Shallow Bearing Capacity in Cilengkrang, Bandung, West Java, Indonesia

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ABSTRACT

Cilengkrang is located on the eastern side of Bandung City, West Java Indonesia. This area is surrounded by the district of Cimenyan, Cijambe, Cileunyi, and Ujung Berung. The population growth in Cilengkrang area has experienced 1.8% over the last six years as evidenced by the quantity of new housing complexes being built. Due the limitations on available land the development of housing complex is predicted settled in Cilengkrang District. This paper is aimed to determine the characteristic of shallow bearing capacity foundation, as an important factor on constructing a housing complex. To analyze shallow bearing capacity, the soil mechanics data is tested in the laboratory. These samples are taken in 14 sites distribute randomly. Based on the field mapping, the soil that covers the research area is dominated by fine-grained soil as the residual and transported soil product of young and old volcanic products. Based on Universal Classification of Soil (USCS), the high plasticity silt (MH) is dominating this area than the low plasticity silt (ML) and high plasticity clay (CH). Based on shallow bearing capacity foundation data, the allowable bearing capacity in this area ranging from 19.42 to 70 Ton/m^2 on square footing. The circular footing values ranging from 19.35 to 69.93 Ton/m^2, and continuous footing values ranging from 15.47 to 52.77 Ton/m^2.

Keywords: Shallow Bearing Capacity, Volcanic Soil, development, Cilengkrang

Introduction

Cilengkrang is located in Bandung Regency administratively. This area is located on the eastern side of Bandung City. This area is surrounded by sub-district of Cimenyan, Cijambe, Cileunyi, and Ujung Berung. The Ujung Berung main road is the main access to this area. The population growth in Cilengkrang was 53,668 in 2017 with the density population is 1,501 people per km^2 (Anonymous, 2018). Meanwhile, the population in 2011 was only 48,248 (Anonymous, 2018). The population growth in Cilengkrang area has experienced 1.8 % over the last six years as evidenced by the quantity of new housing complexes being built. The new governor of West Java, Ridwan Kamil, also stated that East Bandung would develop as a new city including this Cilengkrang sub-district (Ramdhani, 2018).

Cilengkrang is located on undulating volcanic hills on the southern part of Mt. Palasari and Mt. Manglayang. The major lithological found is Quaternary Undifferentiated Young Volcanic (Qyu) product, tuffaceous sand, lapilli, lava, agglomerate mostly from Mt. Tangkubanparahu and Mt. Tampomas and also Quaternary Older Volcanic (Qvu) products as Breccia, Lahar and Sandy Tuff (Silitonga, 2003).

Bearing capacity is the maximum pressure that the soil can support at foundation level without failure. This is a key design parameter for foundation design and also for design of retaining walls at the base level (Ishibashi and Hazarika, 2015). Wesley also stated that Bearing capacity is the term used to describe the ability of the soil to support a load bearing on the surface of the soil or in some cases a load

embedded at depth below the surface. Such a load would normally be the foundation of a building or bridge but could also be a storage tank or a soil embankment. Foundation design normally consists of two components. The first is to ensure the stability of the foundation, which is governed by the strength and therefore the bearing capacity of the soil. The second is to ensure that the settlement of the foundation is within acceptable limits (Wesley, 2009).

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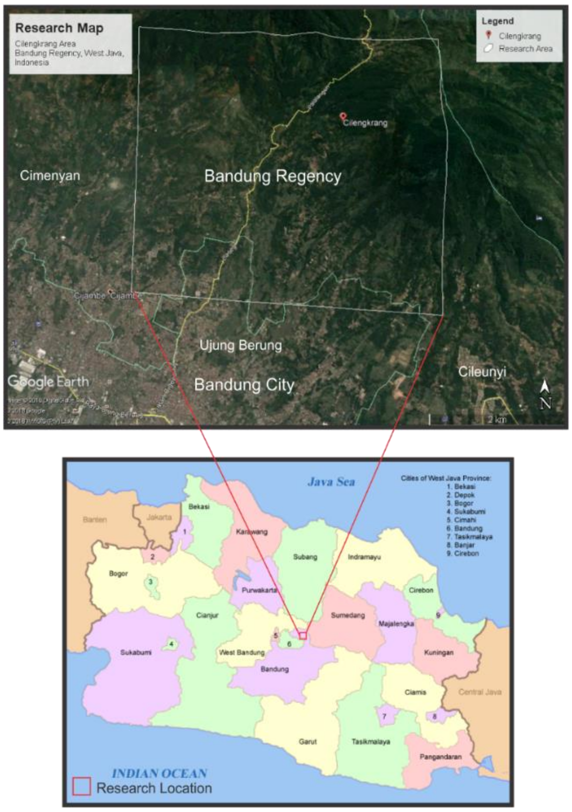

Figure 1 Research Map

Cilengkrang presents as a growing development area. A preliminary study is required to determine the soil mechanics characteristic in order to inform the local government. As an important factor in building housing complex, shallow bearing capacity foundation data is needed.

