Analysis of Shallow Foundation Bearing Capacity in Clay Soil Using PVC Pipe Reinforcement with Grid Pattern

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Abstract. The foundation is the lower structural element that functions to lay the building and transmits the load of the superstructure to the subgrade base and is able to ensure its stability both against the weight of the building itself and other loads. In the Palembang city area, it is found that the soil surface in the form of swamps has a low carrying capacity value which requires special handling so that the carrying capacity of the soil increases, one of which is to treat the soil by planting PVC pipe tubes closed at the ends with a grid pattern. The purpose of this study was to determine how the value of the bearing capacity of the soil using PVC pipe tubes. The study was conducting field experiments by comparing the results of the soil bearing capacity between foundations without PVC pipes and with PVC pipes in 3 treatments, namely 9, 16, and 25 pipes. From the results obtained, there is an increase in the bearing capacity of the soil after being treated with the use of pipes. The highest soil bearing capacity value is seen in the use of 25 pipes. It can be concluded that the use of PVC pipe can increase the bearing capacity of the soil. it can be concluded that the use of PVC pipes can increase the bearing capacity of the soil based on CBR value, especially in shallow foundations. The more pipes used, the higher the bearing capacity of the soil. it can be concluded that the use of PVC pipes can increase the bearing capacity of the soil based on CBR value, especially in shallow foundations. The more pipes used, the higher the bearing capacity of the soil. it can be concluded that the use of PVC pipes can increase the bearing capacity of the soil based on CBR value, especially in shallow foundations. The more pipes used, the higher the bearing capacity of the soil.

Keywords: Foundation · CBR · Soil Bearing Capacity · PVC pipe

1 Introduction

An the foundation is the lower structural element that serves to lay the building and transmit the load of the superstructure to the ground which is able to ensure its stability both against the weight of the building itself and external loads. In general, the type of foundation is divided into 2 criteria, namely shallow foundation and deep foundation [1].

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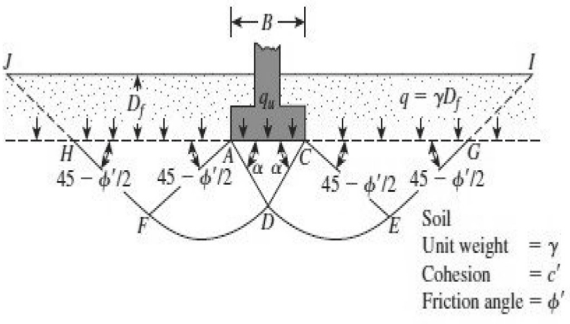

Fig. 1. Collapse Line

Table 1. Description of silt and clay

Soil Properties	Unconfined Compression Strength (kg/cm^2)
Very soft	<0.25
Soft	0.25–0.50
Firm	0.5–1
Stiff	1–2
Very Stiff	2–4
Hard	>4

Shallow foundation technique is to widen the bottom of the column or building wall so that the building load is spread to a smaller size than the allowable soil bearing capacity. Shallow foundations are usually defined as the depth of the foundation base from the ground surface is less than or equal to the foundation width $D \leq B$ [2]. If it is considered an infinitely long foundation, then the failure plane can be described as follows (Fig. 1).

While other soil mechanics think shallow foundation is $D \leq 5B$ [3].

In the area of the city of Palembang found a lot of land surface in the form of swamp/soft soil. Soft soil is an aggregate of microscopic and sub microscopic sized particles derived from the chemical decomposition of rock constituent elements, and is plastic in the range of moderate to wide water content. In a dry state, it is very hard and does not peel off easily with just your fingers [4]. Soft soil properties are small shear force, large compression, small coefficient of permeability and low bearing capacity when compared to other clay soils [5]. Cohesive clay is classified as soft soil if it has a bearing capacity less than 0.5 kg/cm^2 and the standard penetration test value is less than 4 (N value < 4) [2]. Based on field tests, physically soft soil can be squeezed easily by fingers [6].

