ANALYSIS OF CORRELATION BETWEEN BEARING CAPACITY OF THE LAND AGAINST LAND SETTLEMENT AND DURATION OF DECLINE IN SEMARANG CITY

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ABSTRACT: The city of Semarang has a bearing capacity that varies according to the type of land. The phenomenon of land subsidence also occurs with the length of time that varies according to the load and type of soil. Bearing capacity of the land (BCL) has a relationship with land settlement and duration of decline (DOD). The study has been conducted in Semarang city by taking 448 undisturbed soil samples scattered in the study area. Soil sample analysis have been carried out in the laboratory to obtain the bearing capacity of land, land settlement, and duration of decline. Analysis of data bearing capacity of land, land settlement, and duration of decline were using the correlation-regression method to get the level of correlation between variables quantitatively. The results showed that there is a relationship between bearing capacity of the land to settlement and duration of decline for a type of clay, silt, silt-sand, and sand. In silt soil types, the relationship between the bearing capacity of the land to settlement is classified as low with a contribution of 9% due to inconsistent compressibility coefficient of soil volume (Mv) caused by grain size gradation, there are gaps and thickness of the potential sinking layer (deformation) is heterogenous. Also on sand silt soil types, the relationship between settlement and duration of decline has a very low level of correlation with a contribution of 9% due to the consolidation coefficient (Cv) is inconsistent because the mass density of sand material is heterogenous.

Keywords: Correlation, Bearing capacity of the land, Land settlement, Duration of decline, Semarang

1. INTRODUCTION

The Semarang city has a varying bearing capacity of the land (BCL) that contributes to the rate of land settlement [1]. Issues regarding land settlement [2] have caused significant losses due to damage to settlements, infrastructure and environmental problems such as floods and tidal inundation. The problem mainly occurs in the coastal area of Semarang City or the surrounding area. However, a land settlement also occurred in hilly areas in Semarang city, although relatively small about 0.5 – 0.84 cm/year [3]. Types of soil material layers, groundwater level fluctuations [4], infrastructure burdens [5], and climate contributed to the decline that occurred in Semarang City [6].

Geologically, the Semarang plain is composed of river alluvial deposits, delta plain deposits, and tidal deposits. The sediment consists of intermittent intervals between layers of sand, silt-sand and soft clay, with gravel lens insertions and volcanic sand [7]. As a coastal area, it is generally an alluvial plain in the form of sandy silt and clayed silt with high groundwater conditions. Often also found in coastal areas, the land is the dominant type of soft clay which has a condition of water content greater than the liquid limit value of the land [8]. In areas that move away from the coastline, land conditions are generally dominant sandy silt or silt sand which has a strong enough bond because the granules are increasingly heterogeneous and water content is small [9]. Each type of material has a bearing capacity of the land, a rate of land settlement, and a different duration of decline (DOD) [1].

This paper aims to analyze the correlation between the bearing capacity of the land (BCL) against land settlement and the duration of decline (DOD) occurs.

2. METHODS

The research was conducted in the administrative area of Semarang City which is geographically located at $6^0 50'$ – $7^0 10'$ South Latitude and $109^0 50'$ – $110^0 35'$ East Longitude. It located on the coast of Java island with North boundary is Java Sea, South boundary is Semarang Regency Area, West boundary is Kendal Regency Area, and East boundary is Demak Regency Area [10].

The research method used a laboratory experimental approach. The data in this study were bearing capacity of land, land settlement, and the duration of decline. All data were obtained through field and laboratory tests based on soil samples taken at 38 research points with 112 drill points and

448 undisturbed soil samples scattered in the study area. The distribution of research points as shown in Fig 1.

The sample was in the form of soil samples taken from drilling at depths up to 10 meters, with drilling points randomly determined at the research site. Drilling, taking and treating samples refered to SNI 8460: 2017 [11]. Laboratory testing of soil samples i.e. density test, plasticity limit test, grain size distribution test, direct shear test, and consolidation test used the American Society for Testing and Materials reference (ASTM) [12].
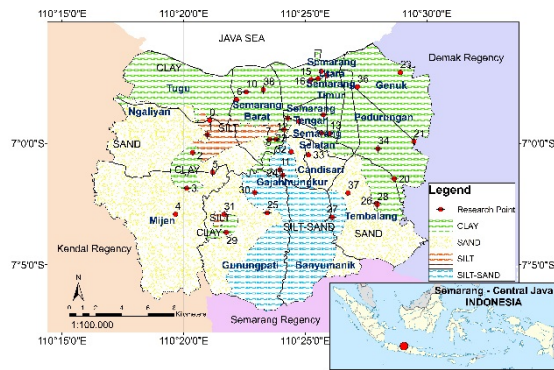