Method and Materials

This research was done by field survey and collecting 14 samples from hand auger and undisturbed samples on completely weathered zone soil around Cilengkrang area. The soil sampling was taken by undisturbed sampling within 1.0 to 1.5 meters in depth. The research area is within 5 km^2 on the northern part of Cilengkrang. The 14 samples picked by random sampling on natural and residual of soil. The sampling also considered the surface mapping distribution on each different soil type based on Unified Soil Classification System (USCS). The existing area covered by housing complex is avoided to sampling due to the non-residual soil or landfill area. The soil characteristics were analyzed to obtain soil mechanics factors in processing bearing capacity analysis. The method is using Terzaghi (1943) shallow foundation with a footing width B and depth D under a level ground.

The calculation of shallow bearing foundation from Terzaghi's method are listed below,

- Continuous footing. $qu = (c.Nc + \gamma.D.Nq + 0{,}5.\gamma.B.N\gamma)$ 1
- Square footing, $qu = (1{,}3.c.Nc + \gamma.D.Nq + 0{,}4.\gamma.B.N\gamma)$ 2
- Circular footing, $qu = (1{,}3.c.Nc + \gamma.D.Nq + 0{,}3.\gamma.B.N\gamma)$ 3

whereas:

qu = Ultimate Bearing Capacity (Ton/m2)

B = width of foundation (m)

D = depth of foundation (m)

γ = unit weight of soil (Ton/m2)

Nc,Nq,Nγ = Bearing capacity factors, function of φ

φ = Angle of internal friction (o)

This Terzaghi's formula is used only for shallow foundation. The foundation is categorized a shallow foundation if the width of the foundation (B) is equal to or greater than the distance from the ground level to the foundation or depth of the foundation (D). Whereas the values of Nc, Nq and Nγ depend on the Angle of internal friction (φ) (Bowles, 1997).

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Table 1 Bearing Capacity Factors (Terzaghi, 1943)

	Keruntuhan geser umum			Keruntuhan geser lokal		
φ°	N_c	N_q	N_γ	N_c	N_q	N_γ
0	5,7	1	0	5,7	1,0	0,0
5	7,3	1,6	0,5	6,7	1,4	0,2
10	9,6	2,7	1,2	8,0	1,9	0,5
15	12,9	4,4	1,2	9,7	2,7	0,9
20	17,7	7,4	5,0	11,8	3,9	1,7
25	25,1	12,7	9,7	14,8	5,6	3,2
30	37,2	22,5	19,7	19,0	8,3	5,7
34	52,6	36,5	35,0	23,7	11,7	9,0
35	57,8	41,4	42,4	25,2	12,6	10,1
40	95,7	81,3	100,4	35,9	20,5	18,8
45	172,3	173,3	297,5	51,2	35,1	37,7
48	258,3	287,9	780,1	66,8	50,5	60,4
50	347,6	415,1	1153,2	81,3	65,6	87,1

According to Zakaria (Zakaria, 2006), Terzaghi prepared the formula for bearing capacity that calculated in the state of ultimate bearing capacity. It means a value limit if exceeded would cause a collapse. Therefore, the allowable bearing capacity must be smaller than the ultimate bearing capacity. The ultimate bearing capacity (qult); kg / cm2, t / m2) of a soil under the foundation load will depend on shear strength. The value of the allowable carrying capacity (qa) for a foundation design involves the strength and deformation characteristic factors.

The allowable bearing capacity (qa) depends on how much the Safety Factor (F) is chosen. In general, the selected F value is 2 to 5, so the allowable support values are as follows:

Qa = qult / F

Whereas:

qa = allowable bearing capacity (T/m2)

qult = ultimate bearing capacity (Ton/m2)

F = safety factor

If F = 3, this means that the planned foundation strength is 3 times the ultimate bearing capacity, so that the foundation is expected to be safe from collapse. With the condition qa <qult, the contact stress (σc) that occurs due to the transfer of external loads to the bottom of the foundation soil becomes small depending on the value of F given (Zakaria, 2006).

Result and Discussion

Based on the field mapping, the soil covered the research area is dominated by fine-grained soil as the residual and transported soil product of Young and Old Volcanic Products. This soil is categorized using the Universal Classification of Soil (USCS). The High Plasticity Clay to Silt (CH-MH) is dominating this area. This residual soil has a reddish brown color, high plasticity, and soft to very soft strength. This result is similar to Djadja and Hermawan's Engineering Geological Map of Bandung. Djadja and Hermawan reported the southern part of Cilengkrang is dominated by silty clay and sandy silt as a residual product of tuffaceous sandstone, tuff, breccia, lapilli, and conglomerate. While the northern part of Cilengkrang is dominated by breccia and lahar (Djadja and Hermawan, 1996).

