A CASE STUDY OF AN ANAEROBIC DIGESTER STRUCTURE

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Abstract: A wastewater treatment plant named as Kızıltepe Wastewater Treatment Plant, construction area is located at the city of Mardin and district of Kızıltepe. The purpose of this study is to design the deep foundation system composed of vertical pile elements for the anaerobic digester structures planned to build in the construction area of Waste Water Treatment Plant. The pile group designed is subjected to vertical and lateral loads. The weight of the digester structure, waste weight containing in the digester structure and the foundation weight have been considered as vertical loads. However, the wind and earthquake loads have been taken into account as lateral loads. The experimental studies both laboratory and in-situ have been performed to obtain the geotechnical parameters which are necessary for the design of the foundation system of anaerobic digester structures. The boring logs including N values obtained from Standart Penetration Tests (SPT) and results of the laboratory studies belonging to the borehole drilled in the anaerobic digester structures construction area have been used for this study.

Keywords : deep foundation, pile group, bearing capacity, lateral load.

Introduction

Pile as a structural element commonly are employed to overcome the problems like low bearing capacity of subsoil layers, high values of overturning moments, considerable subsidence and etc. However, since the very early stage of geotechnical engineering profession, estimation of the bearing capacity of piles had been a challenge for engineers (Karimpour-Fard & Eslami, 2013).

Pile foundations are extensively used to support various structures built on loose/soft soils, where shallow foundations would undergo excessive settlements or shear failure. These piles are used to support vertical loads, lateral loads, or a combination of vertical and lateral loads. However, in view of the complexity involved in analyzing the piles under combined loading, the current practice is to analyze the piles independently for vertical loads to determine their bearing capacity and settlement and for the lateral load to determine their flexural behavior (Karthigeyan, Ramakrishna & Rajagopal, 2007).

The main object of this study is to design the foundation system composed of vertical pile elements for the anaerobic digester structure. As a first step, the pile group designed is subjected to vertical and lateral loads. The weight of the digester structure, waste weight containing in the digester structure and the foundation weight have been considered as vertical loads. Also, the wind and earthquake loads have been taken into account as lateral loads.

The boring log, N values obtained from Standart Penetration Tests (SPT) and results of the laboratory studies have been used in the preparation of this study.

Site Conditions

One borehole was drilled in the anaerobic digester structures construction area. The depth of borehole was about 30.0 m. Laboratory test results performed on the specimen obtained from the borehole BH7 and the SPT-N values belonging to this borehole (S7 in Turkish report) have been used while preparing this study. The layout of the wastewater treatment plant and locations of the soil borings performed in construction area have been shown in Figure 1.