Fig. 1 Location of soil samples at research point

The volume weight and the direct shear test was used to calculate bearing capacity of the land (BCL) with formula in Eq. (1) [13].

$$Q_{all} = N/F(K_d)(K_m) \qquad (1)$$

Equation (1) is a formula to calculate the bearing capacity of the land. Q_{all} refers to the bearing capacity of the land (kg/cm^2). K_d is a depth factor defined as $1+0.33D_f/B < 0.33$. K_m is safety factor that has been set at 1.5. N/F is determined using Terzaghi and Peck's graphs about the relationship of NSPT with permit bearing capacity. B is one unit contact area < 1.2 meter. D_f is a contact area for vertical distance [13].

Furthermore, consolidation test especially M_v and C_v parameters were used to calculate land settlement with formula in Eq. (2) and duration of decline with formula in Eq (3) [13].

$$S = M_v D_p H \qquad (2)$$

Equation (2) is a formula to calculate land settlement. S refers to land settlement (centimeter). M_v is the volume compressibility coefficient of soil (cm^2/kg), D_p is additional stress due to load (kg/cm^2), H is the thickness of the soil layer that has the potential to sink in (meters).

$$T = T_v(^1/_2 H)2/C_v \qquad (3)$$

Equation (3) is a formula to calculate the duration of decline. T refers duration of decline (second). T_v is a time factor for 90% consolidation level that has been set at 0.848, H is the thickness of the soil layer that has potential to sink in (meter), and C_v is coefficient of consolidation (cm^2/sec).

Correlation analysis is a measurement of the interdependency of one variable with another variable [14].

Data analysis was performed using the correlation-regression method to obtain a quantitative relationship between variables and displayed graphically [15]. Qualitative analysis will be needed as an explanation.

Correlation-regression analysis was computed by using SPSS 20 software.

3. RESULT AND DISCUSSION

Determination of bearing capacity of land can be done by the method of knowing to bear of natural environment and resources to support human activities that utilize the land area, for the survival of their existence. The magnitude of capacity of natural environment and resources on an area of land is determined because of circumstances and characteristics of the resources that exist in a stretch of land. The capacity of natural resources is very dependent on the carrying capacity of the land, the comparison of land availability and land requirements, water availability and demand [1].

Land is a land area whose characteristics summarize all signs concerning biosphere, atmosphere, soil, geology, relief, hydrology, plant and animal populations, as well as the results of past and present human activities that are stable or recycled [16]. Determination of bearing capacity of the land is measured by knowing capacity of natural environment and resources to support human life in the space for the existence of his life [17].

Bearing capacity of land can be interpreted as the ability of land to withstand workloads without collapse due to shifting. When the stress load in soil increases, the soil initially solidifies due to dissipation of pore pressure. If the number of loads increases, it will cause cracks in the soil until a state with a soil strength is reached. If the strength limit is exceeded, the ground will break, and therefore burden will be pushed to the side. The event is said that the land balance limit or bearing capacity, that is, bearing capacity of balance has been exceeded. Compacting of soil causes construction to decrease (deformation). If burden gets bigger the construction suddenly drops a lot and it is quickly said that bearing capacity of surge is exceeded [18].

Furthermore, the nature of fine-grained soils would be very different in behavior compared to

coarse-grained soils in their stability and bearing capacity. Fine-grained soil will be largely determined by the nature of its plasticity (Atterberg). For coarse-grained soil is strongly influenced by the nature of its gradation: good gradation (uniform grain size), uniform gradation and poor gradation (have a gap item). Grain size is the most obvious soil characteristic, so the soil classification is firstly based on its texture [19].

Other properties of soil are engineering properties i.e. *qu* free compressive strength (especially for fine-grained) and cohesion (*c*) and internal shear angle (Φ) for coarse grains. The physical and engineering properties of the same soil will provide the same soil characteristics in its stability and bearing capacity [13]. In this study grouping of data based on physical and engineering characteristics parameters and also consider geotechnical conditions based on Geological Map of Magelang - Semarang Sheet [20].

There are 4 soil layers in the research area which are analyzed. Table 1 shows the descriptive statistic of BCL values, land settlement values in Table 2, and DOD values in Table 3 for all of the soil layers.

