https://doi.org/10.1051/e3sconf/202015602006

Alternative foundation for reducing building losses due to foundation failure in soft soil

Susy Srihandayani [1,2*]

[1] Doctoral Program, Departement of Civil Eng., Engineering Faculty, Andalas University,
[2] Civil Engineering Study Program, Sekolah Tinggi Teknologi Dumai, Riau, Indonesia

Abstract. Much damage to buildings occurs in areas that have soft soil layers due to the failure of the foundations. Besides, foundations in soft soils generally require very expensive construction. For this reason, proper research needs to help develop strong foundations that can be used on soft soils with relatively low cost. In this research, foundations with various diameters and depths were tested on soft soil. The foundations were made of PVC pipes with diameters of ½ ", 1", 2 " or 2.5" and the same depth. Soft soil in the form of clay with particle-sizes that passed filter No. 200 was used. Before testing the foundations, carrying capacity analysis was done using the classical method on each pipe with a closed head so that the optimum carrying capacity of each foundation (PVC Pipe) was known. From this test the influence of the size of the foundations on the carrying capacity of soft soil could be seen. The results of this research will help reduce building loss/damage in areas dominated by soft topsoil

1 Introduction

The land must support the strength of building construction in order for the construction to stand secure and safe for its predicted life span. To do this, the land must have the required geotechnical properties [1].

Damage to many buildings frequently occurs in areas that have soft soil layers due to foundation failure. Soft soils have high shear strength and compressibility. Which if it is not properly recognized and accounted for in the design will cause instability and unacceptable long-term decline. The rapid development of infrastructure in Indonesia has increased land demand leading to construction on soft and less stable land that does not meet safety requirements when there is vibration or an earthquake [2].

The characteristics of soft soils mean engineers must determine appropriate methods of stabilization through efficient foundation design. Generally, in Indonesia, construction workers use woodpiles or bamboo to increase bearing capacity for structures on soft and peat soils. [3] Wood piles are resistant to acid content, inexpensive and easy. However, they result in environmental damage because workers have to cut down trees for the woodpiles. To avoid this a more appropriate and efficient strategy is required. One of which is designing lightweight foundations that are environmentally friendly for lightweight / simple buildings specifically for soft soils.

This paper presents the results of preliminary research using classical theory to determine the carrying capacity of light foundations from inexpensive and environmentally friendly materials in soft soils to estimate whether they could bear the burden of simple houses or other civilian buildings.

This type of light foundation design on soft soil is still a new method of soil, which is why this research is necessary. The results contribute to the progress of civil engineering and construction in Indonesia by providing solutions in designing foundations for soft soils.

2 Laboratory experiment

2.1 Soil properties

Having a clear understanding of the land on a building site is essential when planning a building that will be sturdy, safe, stable and economical. The purposes of a ground survey are to:

- Determine the physical and mechanical properties of the soil
- Determine the carrying capacity of the soil
- Determine the type of foundation to be used according to the carrying capacity of the soil.

Soil investigations can be done in the laboratory or in the field. In this research, soil investigation included soil sampling in the field and testing it in the laboratory to obtain the physical and mechanical properties of the soil.

The test results can be seen in Table 1. The result of the UCS test is 0.03 kN /m2 loss/damage meaning that the soil can be categorized as very soft soil. The moisture content was 98.8%, greater than the standard liquid limit.

* Corresponding author: susys3unand18@gmail.com

Table 1. Soil Properties

Type of parameter		Value	Unit
Specific Gravity		2,5	
Unit Volume		0,16	kg/cm^3
Liquid limit		52,9	%
Plastic Limit		31,1	%
Plastic Index		21,8	%
Direct Shear	ϕ	3,21	°
	c	0,02	kg/cm^2

2.2 Foundation materials

The foundation was made of PVC (Poly Vinyl Chloride which is readily available on the market. This material is flexible and relatively resistant to weather and humidity. 30 cm lengths of ½ ", 1", 2 " and 2.5" diameter pipe were used and each pipe was inserted into the soft soil inside a glass box sized 60cm x 20cm x 40 cm. Before the laboratory loading test was conducted, a theoretical carrying capacity analysis was done using the classic Mayerhof method for each diameter pile and then the results of the analysis were graphically compared with the results of the load test.