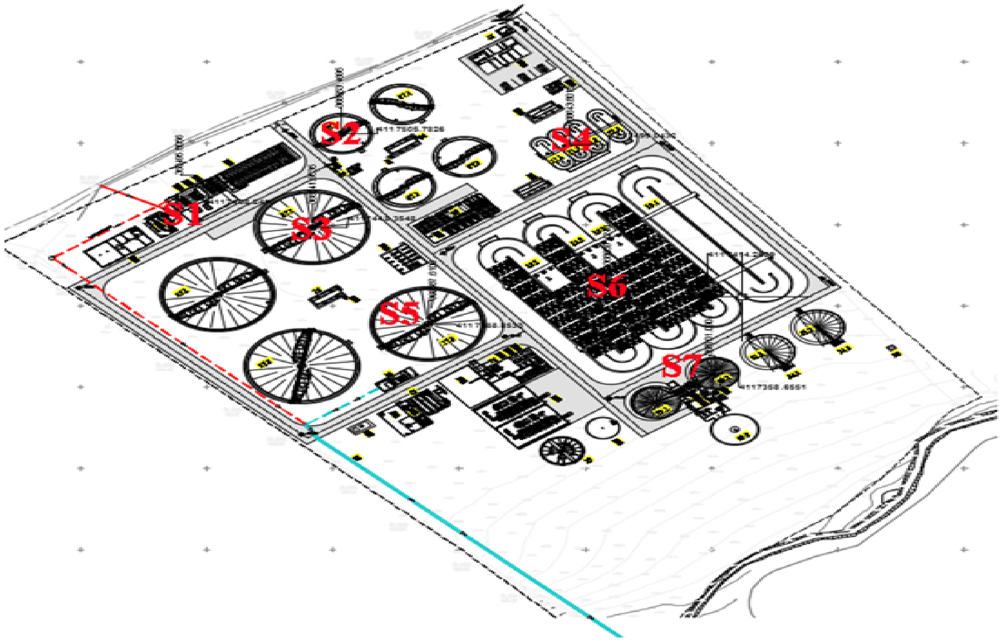

Figure 1. The layout of the Wastewater Treatment Plant and Locations of the Soil Borings

The N_{30} values obtained from Standart Penetration Tests (SPT) for corresponding depths have been summarized for the borehole BH7 in **Table 1**.

The soil profiles encountered in the field has been given in below for borehole BH7.

BH 7 (Boring Log)

0.00 – 0.50 m	Vegetable Soil
0.50 – 30.00 m	Sandy Silty CLAY

The groundwater level was encountered at the depth of **-13.0 m** in the boring.

Table 1. SPT N_{30} Values

Depth (m)	*SPT-N₃₀*	Depth (m)	*SPT-N₃₀*
1.50	*16*	**16.50**	*R*
3.00	*22*	**18.00**	*R*
4.50	*21*	**19.50**	*R*
6.00	*26*	**21.00**	*R*
7.50	*34*	**22.50**	*R*
9.00	*43*	**24.0**	*R*
10.50	*45*	**25.50**	*R*
12.00	*46*	**27.00**	*R*
13.50	*61–R*	**28.50**	*R*
15.00	*58-R*	**30.00**	*R*

The Vertical and Lateral Load Capacities of A Vertical Pile

Pile foundations for buildings and bridges are often subjected to vertical and horizontal loads simultaneously. Yet, the axial and lateral responses of piles are often evaluated separately without considering their possible interactions (Zhang et al., 2002).

Behaviour of single pile under uplift load is well established and classical solutions are available for estimating the uplift load carrying capacity of pile. But, piles are installed in group in general (Ayothiraman & Tank, 2010). In this study, the pile group designed is subjected to vertical and lateral loads. The weight of the digester structure, waste weight containing in the digester structure and the foundation weight have been considered as vertical loads. However, the wind and earthquake loads have been taken into account as lateral loads.

Design methods for piled foundations still concentrate on providing axial capacity from the piles to carry the total structural load (de Sanctis & Mandolini, 2006). The total load has been taken into as equal to **87000 kN** in this study. The base of the pile will have been on the layer which has a SPT N value greater than 50. Therefore, it is not expected settlements which are significantly large.

The Vertical Load Capacity of A Vertical Pile

The axial load capacity of the single vertical pile has been calculated as indicated in below (Table 2).

Table 2. The Axial Load Capacity of the Single Vertical Pile

	c (kPa)	L (m)	ϕ (cm)	Q_f (formula)	Q_f (kN)
1	80	4.50	80	$Q_f = A_s * \alpha * c_u$	**507.00**
2	150	6.00	80		**905.00**
3	200	4.50	80		**860.00**

Q_f = ultimate friction load or skin load
A_s = total surface area of pile embedded below ground surface
c_u = average undrained shear strength of clay along the shaft
α = adhesion factor
ϕ or D = diameter of pile
L = length of pile

The axial load capacity of the single vertical pile has been calculated as indicated in below [7].

