60	25-65	25-65	25-70	25-75
22	–	–	–	–	–	–	–	25-50	25-55	25-60	25-60	25-65	25-65	25-70	25-70	25-75
23	–	–	–	–	–	–	–	26-55	26-55	26-60	26-65	26-65	26-70	26-70	26-75	26-75
24	–	–	–	–	–	–	–	–	28-60	28-60	28-65	28-65	28-70	28-75	28-75	28-80
25	–	–	–	–	–	–	–	–	–	29-60	29-65	29-70	29-70	29-75	29-80	29-80

※[Pile diameter] (pile toe steel pipe thickness) - (toe wing thickness) (Steel pipe: SPP400; pile end steel pipe: SPP490; toe wing: SM490A)

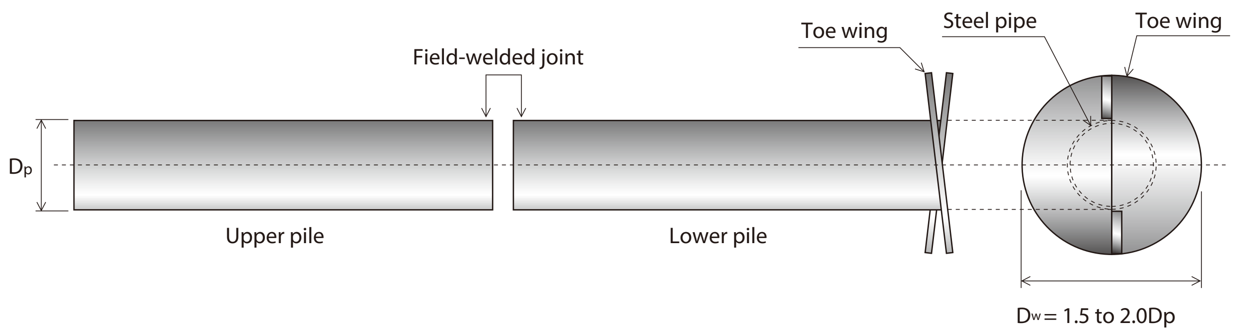
Combinations of pile end steel pipe thickness(ts) and toe wing thickness(tw) (diameter of 2.0 times)

Wall thickness of steel pipe (mm)	Pile diameter (mm)											
	318.5	355.6	400,406.4	450,457.2	500,508.0	600,609.6	700	800	900	1000	1100	1200
9	11-25	10-22	11-25	11-32	11-32	12-36	–	–	–	–	–	–
10	12-25	11-22	12-28	12-32	12-36	12-36	14-40	16-45	–	–	–	–
11	14-28	12-22	14-28	14-36	14-36	14-40	14-45	16-50	18-50	–	–	–
12	15-28	13-25	15-32	15-36	15-40	15-45	15-45	16-50	18-55	20-55	–	–
13	–	–	–	16-40	16-40	16-45	16-50	16-50	18-55	20-60	–	–
14	–	–	–	–	18-45	18-45	18-50	18-55	18-60	20-60	22-65	–
15	–	–	–	–	19-45	19-50	19-55	19-55	19-60	20-65	22-70	24-70
16	–	–	–	–	–	20-50	20-55	20-60	20-65	20-65	22-70	24-75
17	–	–	–	–	–	22-50	22-60	22-60	22-65	22-70	22-75	24-75
18	–	–	–	–	–	23-55	23-60	23-65	23-70	23-70	23-75	24-80
19	–	–	–	–	–	–	24-60	24-65	24-70	24-75	24-80	24-85
20	–	–	–	–	–	–	26-65	26-70	26-75	26-80	26-80	26-85
21	–	–	–	–	–	–	27-65	27-70	27-75	27-80	27-85	27-90
22	–	–	–	–	–	–	–	28-70	28-80	28-85	28-90	28-90
23	–	–	–	–	–	–	–	30-75	30-80	30-85	30-90	30-95
24	–	–	–	–	–	–	–	–	31-80	31-85	31-90	31-95
25	–	–	–	–	–	–	–	–	–	32-90	32-95	32-100