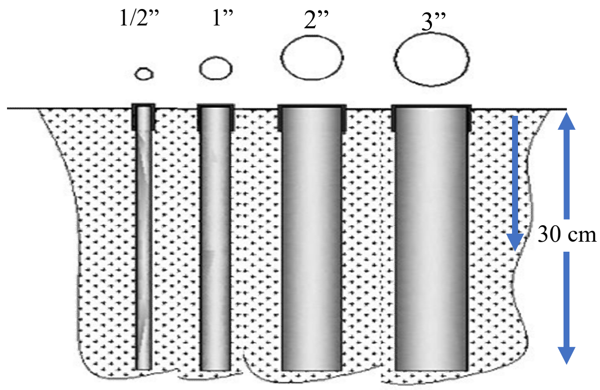

Fig 1. Foundation Prototype and Dimension

2.3 Analytical study

2.3.1. Analytically Load Capacity

The carrying capacity of the pile is a combination of the carrying capacity of the tip with the carrying capacity due to the friction on the pile. Whereas in the foundation model using PVC piping, the bottom end of the pipe was left open and the top of the pipe capped in an airtight manner, thus utilizing the principle of Archimedes's law to increase the carrying capacity of the pole.

The end bearing capacity of the foundation on saturated clay is calculated using the Meyerhof method [4].

$$Q_p = A_p \, Cu_{(p)} \, N_c \qquad (1)$$

$$A_p = \tfrac{1}{4} \pi D^2 \qquad (2)$$

Cu (p) is the undrained soil cohesion condition at the tip of the pole, Ap is the cross-sectional area of the pole tip, and Nc is the carrying capacity factor, the value of Nc varying depending on the method used; 9 for Mayerhof and 5.7 for Jambu's method.

Determination of the surface friction on the pole used the Alpha Method with the equation:

$$Q_s = \alpha \, C_u \, \Theta \Delta L \qquad (3)$$

α being an empirical adhesion factor with its value is based on C_u, as can be seen in **Fig.2**.

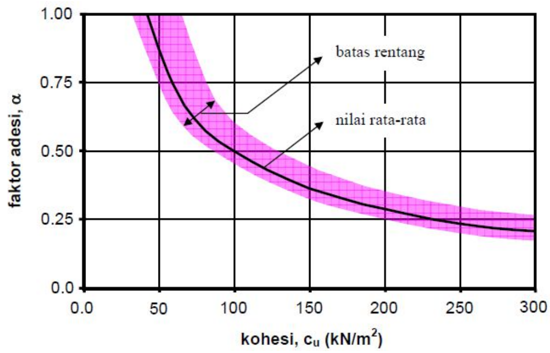

Fig. 2 Value of the Adhesion Factor (Sources: A.Hakam, Rekayasa Pondasi)

Θ is the parameter of the pile in the long section of ΔL. For practical purposes, the ultimate bearing capacity is divided by a safety factor, SF of 1.5 to 4.0. The buoyancy effect of the closed pipe head due to the water pressure was calculated as:

$$F_a = \pi \left(\tfrac{1}{2} D_i\right)^2 H \gamma_w \qquad (4)$$

So, the total carrying capacity for a single pole of each size variation is:

$$Q_{ult} = Q_p + Q_s + F_a \qquad (5)$$

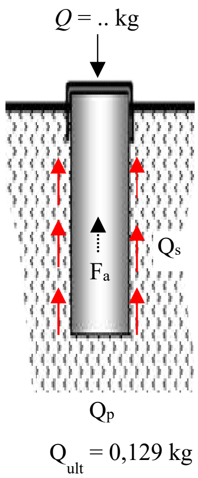

Fig. 3 Carrying Capacity of a Single Pole

2.3.2. Loading Test in the Laboratory

To check the validity of this theoretical analysis, a loading test was also performed on models of each pile diameter inserted in soil that had been left to settle for two weeks in a 60 cm x 40 cm x 20 cm glass box. [5]

The loading test steps were as follows:

- Preparation of the equipment and collection of soil.
- Preparation of the soil sample by passing the soil through a no. 200 sieve.
- Prepared soil left to settle in the glass box for approximately two weeks until it looked solid.
- Conducting the loading test vertically for each pipe. The test results were plotted into a load vs. settlement chart, and the carrying capacity determined using the CRP method.
- Comparison of the test results with analytical calculations

The testing method can be seen in Fig 4

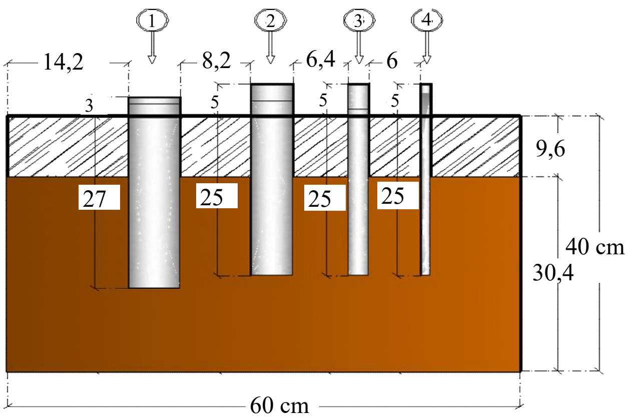

Fig. 4 Detail of the Laboratory test

2.4 Result

2.4.1. Analysis using the Mayerhof method

The results of analytical calculations using equations (1) to (4) can be seen in Table 2.