The form of silt and clay is adjusted according to the terms used according to their strength (Table 1).

The permeability of clay is very low which has a low value of soil bearing capacity and large settlement. The bearing capacity of the soil is the maximum pressure that the soil can carry without sliding [2]. While the ultimate bearing capacity is a condition/limit where the soil is unable to bear the pressure acting on it [5]. To calculate the ultimate soil bearing capacity, it is necessary to know the weight of the soil volume (γ), soil cohesion (c), and the soil shear angle (φ) [7].

Determining the carrying capacity of the limit in real/real is by direct loading by giving an experimental load and measuring the decrease [8]. The method of applying the loading experiment in the implementation of making shallow foundations for tread houses which is usually practiced is by plugging dolken rods into the bottom of the foundation with a certain depth. However, the availability/use of gelam is increasingly depleting/decreasing due to limited natural resources, so it needs to be anticipated.

Several studies have been conducted regarding the bearing capacity of the soil on soft/clay soils. The original soil improvement can be done by adding variations to the embankment soil in terms of the CBR (California Bearing Ratio) value. The results of these tests showed an increase in the carrying capacity of the soil against soft soil after being treated to the soil, namely backfilling and compaction. This is evidenced by the increasing CBR value [9]. The effect of improving the bearing capacity of low soil (peat) by engineered to coat woven bamboo and bamboo grids at the base of the foundation so that it will increase the bearing capacity of the soil. The results of the study concluded that the closer the reinforcement distance to the base of the foundation and the greater the number of layers of reinforcement, the bearing capacity of the soil will increase and the ability of the soil to withstand the load from above will be greater [10].

Existing soil (peat soil, swamp soil and soft soil) if given soil improvement by placing a single model cone on the three types of soil, it will result in an increase in the carrying capacity of the soil [11]. Testing using a combination of woven geotextiles and bamboo grids as reinforcement for shallow foundations for soft soil/clay with a bearing capacity that is greater than the bearing capacity value obtained from modeling without reinforcement.

Based on these studies, a replacement for the increase in soil bearing capacity for shallow foundations was carried out using PVC pipes (PVC pipes were closed at the base). PVC (PolyVinyl Chloride) pipe is a thermoplastic polymer that ranks third in terms of world use, after polyethylene and polypropylene. The placement of the pipe is arranged with a grid pattern configuration at a certain depth just below the base of the foundation (shallow). It is assumed that the presence of air in the tube can provide uplift force so as to provide good soil bearing capacity (Fig. 2).

The reason for using PVC pipe tube as a method of soil repair/reinforcement is because the material can be obtained easily and the price is relatively cheap and durable. Even the use of PVC pipes can work better than using iron pipes that need soldering, are also resistant to almost all alkaline or toxic substances and are easy to install. So it can be easier and more economical to be applied in the field. The purpose of this study is to determine the existing carrying capacity without reinforcement and with reinforcement (using PVC pipe) against the settlement that occurs.

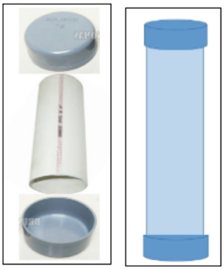

Fig. 2. PVC pipe and cap

2 Methodology

2.1 Research Location

Research locations are separated by activity, are:

a. The location for making reinforced concrete precast in the form of a square foot foundation is in the Open Workshop, Sriwijaya State Polytechnic Campus, Palembang.
b. The location of soil testing is in the laboratory Examination of physical and mechanical properties of soil, Soil Laboratory of Sriwijaya State Polytechnic, Palembang.
c. Location of direct/field research carried out in areas that have soft soil potential, atLebak Kranji, Bukit Lama, Palembang

2.2 Type of Research

The type of research that is Experimental Research is an experimental activity that aims to determine a symptom or effect that arises, as a result of certain treatments.