※[Pile diameter] (pile toe steel pipe thickness) - (toe wing thickness)
(Steel pipe: SPP400; pile end steel pipe: SPP490; toe wing: SM490A)

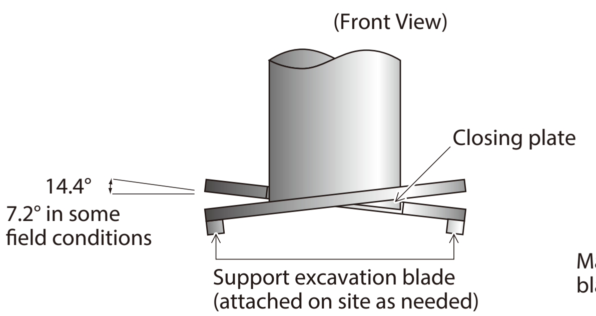
Closed-end Type

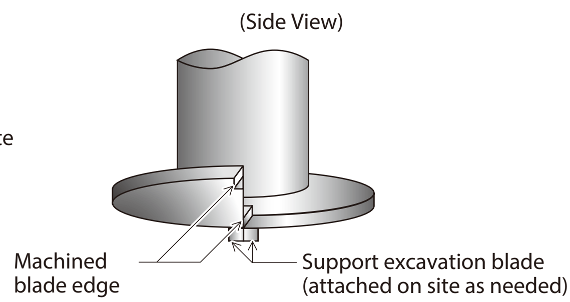
Pile Structure



Pile End Structure

A toe wing consists of two semicircular steel plates.





Scope of Application

The scope of application the Tsubasa (Wing) Pile (open-end type) is as follows.
For the other applications, please consult us in advance.

Pile diameter (D_p)	φ318.5 to φ1200 mm
Wing diameter (D_w)	D_p = φ318.5 to φ1200 mm : $D_w = D_p \times$ 1.5 to 2.0
Maximum penetration depth	60m
Supporting layer	Sandy soil, gravel
Pile inclination angle	Max. 15°

Closed-end Type

Standard Pile Dimensions

TCCS 01 / 2017 / VJIAT-JFE

Steel pipe		Toe wing	
Outer diameter D_p (mm)	Wall thickness t (mm)	Wing diameter D_w (mm)	Thickness t_w (mm)
318.5	9～16	477.75～637.0	25～30
355.6	9～16	533.4～711.2	25～35
400 / 406.4	9～18	600～812.8	25～35
450 / 457.2	9～20	675～914.4	30～40
500 / 508.0	9～22	750～1016	30～40
600	9～25	900～1200	30～45
700	9～25	1050～1400	35～50
800	9～30	1200～1600	40～55
900	10～30	1350～1800	40～60
1000	11～35	1500～2000	45～65
1100	12～35	1650～2200	45～70
1200	13～40	1800～2400	50～80

The thickness of the toe wing shall be selected based on the dimension and material specification of the steel pipe(lower pile)

※ Lower pile wall thickness of steel pipe : $t/Dp \geqq 1.5\%$ (9 mm or more)

Material Specifications

Steel Pipe

[TCVN 9245 Steel Pipe Piles 2012]

Type code	Tensile test				Flattening test *2	Chemical components %				
	Tensile strength N/mm²	Yield point or yield strength N/mm²	Extension No.5 specimen Vertical direction to pipe axis %	Tensile strength at welded part N/mm² *1	Distance between flat plates (D: indicates outer diameter)	C	Si	Mn	P	S
SPP400	400 or more	235 or more	18 or more	400 or more	2/3D	0.25 or less	—	—	0.040 or less	0.040 or less
SPP490	490 or more	315 or more	18 or larger	490 or more		0.18 or less	0.55 or less	1.65 or less	0.035 or less	0.035 or less

*1 "Tensile strength at welded part applies to arc-welded steel pipes.
*2 "Flattening test applies to electric resistance-welded steel pipes.

Toe Wing

Open-end Type

Either of the following toe wings should be used.

