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Bearing capacity of driven piles with different types of cross section

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ABSTRACT

The research of influence of piles with cross section on the pile's load capacity is published in this article. Special attention to driven piles was paid, because they are very popular in building area. There are five cross-sectional shapes: round, square, cruciform, T-bar, I-beam. As a soil selected a single layer from the fine-grained sandy soil. The calculation of the bearing capacity of piles was conducted with the data cross-sectional shapes. As a result, authors explored that constituent which depends on exterior perimeter of pile's cross section is very important.

Contents

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1. Introduction

The most important step in the design of pile foundation is to assign type of piles not only by nature of their work in the soil and method of penetration, but also in design and shape of cross section.

Driven piles are made of various building materials and various designs. The cross section of such piles can also be of different configurations: from simple shapes (round, square) to complex cross sections (T-bar, I-beam, etc.) [14].

Considering that friction force of side surface has a significant effect on a bearing capacity of a pile, it may be assumed that a cross section of the pile has also a considerable importance in determining the bearing capacity. In addition, changing the cross sectional shape of the pile while maintaining the bearing capacity can significantly change consumption of materials.

Unfortunately, in literature describing determination of a bearing capacity of a pile is not given, in our opinion, proper attention to the cross section of the pile. Most authors describe the study of bearing capacity under vertical load, depending on the material of the pile [2, 4 - 6, 10, 13, 14, 24 – 32, 34], depth of piles [2, 3, 5, 6, 10, 14, 23, 33] and physical properties of soil [1, 2, 6, 11, 14, 25, 26]. Several studies have shown relationship between load-bearing capacity and rigidity of cross section for horizontal loads, and issues directly related to calculation load-bearing capacity of the pile according to the cross sectional shape reflected only in the work of Kalachuk T. G. [11].

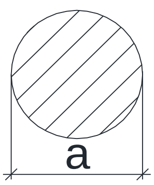
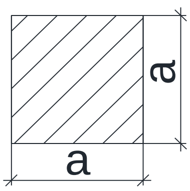
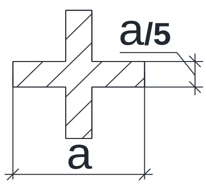
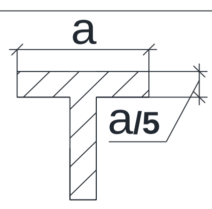
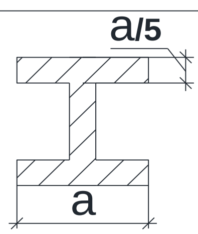
According to literature review there is a need of further studies of relationship bearing capacity of the pile with the shape of its cross section. At this article attempt of such research in uniform soil conditions (as the soil is considered a fine-grained sandy soil) is made.

For the study were selected five cross-sectional shapes of piles:

- round (I);
- square (II);
- cruciform (III);
- T-bar (IV);
- I-beam (V).

The calculation of bearing capacity for all types of cross-section length of piles was adopted by 10 meters, and the same parameter "a" across the width and height of the cross section of the pile (Table 1).

Table 1. Section types

I	II	III	IV	V
				

For all types of cross-sections are defined by their geometric characteristics - outer the perimeter of the section «U» and bearing area of the pile on the ground «A» (accepted for gross cross-sectional area or largest diameter); parameter "a" taken equal 0.4 meters. The results are shown in Table 2.

Table 2. Geometric characteristics of the piles

Number of sections / Characteristics	I	II	III	IV	V
U, m	1,257	1,6	1,6	1,6	2,24
A, m^2	0,126	0,16	0,058	0,058	0,083

Bearing capacity of the pile was determined by the method described in the regulations [16-20], and is given by:

$$F_d = \gamma_c \cdot (F_{df} + F_{dR}), \quad (1)$$

γ_{cR} - coefficient of working conditions in the soil of the pile are set to 1;
F_{df} – bearing capacity at the side surface of the pile;
F_{dR} – bearing capacity under the end of the pile.

In turn,

$$F_{df} = u \sum \gamma_{cf} \cdot f_i \cdot h_i, \quad (2)$$

$$F_{dr} = \gamma_{cR} \cdot R \cdot A \quad (3)$$

γ_{cR}, γ_{cf} – factors for the condition of the soil below the bottom end of the pile and on the side of the pile, taking into account the effect of the method piling on the calculated resistance of the soil;

u – outer perimeter of the cross-section of the pile, m;

f_i – calculated resistance of the i-th layer of foundation soil on the side of the pile, take the SNIP 2.02.03-85 Table 2, kPa;

h_i – power i-th layer of foundation soil in contact with the side surface of the pile, m;

R – calculated resistance of the soil below the bottom end of the pile, take the snip 2.02.03-8 Table 1, kPa;

A – bearing area of the pile on the ground, is taken over cross-sectional gross or the largest diameter, m^2.