2.3 Data Collection Technique

2.3.1 Primary Data (Laboratory Data and Field Data)

This data is obtained directly from the results of tests in the field and in the laboratory. Covers the value of soil subsidence and examination of undisturbed soil samples which includes examination of soil physical properties (water content, soil density, density, atterberg limit, soil gradation inspection). Meanwhile, the examination of mechanical properties includes free compressive strength and direct shear strength and soil cohesion. Primary data generated from the field is used as the ratio of the bearing capacity of the soil with the reinforcement to the carrying capacity of the existing soil.

2.3.2 Secondary Data (Supporting Data)

Secondary data in the form of references from journals and books as well as applicable rules.

2.4 Research Variables

2.4.1 Independent Variables

The independent variable here is the planting of PVC pipes (which have been closed up and down) combined with the configuration/planting pattern (grid). The size of the pipe used is 3 inches with a length of 25 cm.

The amounts used for each field 'test object' are as follows:

1. P Ex is an Existing Foundation without reinforcement, without using PVC pipes.
2. PG-1 is a reinforced foundation, using 9 PVC pipes planted with a perimeter configuration
3. PG-2 is a reinforced foundation, planted with 16 PVC pipes in an evenly distributed configuration.
4. PG-3 is a reinforced foundation, planted with 25 PVC pipes with a perimeter configuration.

For more details, see the Fig. 3.

The tread foundation is made with a size of 60 × 60 × 20 cm and a pedestal size of 20 × 20 × 100 cm. Then fill the sacks/bags with split stones weighing 50 kg/sack as many as 20 sacks which will be used as loading models.

2.4.2 Independent Variables

The dependent variable here is the magnitude of the effect of giving the load gradually up to the maximum load for each point of the foundation. For the 4 specimens, the first load was 250 kg, given a 30 min break, then added a second load of 250 kg, given a 30 min break, then added a third load of 250 kg, given a 30 min break, then added a fourth load (last) 250 kg so that the total final load is 1000 kg.

2.5 Research Procedure

The research process can be seen in Fig. 4.