1. JIS G 3106 (Rolled Steels for Welded Structure)

Type code	Thickness mm	Tensile strength N/mm²	Yield point or yield strength N/mm²	Elongation			Chemical components %					
				Thickness mm	Test piece	%	Thickness mm	C	Si	Mn	P	S
SM490A	16<t≤40	490 to 610	315 or more	16<t≤50	No. 1A	21 or more	16<t≤50	0.20 or less	0.55 or less	1.65 or less	0.035 or less	0.035 or less
	40≤t≤100		295 or more	40 < t	No. 4	23 or more	50<t≤200	0.22 or less				
	100≤t≤100		285 or more									

2. HBL385B (550N/mm²class TMCP steel materials for construction sttructures)

Code type	Thickness mm	Tensile strength N/mm²	Yield point or yield strength N/mm²	Elongation			Chemical components %				
				Thickness mm	Test piece	%	C	Si	Mn	P	S
HBL385B	19 to100	550 to 670	385 to 505	t<38	Type 1A	15 or more	0.20 or less	0.55 or less	1.60 or less	0.030 or less	0.015 or less
				t ≤50	Type 5	26 or more					
				40<t	Type 4	20 or more					

Closed-end Type

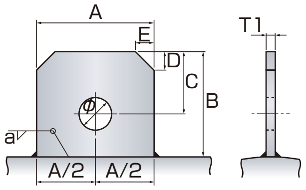
HBL385B (550N/mm²class TMCP steel materials for construction sttructures)

Code type	Thickness mm	Tensile strength N/mm²	Yield point or yield strength N/mm²	Elongation			Chemical components %				
				Thickness mm	Test piece	%	C	Si	Mn	P	S
HBL385B	19 to 100	550 to 670	385 to 505	t<38	Type 1A	15 or more	0.20 or less	0.55 or less	1.60 or less	0.030 or less	0.015 or less
				t ≤50	Type 5	26 or more					
				40<t	Type 4	20 or more					

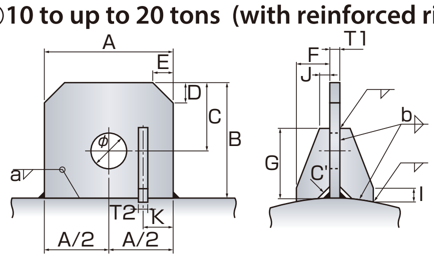
Accessories (Reference)

Lifting Lug

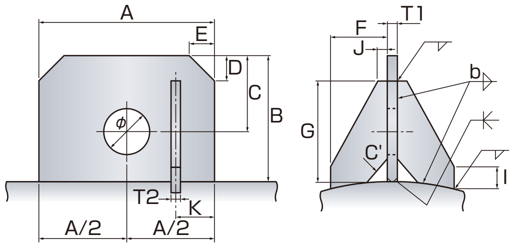
①Up to 10 tons (with no reinforced ribs)



②10 to up to 20 tons (with reinforced ribs)



③20 to up to 40 tons (with reinforced ribs)

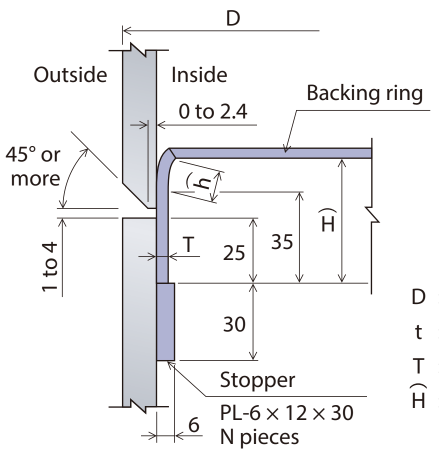


(mm)