2. Calculations

Table 3. The calculation of circular section I

Circular section (I)												
N curr. layer	**h_i, m**	**EOL, m**	**H_{pil}, m**	**h_{cpi}, m**	**GTE**	**f_i, kN/m^2**	**$f_i * h_i$, kN/m^2**	**$\Sigma f_i * h_i$,**	**Ri, kPa**	**F_{df}, kN**	**F_{dR}, kN**	**F_d, kN**
1	2	3	4	5	6	7	8	9	10	11	12	13
1	2	-3	2	1	sand	30	60	60	1900	75,4	239,4	314,8
2	2	-5	4	3	sand	38	76	136	2100	171,0	264,6	435,6
3	2	-7	6	5	sand	42	84	220	2300	276,5	289,8	566,3
4	2	-9	8	7	sand	44	88	308	2540	387,2	320,0	707,2
5	2	-11	10	9	sand	46	92	400	2600	502,8	327,6	**830,4**

Table 4. The calculation of square section II

Square section (II)												
N curr. layer	h_i, m	EOL, m	H_{pil}, m	h_{cpi}, m	GTE	f_i, kN/m^2	$f_i * h_i$, kN/m^2	$\Sigma f_i * h_i$,	Ri, kPa	F_{df}, kN	F_{dR}, kN	F_d, kN
1	2	3	4	5	6	7	8	9	10	11	12	13
1	2	-3	2	1	sand	30	60	60	1900	96,0	304,0	400,0
2	2	-5	4	3	sand	38	76	136	2100	217,6	336,0	553,6
3	2	-7	6	5	sand	42	84	220	2300	352,0	368,0	720,0
4	2	-9	8	7	sand	44	88	308	2540	492,8	406,4	899,2
5	2	-11	10	9	sand	46	92	400	2600	640,0	416,0	**1056,0**

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Table 5. The calculation of cruciform section III

Cruciform section (III)												
N curr. layer	h_i, m	EOL, m	H_{pil}, m	h_{cpi}, m	GTE	f_i, kN/m^2	$f_i * h_i$, kN/m^2	$\Sigma f_i * h_i$,	Ri, kPa	F_{df}, kN	F_{dR}, kN	F_d, kN
1	2	3	4	5	6	7	8	9	10	11	12	13
1	2	-3	2	1	sand	30	60	60	1900	96,0	110,2	206,2
2	2	-5	4	3	sand	38	76	136	2100	217,6	121,8	339,4
3	2	-7	6	5	sand	42	84	220	2300	352,0	133,4	485,4
4	2	-9	8	7	sand	44	88	308	2540	492,8	147,3	640,1
5	2	-11	10	9	sand	46	92	400	2600	640,0	150,8	**790,8**

Table 6. The calculation of T-bar section IV

T-bar section (IV)												
N curr. layer	h_i, m	EOL, m	H_{pil}, m	h_{cpi}, m	GTE	f_i, kN/m^2	$f_i * h_i$, kN/m^2	$\Sigma f_i * h_i$,	Ri, kPa	F_{df}, kN	F_{dR}, kN	F_d, kN
1	2	3	4	5	6	7	8	9	10	11	12	13
1	2	-3	2	1	sand	30	60	60	1900	96,0	110,2	206,2
2	2	-5	4	3	sand	38	76	136	2100	217,6	121,8	339,4
3	2	-7	6	5	sand	42	84	220	2300	352,0	133,4	485,4
4	2	-9	8	7	sand	44	88	308	2540	492,8	147,3	640,1
5	2	-11	10	9	sand	46	92	400	2600	640,0	150,8	**790,8**

Table 7. The calculation of I-beam section V

I-beam section (V)												
N curr. layer	h_i, m	EOL, m	H_{pil}, m	h_{cpi}, m	GTE	f_i, kN/m^2	$f_i * h_i$, kN/m^2	$\Sigma f_i * h_i$,	Ri, kPa	F_{df}, kN	F_{dR}, kN	F_d, kN
1	2	3	4	5	6	7	8	9	10	11	12	13
1	2	-3	2	1	sand	30	60	60	1900	134,4	157,7	292,1
2	2	-5	4	3	sand	38	76	136	2100	304,6	174,3	478,9
3	2	-7	6	5	sand	42	84	220	2300	492,8	190,9	683,7
4	2	-9	8	7	sand	44	88	308	2540	689,9	210,8	900,7
5	2	-11	10	9	sand	46	92	400	2600	896,0	215,8	**1111,8**

By the results obtained has been constructed dependence the bearing capacity of the pile from the cross-sectional shapes that are shown at Figure 1.

The graph shows that a pile of the square cross section «II» has a maximum value and average value of the outer perimeter. However, the total value of a pile bearing capacity is substantially less than the pile I-beam cross section «V», having a small cross-sectional area, but the maximum perimeter.