Table 2. Results of the Meyerhoff method analysis

No	Pile Size (inc)	Q_p (Kg)	Q_s (Kg)	F_a (Kg)	Qult (Kg)
1	0,5	0,00073	0,032	0,096	0,129
2	1	0,00134	0,046	0,208	0,255
3	2	0,00342	0,086	0,759	0,848
4	2,5	0,00483	0,110	1,231	1,346

Table 2 shows the maximum carrying capacity of each pipe diameter. The pole diameter affected the carrying capacity of the pole. The higher the diameter of the pole, the higher the carrying capacity.

2.4.2. Loading Test Analysis Results

The ½ "pipe pole model experienced a settlement in the load-bearing pile from 15 to 20 mm as shown in Figure 5

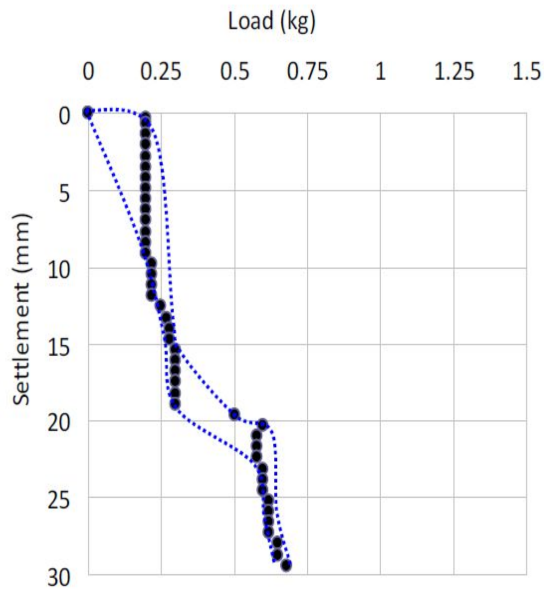

Fig. 5. Load - Settlement for ½" diameter pile

For other foundation models 1 ", 2" and 2.5 ", the results showed settlements in response to loads as seen in Fig 6 to Fig 8. Settlement depth increased with load with a maximum of 20 mm when the load was maximum. [5]

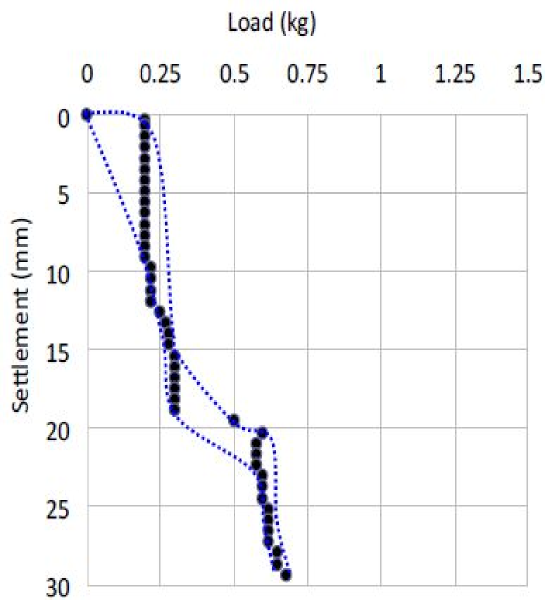

Fig. 6 Load-Settlement for 1" diameter

To obtain the bearing capacity of each pole, the ultimate load, which is the maximum load, was reduced by the air held inside the pipe pile, and each load was divided by the diameter of the pile, as shown in Table 3.