Table 1 Descriptive statistic of BCL

Soil Type	Depth (meter)	BCL (kg/cm^2) Range	Mean
Clay	2.50	0.20 – 11.69	6.04
	5.00	0.20 – 10.57	5.49
	7.50	0.20 – 14.24	7.32
	10.00	0.20 – 14.24	7.32
Silt	2.50	0.31 – 0.71	0.66
	5.00	0.31 – 0.91	0.77
	7.50	0.31 – 7.22	3.92
	10.00	2.03 – 11.17	7.61
Silt-Sand	2.50	0.40 – 7.12	3.96
	5.00	3.05 – 12.40	6.20
	7.50	0.40 – 14.24	7.52
	10.00	0.40 – 14.24	7.52
Sand	2.50	0.31 – 14.24	7.43
	5.00	0.40 – 14.24	7.52
	7.50	0.40 – 13.73	7.27
	10.00	0.60 – 14.03	7.62

Table 2 Descriptive statistic of land settlement

Soil Type	Depth (meter)	Settlement (centimeter) Range	Mean
Clay	2.50	0 – 604.42 *	302.21
	5.00	0 – 442.91 *	221.45
	7.50	0 – 513.83 *	256.91
	10.00	0 – 366.63 *	183.31
Silt	2.50	20.86 – 67.67	45.82
	5.00	5.40 – 82.75	37.44
	7.50	9.04 – 112.65	69.71
	10.00	8.90 – 21.05	15.63
Silt-Sand	2.50	3.72 – 259.20 *	122.76
	5.00	5.58 – 317.01 *	158.24
	7.50	4.95 – 166.72 *	81.83
	10.00	0 – 173.80 *	89.46
Sand	2.50	0 – 537.08 *	183.26
	5.00	0 – 637.05 *	248.81
	7.50	0 – 424.47	86.43
	10.00	0 – 429.46	73.99

(*) Density of landfill/sediment is not homogeneous

Table 3 Descriptive statistic of DOD

Soil Type	Depth (meter)	DOD (year) Range	Mean
Clay	2.50	0 – 5.36	3.11
	5.00	0 – 4.18	2.52
	7.50	0 – 3.15	2.05
	10.00	0 – 2.27	1.89
Silt	2.50	0.28 – 3.43	1.77
	5.00	0.11 – 2.52	1.09
	7.50	0.02 – 1.75	1.30
	10.00	0.43 – 1.12	0.95
Silt-Sand	2.50	0.05 – 1.23 *	0.93
	5.00	0.03 – 0.81 *	0.64
	7.50	0 – 1.79	0.55
	10.00	0 – 1.15	0.60
Sand	2.50	0 – 3.47	0.95
	5.00	0 – 2.52	0.85
	7.50	0 – 1.75	0.53
	10.00	0 – 2.42	0.39

(*) Density of landfill/sediment is not homogeneous

The results of the study showed that criteria for subgrade characteristics reached a depth of -0.00 to -10.00 m by Kezdi - Sanglerat criteria. At the same criteria, points are grouped side by side and careful visual field observation is carried out concerning the technical geological map by taking into account the geological characteristics with the Environmental Geology unit notation [20]. Sample test points are grouped based on the same soil characteristics, namely Clay, Silt, Silt-Sand, and Sand [21]. Thus obtained a set of points that have an indication of the nature of homogeneous in a classification that has been determined. The classification is very soft to soft, somewhat soft, rather rigid to rigid and very rigid or very loose,

loose, rather dense and dense to very dense [22].

Based on Table 1, Table 2, and Table 3 can be correlation-regression analysis. Correlation analysis is an analysis to determine the level of closeness of the relationship between two variables. Regression analysis is one analysis that aims to determine the effect of a variable on other variables [15]. Correlation-regression analysis used is a simple continuous analysis, where the depth factor is an independent variable on bearing capacity of land and bearing capacity of the land is an independent variable on land settlement, then the factor of land settlement is an independent variable on the length of land settlement. The analysis results were shown in Fig 2.
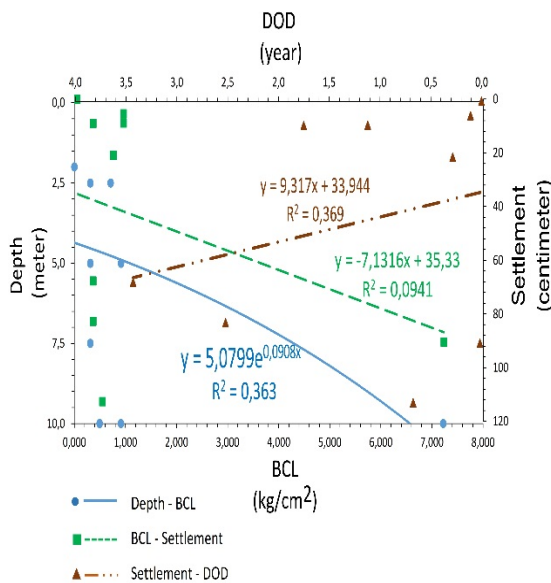