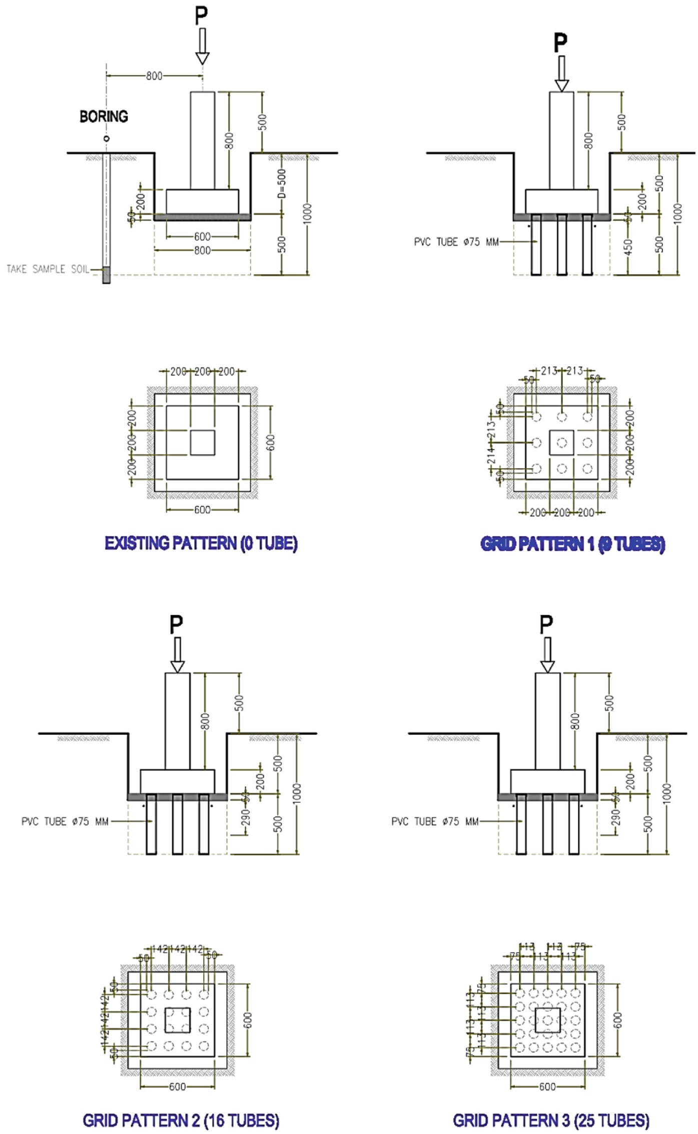

Fig. 3. Bottle planter pattern under the foundation

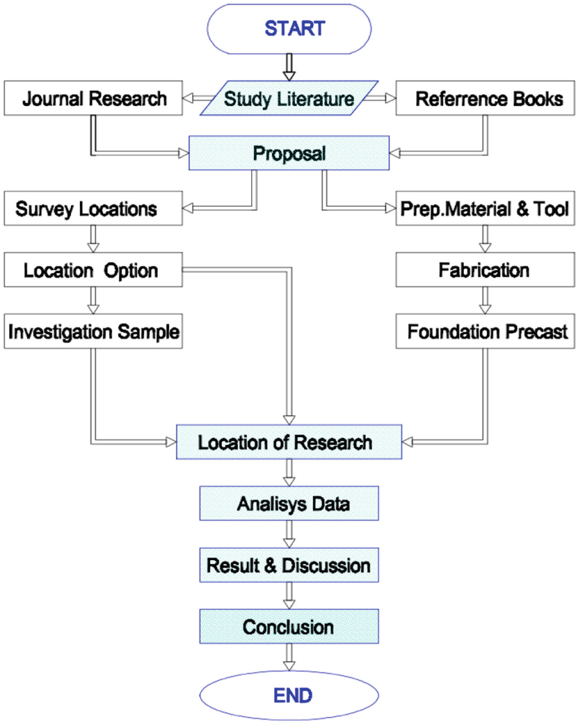

Fig. 4. Flow chat research method

Table 2. Sample Data

Long (cm)	Wide (cm)	Hight (cm)	Luas Normal (cm^2)	Sliding Area (cm^2)	Volume (cm^3)
(1)	(2)	(3)	(1 × 2)	(1 × 3)	(1 × 2 × 3)
6.00	6.00	3.00	36.00	18.00	108.00

3 Result and Discussion

3.1 Sample Data

Ring Volume = 108.00 cm^3
Weight Volume = 224.81 gr

See Tables 2 and 3.

Table 3. Fill weight

Code Sample	Sample A					
A.01 (−0.50 m)	Ring Weight + Soil		=	394.73	gr	
	Soil Weight		=	169.92	gr	
	Fill weigh γ =	**169.92 gr**	**=**	**1.573**	**gr/cm^3**	
		108.00 cm^3				
A.01 (−0.46 m)	Ring Weight + Soil		=	404.08	gr	
	Soil Weight		=	179.27	gr	**γ Average**
	Fill weigh γ =	**179.27 gr**	**=**	**1.660**	**gr/cm^3**	**gr/cm^3**
		108.00 cm^3				
A.01 (−0.42 m)	Ring Weight + Soil		=	389.54	gr	
	Soil Weight		=	164.73	gr	
	Fill weigh γ =	**164.73 gr**	**=**	**1.525**	**gr/cm^3**	
		108.00 cm^3				
Kode Sample	Sample B					
B.01 (−1.00m)	Ring Weight + Soil		=	396.26	gr	
	Soil Weight		=	171.45	gr	
	Fill weigh γ =	**171.45 gr**	=	**1.588**	**gr/cm^3**	
		108.00 cm^3				
B.01 (−0.96m)	Ring Weight + Soil		=	398.9	gr	
	Soil Weight		=	174.09	gr	**γ Average**
	Berat isi γ =	**174.09 gr**	**=**	**1.612**	**gr/cm^3**	**gr/cm^3**
		108.00 cm^3				
B.01 (−0.92m)	Ring Weight + Soil		=	404.14	gr	
	Soil Weight		=	179.33	gr	
	Fill weigh γ =	**179.33 gr**	**=**	**1.660**	**gr/cm^3**	
		108.00 cm^3				