Figure	product weight (ton)	A	B	C	D	E	T1	ϕ	a	F	G	I	J	K	T2	C'	b	Waight of lifting lug (kg/piece)
①	3 or less	120	100	55	25	25	12	40	6	—	—	—	—	—	—	—	—	1
	3 ≤ 5	120	100	55	25	25	16	40	9	—	—	—	—	—	—	—	—	2
	5 ≤10	200	150	90	30	30	22	65	15	—	—	—	—	—	—	—	—	5
②	10 ≤ 20	300	250	150	50	50	22	80	15	80	150	30	25	60	22	C30	15	17
③	20 ≤ 30	350	250	150	50	50	22	90	—	125	200	50	25	70	22	C50	15	23
	30 ≤ 40	400	300	150	50	50	25	100	—	150	260	50	25	80	22	C50	15	37

※1 The tensile strength is 490 N/mm2 or higher (SM 490 A).
※2 As a general rule, use a pair of lifting lugs to conduct lifting work.

Shape and Dimension of Backing Ring and Stopper



D : Pipe diameter (mm)
t : Pipe thickness (mm)
T : Backing ring thickness (mm)
H : Backing ring height (mm)

D	T	H	h
ϕ1000 or less	4.5	50	15
ϕ1100 or more	6.0	70	35

Number of Stoppers

D (mm)	N
ϕ609.6 or less	4
ϕ700 to ϕ1000	6
ϕ1100 or more	8

Design of Tsubasa (Wing) Pile™

TCCS 01/2017/VJIAT-JFE January 2018
Based on the Japan Specifications for Highway Bridges (Part I to Part V) 2017

Characteristic Value of Ultimate Push-In Bearing Capacity Determined by Ground Properties

Characteristic value of ultimate push-in bearing capacity is given by the following formula from the ground properties.

$$R_u = q_d A + U \Sigma L_i f_i$$

q_d : Characteristic value of ultimate pile toe bearing capacity (kN/m²)

Soil type	Diameter of toe wing / Pile diameter	End bearing capacity factor α
Sand layer	1.5 times	120N (≦6,000)
	2.0 times	100N (≦5,000)
Gravel layer	1.5 times	130N (≦6,500)
	2.0 times	115N (≦5,750)

N : N value of the standard penetration test at the end layer. However, the maximum N value is 50.

A : Toe wing area (m²) $\quad A = \pi \times \frac{D_w^2}{4}$

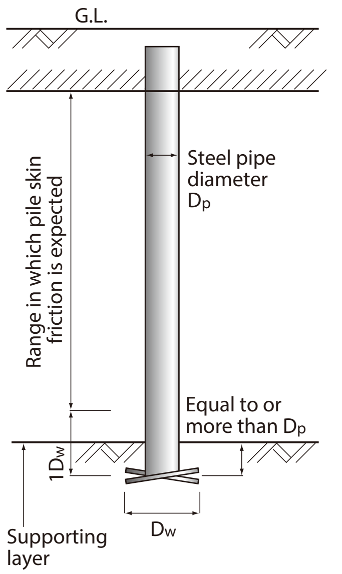
D_w : Outer diameter of toe wing (m)

U : Circumference of steel pipe (m), for the enlarged head, apply the circumference of the enlarged head steel pipe.

L_i : Thickness of the "i" th layer considering skin friction(m)

f_i : Characteristic value of maximum saft resistance intensity in the "i" th layer (kN/m²)

Ground type	Characteristic value of maximum shaft resistance intensity (kN/m²)
Sandy soil	3N (≦150)
Cohesive soil	C or 10N (≦100)



*This figure shows the closed-end type.

Characteristic Value of Ultimate Pull-Out Bearing Capacity Determined by Ground Properties

$$P_u = U \Sigma L_i f_i + \pi D_w \left(\Sigma \gamma_i L_i + \gamma \frac{H}{2}\right) H \frac{3N}{L/D}$$

How ever: $\frac{3N}{L/D} \leqq 5.0$

Here,

U : Circumference of steel pipe (m)

L_i : Thickness of the "i"th layer considering skin friction (m)

f_i : Characteristic value of maximum pile skin friction in the "i"th layer (kN/m²)

D_w : Outer diameter of toe wing (m)