$Q_b = (c * N_c * A_b) = 200 * 9 * 0{,}503 = \mathbf{905{,}0\ kN}$ (the base or point load) (1)
$Q_a = (507{,}0 + 905{,}0 + 860{,}0 + 905{,}0)/2{,}5 = \mathbf{1271{,}0\ kN}$ (allowable total loads) (2)

The axial load capacity of the pile element has been chosen as equal to the **Q_a = 1270 kN.**

The pile length, diameter and spacing of the pile centers are summarized in below:

- L = 15 m D=80cm S=2.40 m = 3D

The pile number in the pile group has been calculated as the ratio of total load / axial load capacity of a pile.

Number of the pile in the pile group = 87000 kN / 1270 kN = **69**

The piles will be placed beneath the foundation of the digester structure with the grid of **2.40 m x 2.40 m.**

The distance between the centers of the piles is equal to **3D**.

The Lateral Load Capacity of A Vertical Pile

Pile foundations are generally preferred when heavy structural loads have to be transferred through weak subsoil to firm strata. These foundations in some situations are subjected to significant amount of lateral loads besides vertical loads (Juvekar & Pise, 2008). In order to that, amount of lateral loads must have to known by researchers. The lateral load capacity of the pile element has been calculated using the method proposed by Broms. The smallest lateral load capacity value calculated for the cases mentioned above has been chosen as the lateral load capacity.

$$M_y = \frac{f'^{c} * I}{h} \tag{3}$$

For C30 concrete, $f_{ck} = 30\ MPa = 30000\ kN/m^2$,

$$I = \frac{\pi * R^4}{64} = \frac{\pi * (0.8)^4}{64} = 0.02011 \tag{4}$$

$$M_y = \frac{30000 kN/m^2 * 0.02011\ m^4}{0.40} = 1508.25\ kN \tag{5}$$

c=100 kPa L=15.0 metre Ø80 cm e=0

$$P_{ult-1} = \frac{M_y}{0.5L + 0.75b} = 845\ kN \tag{6}$$

$$P_{ult-2} = \frac{2M_y}{1.5b + 0.5f} = \frac{3016.5}{1.5*0.80+0.5*2.40} \cong 1256\ kN \tag{7}$$

$$The\ minimum\ \rightarrow \boldsymbol{P_{ult} = 845\ kN}\ are\ chosen.$$

$$P = \frac{845}{3.0} = \boldsymbol{281\ kN}$$

Conclusions

In this study, the total load is about equal to 87000 kN. The axial load capacity of a single vertical pile has been calculated as 1270 kN. Number of vertical pile are 69. The lateral load capacity of the pile has been calculated using the method proposed by Broms and are chosen according to the smallest value. The smallest lateral load has been calculated 845 kN. Safety factor is taken 3.0 in this study. Allowable lateral load is about to equal to 281 kN.

References

Karimpour-Fard, M., & Eslami, A. (2013). Estimation of vertical bearing capacity of piles using the results CPT and SPT tests.

Karthigeyan, S., Ramakrishna, V. V. G. S. T., & Rajagopal, K. (2007). Numerical investigation of the effect of vertical load on the lateral response of piles. Journal of Geotechnical and Geoenvironmental Engineering, 133(5), 512-521.

Zhang, L. M., McVay, M. C., Han, S. J., Lai, P. W., & Gardner, R. (2002). Effects of dead loads on the lateral response of battered pile groups. Canadian Geotechnical Journal, 39(3), 561-575.

Ayothiraman, R., & Tank, R. K. (2010). Group Efficiency Factor for Pile Groups in Clay Under Uplift Loading.

de Sanctis, L., & Mandolini, A. (2006). Bearing capacity of piled rafts on soft clay soils. Journal of Geotechnical and Geoenvironmental Engineering, 132(12), 1600-1610.

Juvekar, M. S., & Pise, P. J. (2008). Behavior of rigid batter piles and pile groups subjected to horizontal load in sand. Indian Geotechnical Journal, 38(2), 221-242.

Murthy, V. N. S. Advanced Foundation Engineering. CBS Publishers & Distributors, 2007.