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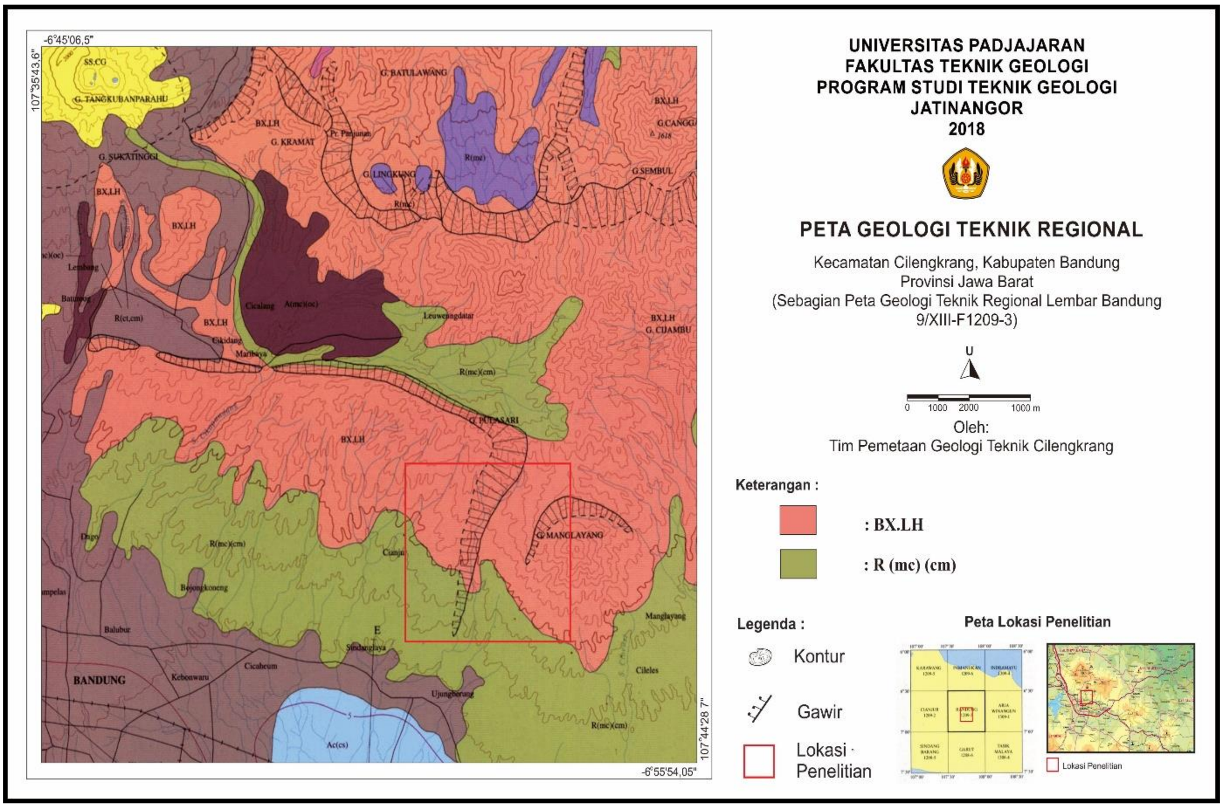

Figure 2 The Regional Engineering Geological Mapping modified from Djadja and Hermawan (Djadja and Hermawan, 1996)

Figure 3 The typical fine-grain Soil In Cilengkrang area

Based on laboratory identification, the grain size distribution in Cilengkrang was dominated by fine-grained soil e.g. clay and silt. This soil has varied wet density or unit weight values ranging from 1.36 gr/cm^3 to 1.79 gr/cm^3 with average 1.59 gr/cm^3. While the cohesion shows 3.32 ton/m^2 to 10/85 ton/m^2 with average 5.53 ton/m2. And the angle of internal friction (φ) shows 11.40^o to 26.08 ^{o} with average 20.18 ^{o}. these soil mechanics data then processed to shallow bearing capacity formula using terzaghi's method. The safety factor used is F = 3. The ultimate bearing capacity (qult) and allowable bearing capacity (qa) result, is listed below

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Table 2 The Ultimate and Allowable Bearing Capacity in Cilengkrang Area