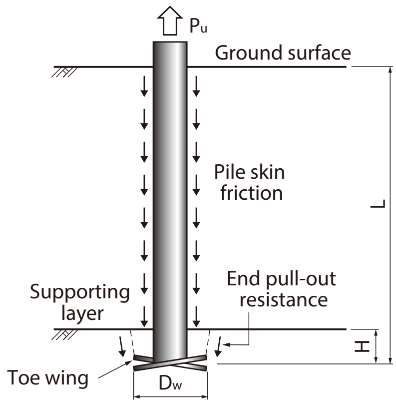
γ_i : The effective unit volume weight of soil in the "i"th layer (kN/m³)

γ : The effective unit volume weight of soil in the supporting layer (kN/m³)

H : Penetration depth into the supporting layer (m) However, H should be 2.5Dw or less.

L : Pile length (m)

D : Pile Diameter (m)



*This figure shows the closed-end type.

Design of Tsubasa (Wing) Pile™

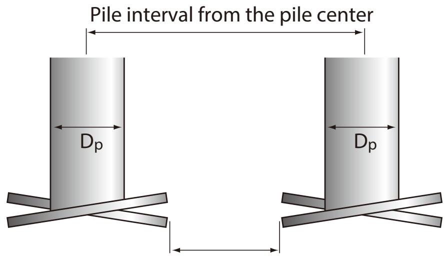
TCCS 01/2017/VJIAT-JFE January 2018
Based on the Japan Specifications for Highway Bridges (Part I toPart V) 2017

Pile Interval

The minimum pile interval is shown below.

Toe wing diameter	Pile interval from the pile center
1.5 times	$2.5D_p$
2.0 times	$3.0D_p$

D_p stands for the pile diameter.



*This figure shows the closed-end type.

Spring Constant in Axial Direction

The spring constant of the Tsubasa (Wing) Pile in the axial direction is given by the following formula.

$$K_V = \frac{1}{\frac{L}{2AE}(1+\gamma_y-\zeta_e)+\zeta_d\frac{4\gamma_y}{\pi D_p^2 k_v}}$$

K_V : Spring Constant in Axial Direction (kN/m)
A : Net cross-sectional area of pile (m^2)
E : Young's modulus of pile (kN/㎟)
L : Pile length (m)
D_p : Pile diameter (m)
k_v : Coefficient of vertical subgrade reaction of pile toe (kN/m^3)
γ_y : Etimated value of transmission rate of pushing force act in the axial direction from pile head to pile toe, when pile reaches to it's yield bearing capacity

$$\gamma_y=\lambda_{yu}\gamma_u \ (0\leqq\gamma_y\leqq1)$$

λ_{yu} : Correction factor for calculation of pile toe transmission rate
γ_u : Estimated value of transmission rate of pushing force act in axial direction from pile head to pile toe, when pile reaches to it's ultimate bearing capacity

$$\gamma_u=R_{up}/R_u$$

R_{up} : Characteristic value of the ultimate bearing capacity of the pile end of the characteristic values of the ultimate bearing capacity of the pile as determined by the ground (kN)

$$R_{up}=q_dA$$

R_u : Characteristic value of ultimate bearing capacity decided by ground properties (kN)
ζ_e : Correction factor for pile shrinkage
ζ_d : Correction factor for pile toe displacement

λ_{yu}	ζ_e	ζ_d
0.84	0.25	0.58

Precautions for Design

Selection of Pile Dimensions

(1) Pile diameter : To avoid using pile head rotation type and pile body rotation type on the same site, the pile diameter should be selected within either of the following ranges.