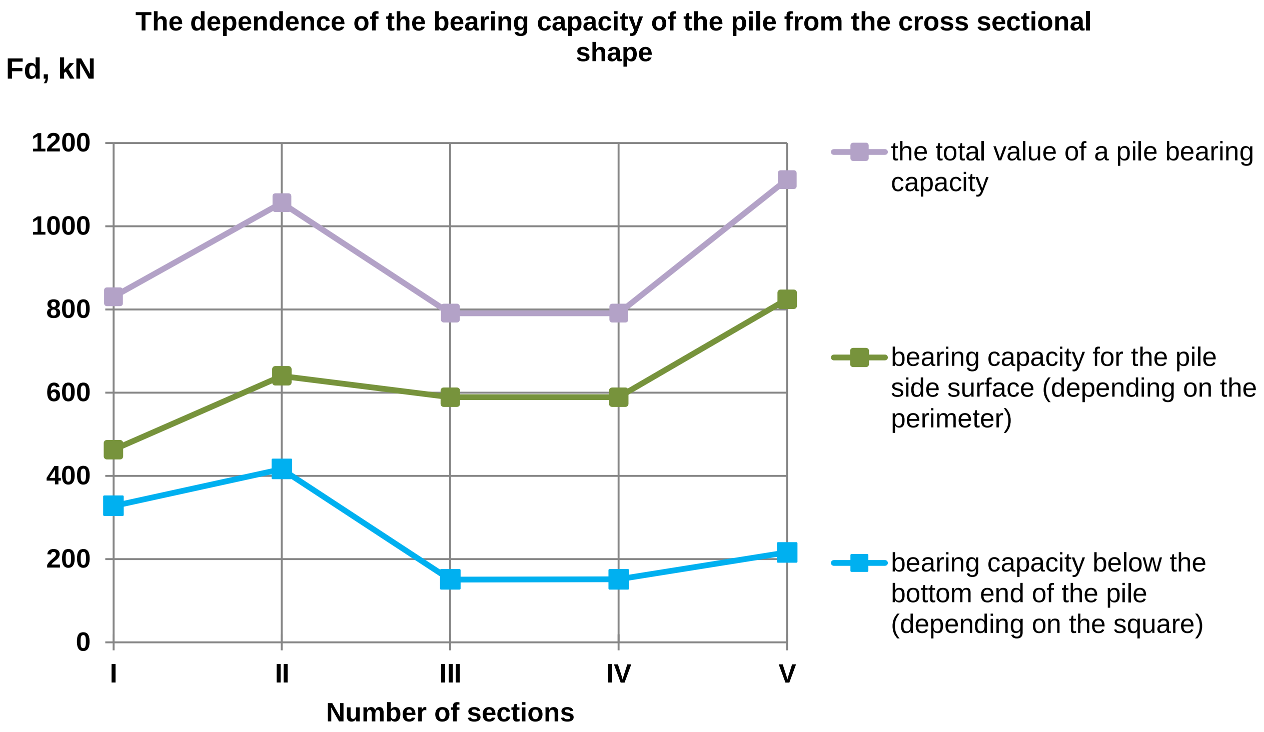

Figure 1. The dependence of the bearing capacity of the pile from the cross sectional shape

3. Findings

1. Maximum bearing capacity corresponds to I-beam cross-sectional shape.

2. The largest contribution to the value bearing capacity of the pile contributes component, depending on the outer cross-sectional perimeter of the pile rather than by its area.

3. Given that the perimeter cross-sectional of the pile is nothing else than the side surface of the pile with the mating surface of the ground, the value of the bearing capacity is highest in the pile with an extended side surface.

4. Applying the pile with an extended side surface may significantly reduce material piles not only by reducing the cross-sectional area, but also due to the length of the pile.

As a conclusion, we consider it is necessary to note that the confirmation of the results would be advisable to conduct full-scale tests. However, it should be borne in mind that the choice of pile driving equipment must take into account a number of factors (criteria) that can make such choice as optimal as possible [3, 21, 22].

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Несущая способность забивной сваи различных форм поперечного сечения

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ИНФОРМАЦИЯ О СТАТЬЕ	**История**	**Ключевые слова**
УДК 624.155	Подана в редакцию 12 декабря 2013	свайные фундаменты типы свай поперечное сечение сваи забивные сваи несущая способность свай

АННОТАЦИЯ

В статье опубликовано исследование влияния формы поперечного сечения на величину несущей способности сваи. Особое внимание уделено забивным сваям, ввиду их массового применения в строительстве. Для исследования взяты пять форм поперечного сечения: круглое, квадратное, крестообразное, тавровое, двутавровое. В качестве грунта рассматривается мелкозернистый песчаный грунт. Произведен расчет несущей способности свай с данными формами поперечного сечения. В результате исследования, выяснилось, что больший вклад в несущую способность сваи вносит составляющая, зависящая от наружного периметра поперечного сечения сваи.

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