Site Code	Qult (ton/m2)			Qa (ton/m2)		
	Square	**Circular**	**Continuous**	**Square**	**Circular**	**Continuous**
1	117.06	116.64	92.74	39.02	38.88	30.91
2	181.34	180.78	142.91	60.45	60.26	47.64
3	129.04	128.47	102.69	43.01	42.82	34.23
4	58.27	58.06	46.41	19.42	19.35	15.47
5	145.51	144.66	116.72	48.50	48.22	38.91
6	146.87	145.17	121.42	48.96	48.39	40.47
7	145.02	143.83	117.90	48.34	47.94	39.30
8	210.21	209.80	164.30	70.07	69.93	54.77
9	150.50	149.43	121.46	50.17	49.81	40.49
10	181.84	180.31	147.81	60.61	60.10	49.27
11	91.63	91.05	74.07	30.54	30.35	24.69
12	187.11	186.52	147.40	62.37	62.17	49.13
13	200.71	199.62	160.14	66.90	66.54	53.38
14	98.89	98.11	80.63	32.96	32.70	26.88

The distribution of shallow bearing capacity using square footing can be seen on picture below,

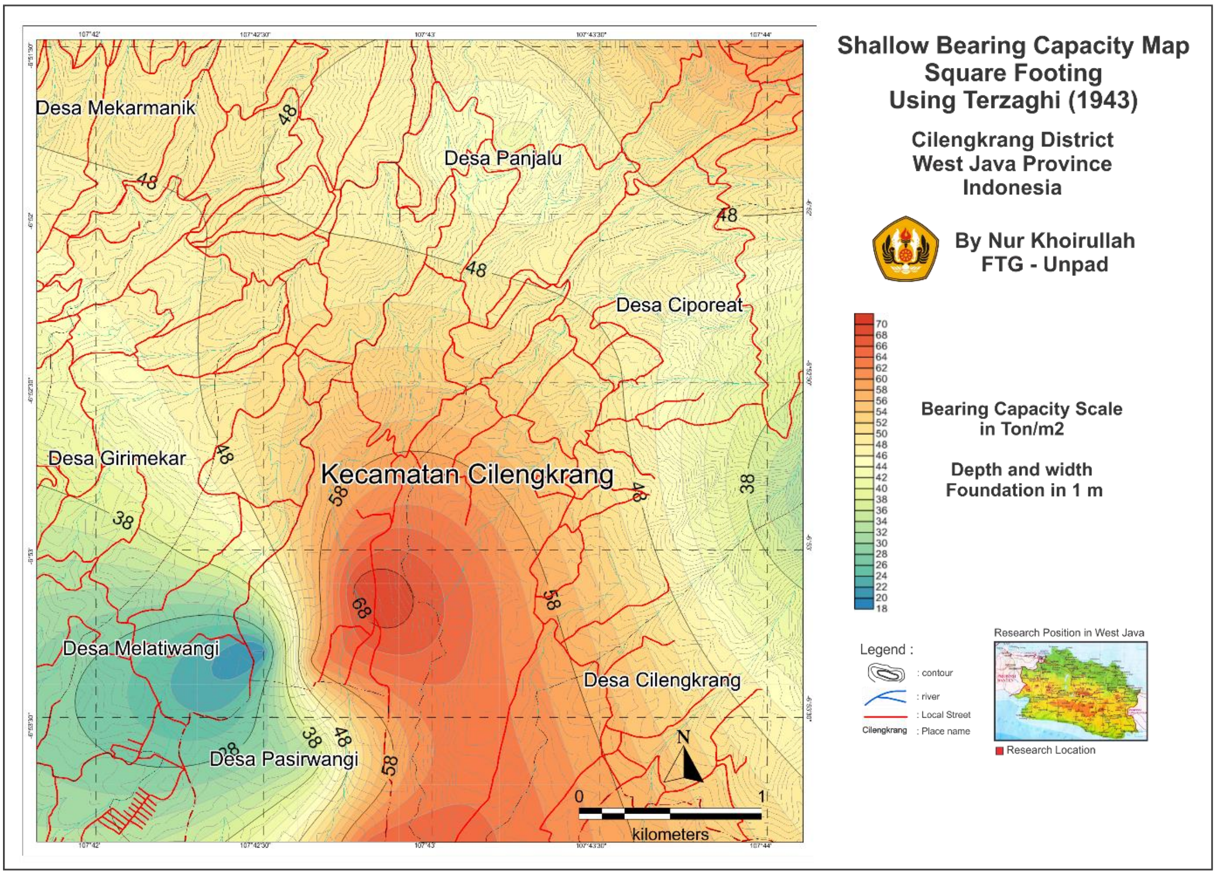

Figure 4 distribution of shallow bearing capacity using square footing

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Conclusion

Cilengkrang area is covered by fine-grain soil, high plasticity silt to clay. This soil is interpreted as weathered Old and Young Volcanic materials. The shallow bearing capacity (Qa) is ranging from 15 ton/m^2 to 70 ton/m^2 with depth and width 1 meter. This Allowable bearing capacity is categorized from moderate to high bearing capacity. However, this analysis didn't consider ground water condition, vibration condition due to Lembang Fault potential earthquake, and also the flat condition of the foundation.

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