3.2 Soil Carrying Capacity

3.2.1 G-0 Existing Soil

See Table 4 and Fig. 5.

From the data obtained, it can be seen that shallow foundations that do not lay PVC pipe tubes experience low soil bearing capacity. A fairly high subsidence of the soil can be seen from each additional load. Most drop at 1025 kg load with 32 mm of soil subsidence. When the load is lifted one by one, the soil increases by 12 mm.

Table 4. Existing soil result (Exixting Pattern 0 Tube)

Date	Time/Duration (hours)		Load (kg)	Loading Set. (mm)	Unloading (mm)
18-Sep-22	09.00/0		0	0	
	09.05/5’		225 = ow	2	
	10.35/65’	(1 h)	425	3	
	11.35/125’	(2 h)	625	5	
	12.35/185’	(3 h)	825	14	
19-Sep-22	08.35/1445’	(23 h)	1025	32	
19-Sep-22	08.35/0		1025		32
	09.35/60’	(1 h)	825		29
	10.35/120’	(2 h)	625		27
	11.35/180’	(3 h)	425		25
	12.35/240’	(4 h)	225 = ow		20

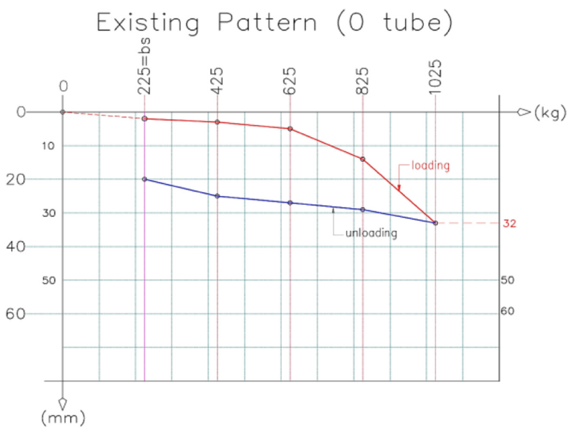

Fig. 5. Exixting Pattern

3.2.2 G1 (9 PVC Pipe Tubes)

See Table 5 and Fig. 6.

In the use of 9 PVC pipes with the grid method, it is seen that the soil subsidence is less than without the use of tubes. Maximum drop is 26 mm with 8 mm increments.

Table 5. G1 results G1 Pattern (9 Tube)

Date	Time/Duration (hours)		Load (kg)	Loading Set. (mm)	Unloading (mm)
19-Sep-22	09.00/0		0	0	
	09.05/5'		225 = ow	0	
	10.35/65'	(1 h)	425	7	
	11.35/125'	(2 h)	625	11	
	12.35/185'	(3 h)	825	15	
20-Sep-22	08.35/1445'	(23 h)	1025	26	
20-Sep-22	08.35/0		1025		26
	09.35/60'	(1 h)	825		25
	10.35/120'	(2 h)	625		23
	11.35/180'	(3 h)	425		21
	12.35/240'	(4 h)	225 = ow		18