(c)

(a)

(d)

(b)
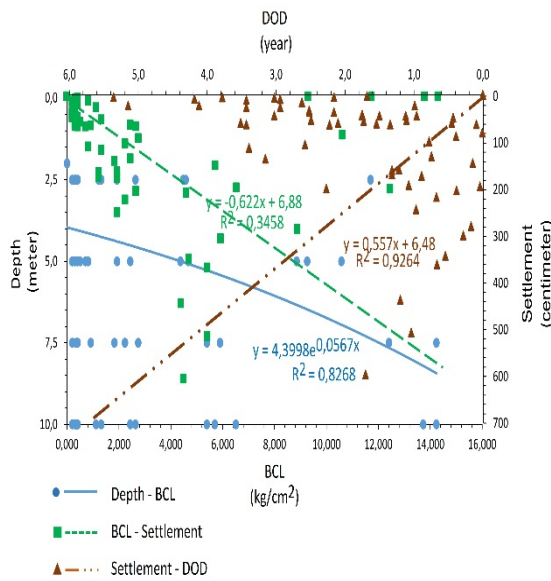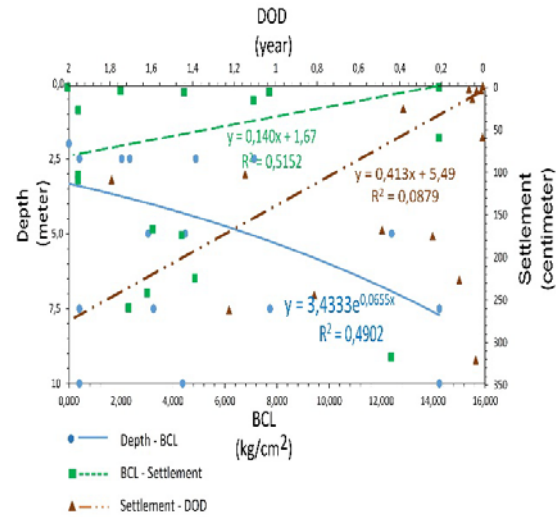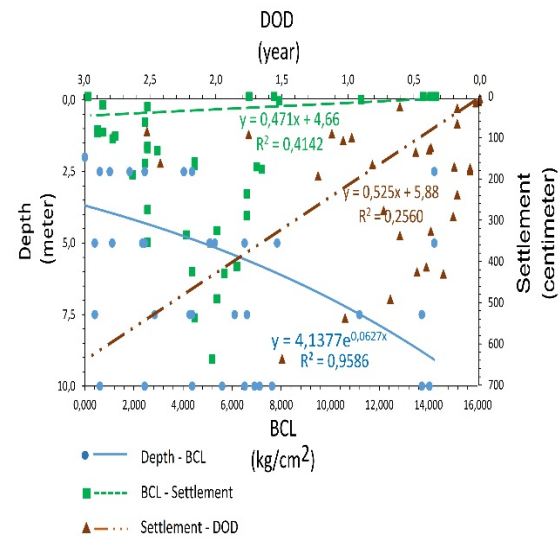
Fig. 2 Correlation of BCL/Settlement/DOD: (a) clay; (b) silt; (c) silt-sand; (d) sand

Correlation between depth and bearing capacity is shown by equation $y = 4.3998e^{0.0567x}$ (R = 0.909) for clay, $y = 5.0799e^{0.0908x}$ (R = 0.602) for silt, $y = 3.4333e^{0.0655x}$ (R = 0.700) for silt-sand, and $y = 4.1377e^{0.0627x}$ (R = 0.979) for sand. Correlation between bearing capacity of land with land settlement is shown by equation $y = -0.622x + 6.88$ (R = 0.588) for clay, $y = -7.1316x + 35.33$ (R = 0.307) for silt, $y = 0.140x + 1.67$ (R = 0.718) for silt-sand, and $y = 0.471x + 4.66$ (R = 0.644) for sand. And correlation between land settlement and duration of decline is shown by equation $y = 0.557x + 6.48$ (R = 0.963) for clay, $y = 9.317x + 33.944$ (R = 0.608) for silt, $y = 0.413x + 5.49$ (R = 0.297) for silt-sand, and $y = 0.525x + 5.88$ (R = 0.506) for sand. Correlation coefficient indicates closeness of relationship between two variables [23].