ϕ318.5 to ϕ609.6 mm (Pile head rotation type)
ϕ500 to ϕ1600 mm (Pile body rotation type)

(2) Thickness :

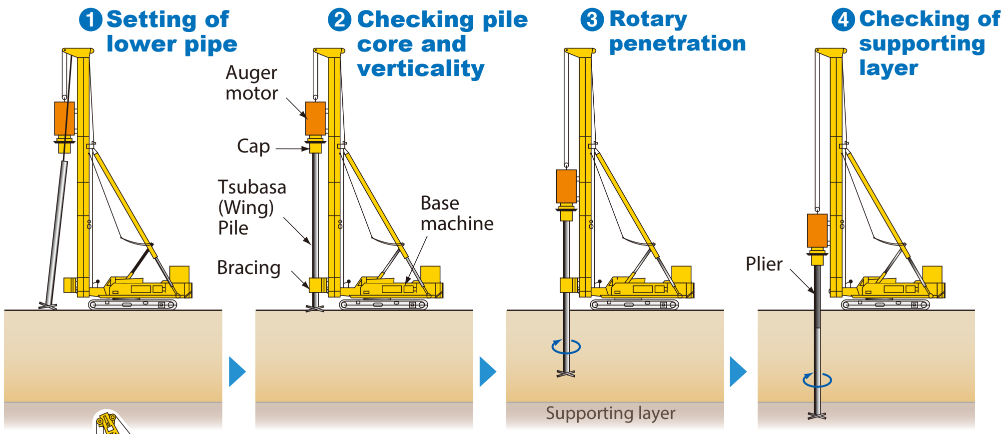
- In general, the wall thickness is not constant for long piles (Ex. Upper part: 16 mm, Lower part: 9 mm). The thickness change point (point of uneven thickness welding) should be determined considering that the pile might stop at a high position. Uneven thickness welding should be done at factory in principle.
- The thickness of steel pipes should be determined also considering the soundness during construction.
- As a general rule, a corrosion allowance of 1 mm shall be considered in design for corrosion protection purpose on the outside of steel pipes. However, it should be separately considered for highly corrosive environments.