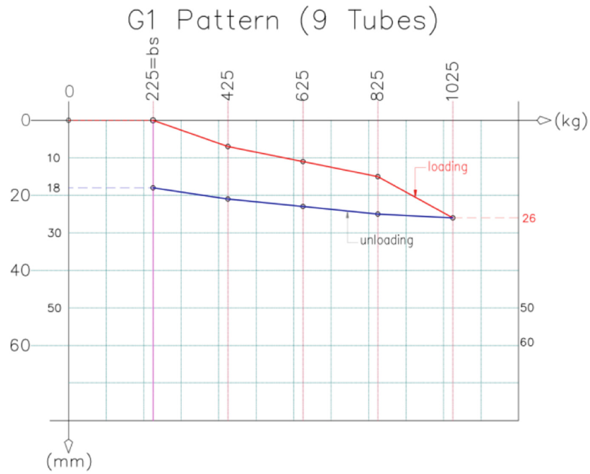

Fig. 6. G1 pattern

3.2.3 G 2 (16 PVC Pipe Tubes)

See Table 6 and Fig. 7.

The results of using 16 PVC pipe tubes showed a better soil bearing capacity with a decrease of only 24 mm.

Table 6. G2 results G2 Pattern (16 Tube)

Date	Time/Duration (hours)		Load (kg)	Loading Set. (mm)	Unloading (mm)
20-Sep-22	09.00/0		0	0	
	09.05/5'		225 = ow	0	
	10.35/65'	(1 h)	425	5	
	11.35/125'	(2 h)	625	7	
	12.35/185'	(3 h)	825	13	
21-Sep-22	08.35/1445'	(23 h)	1025	24	
21-Sep-22	08.35/0		1025		24
	09.35/60'	(1 h)	825		22
	10.35/120'	(2 h)	625		20
	11.35/180'	(3 h)	425		19
	12.35/240'	(4 h)	225 = ow		17

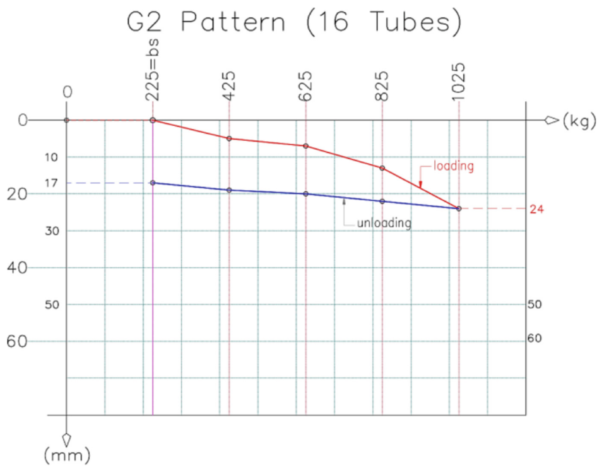

Fig. 7. G2 pattern

3.2.4 G3 (25 PVC Pipe Tubes)

See Table 7 and Fig. 8.

The best results are seen in the planting of 25 tubs of pvc pipe tube with an arrangement of 5 rods × 5 rods in one hole with a grid pattern, which only experienced 17 mm of soil subsidence and the balance was at 15 mm with the meaning of settlement (Fig. 9).

Table 7. G3 results

G3 Pattern (25 Tube)					
Date	**Time/Duration (hours)**		**Load (kg)**	**Loading Set. (mm)**	**Unloading (mm)**
21-Sep-22	09.00/0		0	0	
	09.05/5'		225 = ow	4	
	10.35/65'	(1 h)	425	7	
	11.35/125'	(2 h)	625	9	
	12.35/185'	(3 h)	825	13	
22-Sep-22	08.35/1445'	(23 h)	1025	17	
22-Sep-22	08.35/0		1025		17
	09.35/60'	(1 h)	825		17
	10.35/120'	(2 h)	625		16
	11.35/180'	(3 h)	425		15
	12.35/240'	(4 h)	225 = ow		15