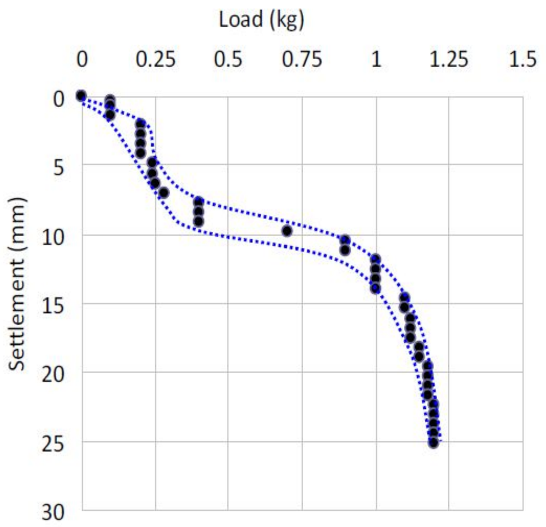

Fig. 7 Load-Settlement for 2" diameter

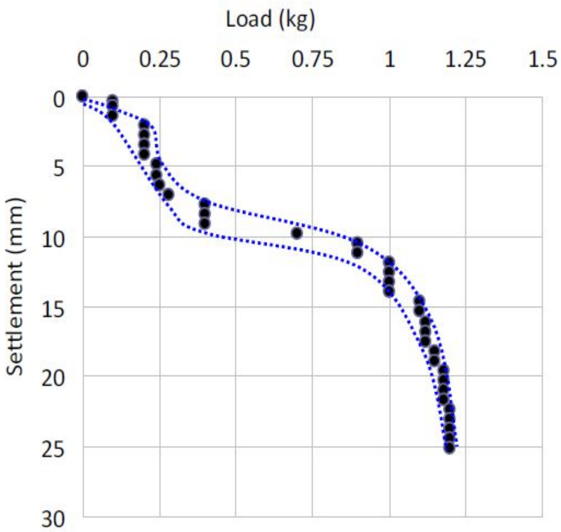

Fig. 8 Load-Settlement for 2.5" diameter

The results of loading and settlement tests can be seen in table 3

Table. 3 Test results summary

MODEL TYPE	½"	1"	2"	2,5"
Dia (cm)	1,27	2,54	5,08	6,35
Length (cm)	30	30	30	30
Skin Area (cm2)	3,8	8,04	28,26	41,83
Air (kg)	0,09	0,21	0,76	1,23
Load (kg)	0,25	0,60	1,02	1,18
P_{net} (kg)	0,23	0,52	0,72	0,70
P_{net}/ Dia	0,18	0,21	0,14	0,11

The relationship between maximum load and pile diameter is shown in Fig 9

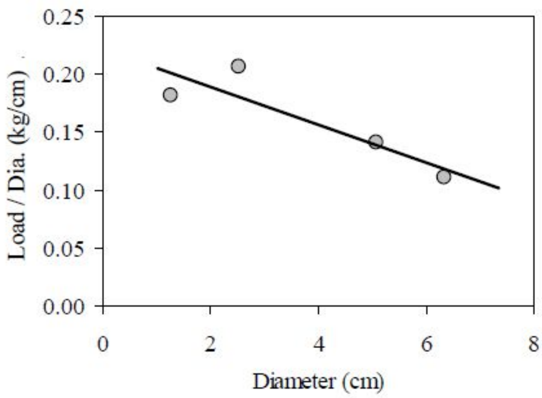

Fig. 9. Maximum load – diameter ratio

Based on the results of analytical and graphical calculations, a comparison chart of the carrying capacity values is shown in Fig 10. The analytical carrying capacity using the Meyerhoff method was found to be higher than the results of the loading test.

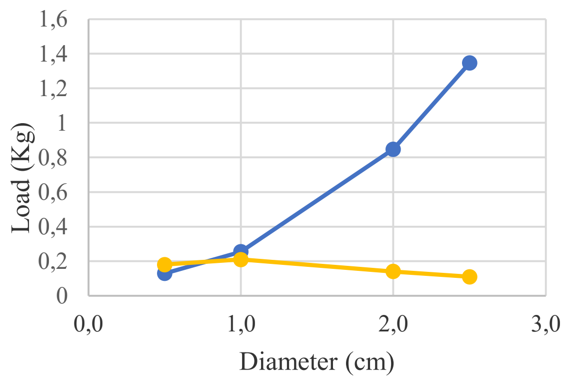

Fig. 10 Graphs of analytical carrying capacity and laboratory loading test.

Conclusions

Based on the results above the following conclusions can be drawn:

- The use of top sealed PVC pipe piles can increase the total capacity of the foundation. The higher the diameter of the pole, the higher the load that can be supported by the pile system.
- Analysis using the classical method gives carrying capacity values that are higher than those calculated from the graphical analysis of laboratory observations.

References

1. I. T. Sitompul, A. Alwi, and E. Priadi, *Studi Daya Dukung Pondasi Kolom - semen Pada Tanah Lunak Dengan Pondasi Kolom - semen D engan Metode Loading Test Di Kota Pontianak*, UTAN (2016)
2. S. Srihandayani, D. Putri, N. Kurniasih, and L. D. Putri, Int. J. Eng. Technol, **7** (2.5 Special Issue 5), 2–5 (2018)

3. Sudarwanto, Muhardi, and F. Fatnanta, Racic J. Tek. Sipil Univ. Abdurrab **2** (2) 248–264 (2017).
4. A. Hakam and I. F. Pane, J. Arsit. Atrium **2** (1) 5–14 (2005)
5. A. Hakam and S. Srihandayani, in *IOP* Conference *Series: Materials Science and Engineering*, 1–8 (2019)