Construction of Tsubasa (Wing) Pile™

Construction Flow

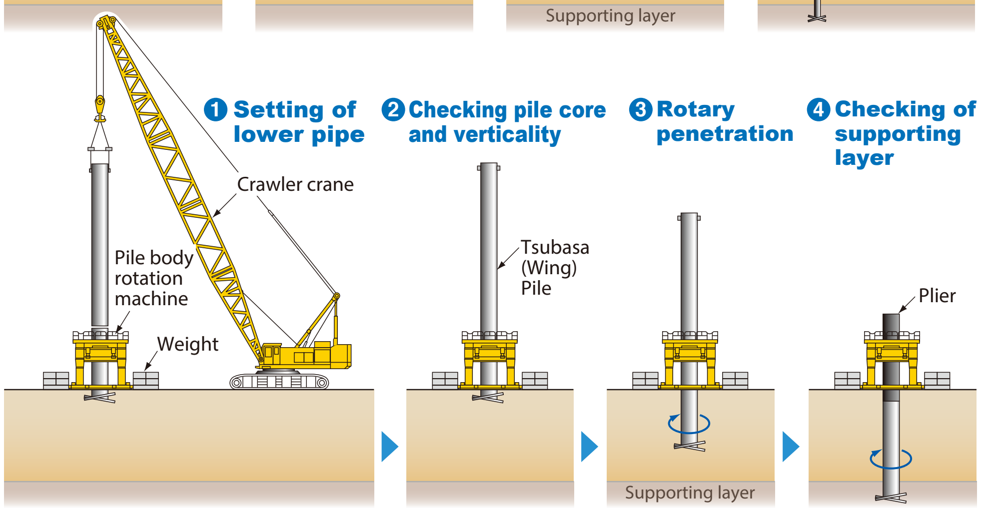
Pile head rotation type

Steel pipe diameter: ϕ318.5 to ϕ609.6



Pile body rotation type

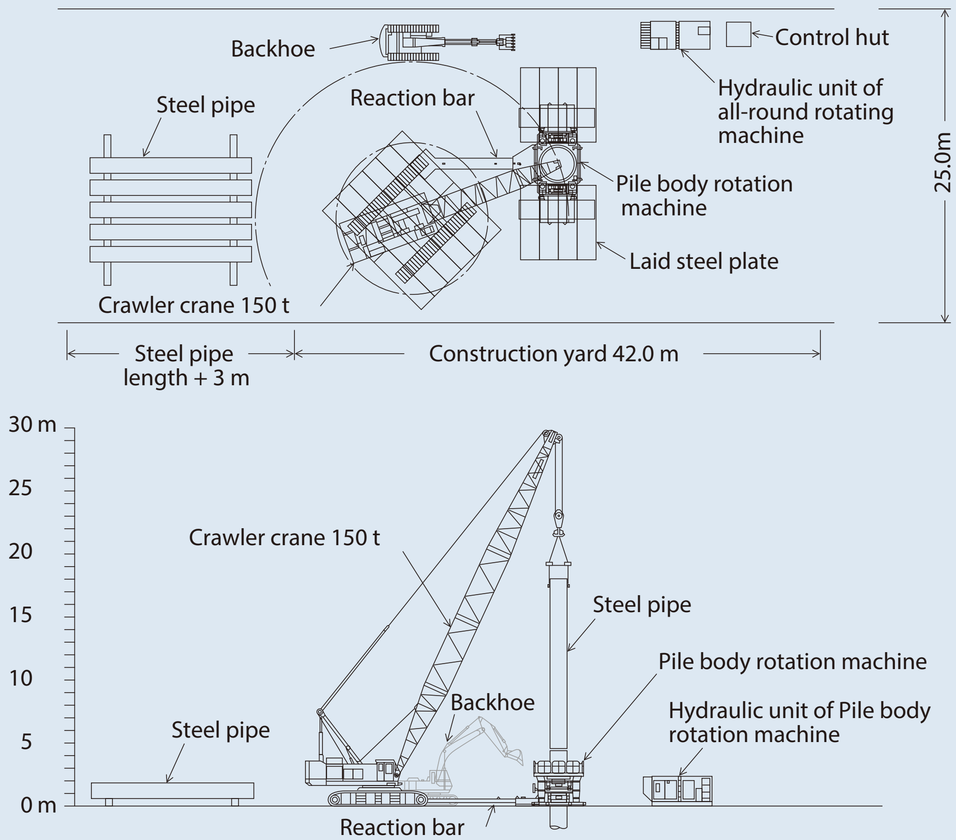
Steel pipe diameter: ϕ500 to ϕ1600



Pile drivers suitable for low height or narrow space construction are also available. Please consult us.

Construction of Tsubasa (Wing) Pile™

Example of Construction Work Space Using a Pile Body Rotation Machine



※In cases of narrow space construction and limited overhead clearance, please contact us.

Construction Example

Location	: Saitama Prefecture
Pile diameter	: ϕ1200 mm
Toe wing diameter	: ϕ1800 mm (1.5 times wing)
Pile penetration length	: L = 44 m
Conditions of construction	: Checking the penetrativity of the ground with an intermediate hard sand layer (N≥40)

Piling Finish Control

In principle, a pile end should be penetrated into the supporting layer to the depth required on design, but if it is difficult to penetrate the pile to the prescribed depth because of the hardness of the supporting layer, piling finish control may be applied using the hardness index given by the following formula. However, in case the pull-out resistance of the toe wing is expected in design but the prescribed penetration depth cannot be ensured, the design pull-out strength should be reconsidered.

$$\text{Hardness index [K]} = \frac{\text{Rotation torque [T] (kN·m)}}{\text{Penetration per rotation [S] (cm)}}$$