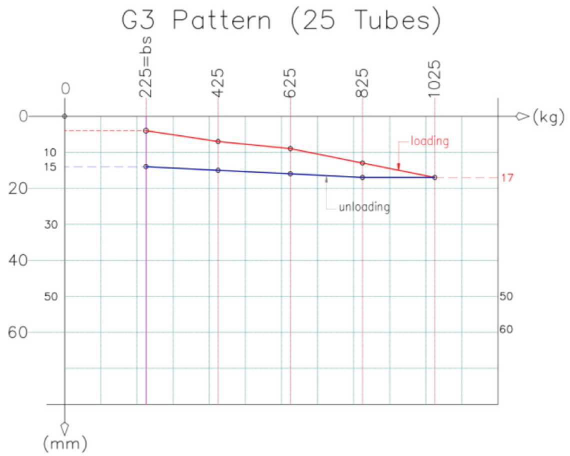

Fig. 8. G3 pattern

When compared from the four test results, it can be seen that the increase in the bearing capacity of the soil is quite high in the foundation using 25 tupes PVC pipes. The settlement result is only 2 mm with a maximum reduction of 17 mm. This is very much different from without the use of PVC pipe tubes, where the soil subsides up to 32 mm and the settlement value reaches 12 mm.

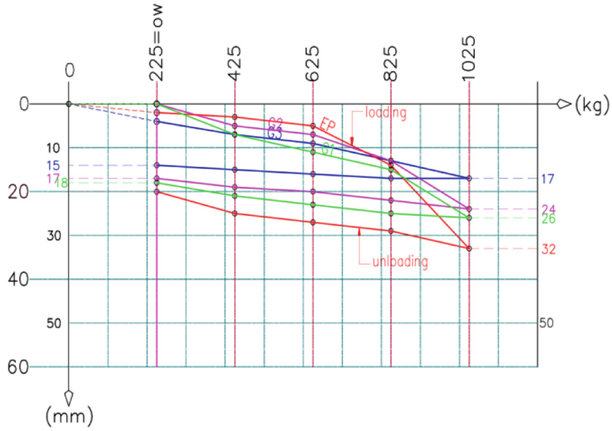

Fig. 9. Comparison all off samples.

4 Conclusion

From the test results, the conclusions obtained:

1. PVC pipe tube is able to increase the bearing capacity of the soil and the stability of the soil in accepting the load on it.
2. The more tubes used, the less land subsidence occurs. This means that the carrying capacity is higher with a small/stable indicator of decreasing and reborn.

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References

1. JE Bowles, *Foundation Analysis and Design Volume 1*. Jakarta: Erlangga, 1986.
2. PRB Terzaghi Karl, "Soil Mechanics in Engineering Practice Second Edition," Jakarta: Erlangga.
3. JK Bowles, Joseph E., Hainin,*Physical and Geotechnical Properties of Soil Second Edition*. Jakarta: Erlangga, 1993.
4. Dunn,*Basics of Geotechnical Analysis*. Semarang: Semarang Press, 1990.
5. WLD,*Soil Mechanics*. South Jakarta: Public Works Publishing Agency.
6. R. Gunawan,*Introduction to Foundation Techniques*. Yogyakarta: Kanisius, 1989.
7. SL H, "Practical Guide to Geotechnical And Soil Mechanics," Bandung, 2000.
8. JBE Cheng Liu., "Soils And Foundations," Prentice Hall, Inc., Engglewood Clifts New Jersey.
9. SNM Ibrahim., Herius Andi., "Improvement of Original Soil with Addition of Variation of Embankment Based on CBR (California Bearing Ratio) Value," 2021.

10. WE Patri, "Study of Shallow Foundation Bearing Capacity in Peat Soil Using a Combination of Reinforcement of Woven Bamboo and Bamboo Grids with Variations in Width and Number of Reinforcement Layers,"*J. Tech. Environmental Civil.*, vol. Volume 2N, 2014.
11. MSF Ferry, "Analysis of the Bearing Capacity of Cushions on Peat and Soft Soils in Siak Regency,"*J. Tech. Civil Univ. Riau*, vol. Volume 2N, 2017.