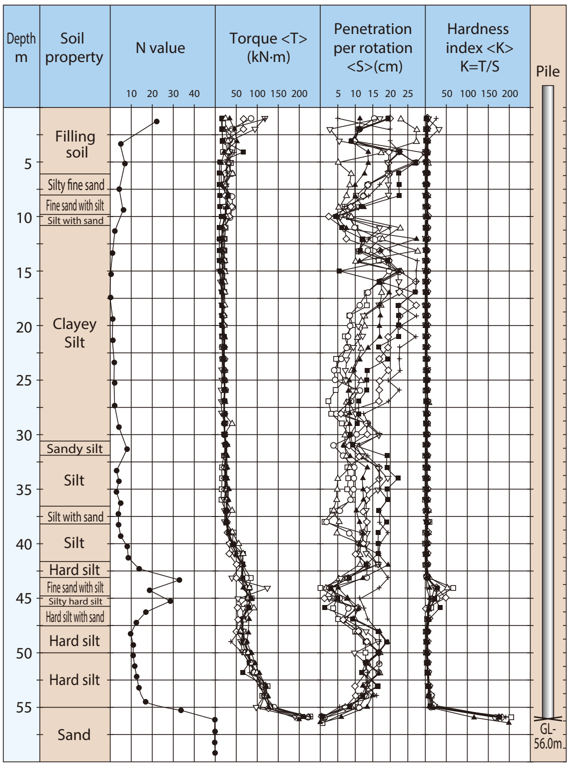
The rotation torque [T] and penetration per rotation [S] are measured during construction using a construction control meter or an ammeter.

Example of construction control meter

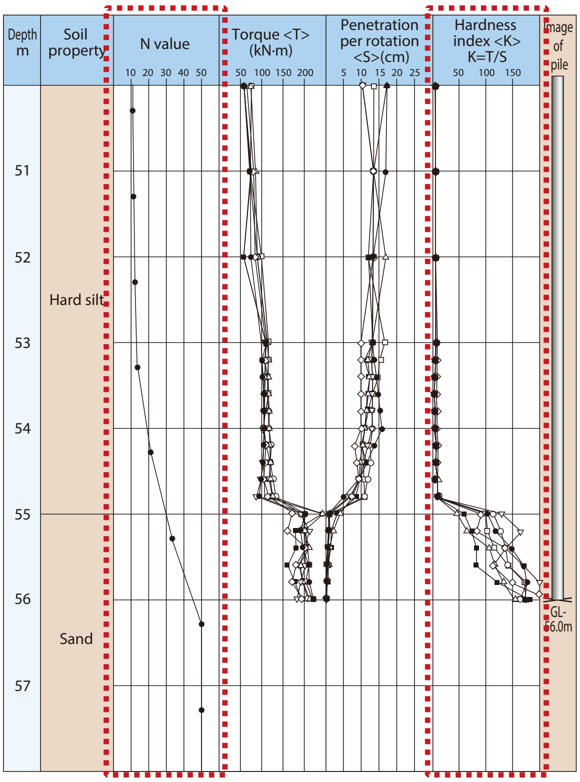
Example of ammeter

Construction Record

The following figure shows an example of the record of the N value and hardness index when the above-mentioned piling finish control is applied.



Full length record



Record around finish depth

Construction examples of Tsubasa (Wing) Pile™

Construction Scenes

Pile head rotation type

Pile head rotation type (Batter pile)

Pile body rotation type (Batter pile)

Construction near extcting structure

Low overhead restriction or a narrow space

Plier set over a main pile

Pliers (Pile body rotation type)

Pliers (Pile head rotation type)

Cap(Pile head rotation type)

Official Authorization of Tsubasa (Wing) Pile™

The TCCS for the design and construction of the Tsubasa pile has approved and published by VJIAT-JFE


TCCS BASIC STANDARD

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ROTARY PENETRATION STEEL PIPE PILE
WITH TOE WINGS
"TSUBASA PILE"
TECHNICAL REQUIREMENT FOR DESIGN
CONSTRUCTION AND ACCEPTANCE

January 2018

English


TCCS TIÊU CHUẨN CƠ SỞ

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YÊU CẦU THIẾT KẾ, THI CÔNG
VÀ NGHIỆM THU

Tháng 01 năm 2018

Vietnamese

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The construction of the Tsubasa (Wing) Pile is conducted by the pile construction companies that are members of the Engineering Society of Tsubasa (Wing) Pile.

- Geo Dynamic Co., Ltd.
- Chiyoda Geotech Co., Ltd.
- Marugo Foundation Corp.
- Japan Pile Corporation
- Nittoc Construction Co., Ltd.
- Yokoyama-Kiso
- Taiyo Foundation Co., Ltd.
- Nozaki Kenko
- Ryoken Kiso Co., Ltd.

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