In clay zone on Fig. 2 (a) can be explained as follows correlation between depth and bearing capacity of land are significant with $R^2 = 0.8268$. It can be interpreted that subgrade conditions from -2.5 to -10.0 m are relatively homogeneous related to physical characteristics (grain, volume weight) and engineering properties (cohesion, shear angle) and mass consistency nature of clay. Correlation between bearing capacity of land and settlement shows the insignificant relationship with $R^2 = 0.3458$ this is very possible because the character of the compressive coefficient of soil volume (Mv) is not consistent due to grain size gradation there are gaps and thickness of potential sinkhole layer (deformation) is not same. Correlation between settlement and duration of decline is significant with $R^2 = 0.9264$. It is caused by a coefficient of consolidation (Cv) is consistent and homogeneous clay [24].

The silt zone on Fig. 2 (b) can be explained as follows correlation between depth and bearing capacity of land are insignificant with $R^2 = 0.3630$. It can be interpreted that subgrade conditions from -2.5 to -10.0 m are not relatively homogeneous related to physical characteristics (grain, volume weight) and engineering properties (cohesion, shear angle) and mass consistency nature of silt. Correlation between bearing capacity of land and settlement shows an insignificant relationship with $R^2 = 0.0941$ this is very possible because the character of the compressive coefficient of soil volume (Mv) is not consistent due to grain size gradation there are gaps and thickness of potential sinkhole layer (deformation) is not same. Correlation between settlement and duration of decline is insignificant with $R^2 = 0.3690$. It is caused the coefficient of consolidation (Cv) is inconsistent and nonhomogeneous silt [25].

The silt-sand zone on Fig. 2 (c) can be explained as follows correlation between depth and bearing capacity of land are insignificant with $R^2 = 0.4902$. It can be interpreted that subgrade conditions from -2.5 to -10.0 m are not relatively homogeneous related to physical characteristics (grain, volume weight) and engineering properties (cohesion, shear angle) and mass consistency nature of silt-sand. Correlation between bearing capacity of land and settlement shows an insignificant relationship with $R^2 = 0.5152$ this is very possible because the character of the compressive coefficient of soil volume (Mv) is not consistent due to grain size gradation there are gaps and thickness of potential sinkhole layer (deformation) is not same. Correlation between settlement and duration of decline are insignificant with $R^2 = 0.0879$. It is caused the coefficient of consolidation (Cv) is inconsistent and nonhomogeneous silt-sand [25].

The sand zone on Fig. 2 (d) can be explained as follows correlation between depth and bearing capacity of land are significant with $R^2 = 0.9586$. It can be interpreted that subgrade conditions from -2.5 to -10.0 m are relatively homogeneous related to physical characteristics (grain, volume weight) and engineering properties (cohesion, shear angle) and mass consistency nature of sand. Correlation between bearing capacity of land and settlement shows an insignificant relationship with $R^2 = 0.4142$ this is very possible because the character of the compressive coefficient of soil volume (Mv) is not consistent due to grain size gradation there are gaps and thickness of potential sinkhole layer (deformation) is not same. Correlation between settlement and duration of decline are insignificant with $R^2 = 0.2560$. It is caused the coefficient of consolidation (Cv) is inconsistent due to the mass density of sand material is not homogeneous [25].

A correlation coefficient is the degree of relationship closeness between two or more variables compared [23]. Furthermore, the coefficient of determination is a measure of the contribution made by independent variables to influence the dependent variable [26]. Table 4 shows the contribution of the depth to influence the bearing capacity of the land. And then Table 5 shows the contribution of bearing capacity of the land to influence land settlement. And Table 6 shows the contribution of land settlement to influence the duration of decline.

Table 4 Contribution of depth against BCL

Soil Type	Contribution
Clay	0,8268
	(83% contribution)
Silt	0,3630
	(36% contribution)
Silt-Sand	0,4902
	(49% contribution)
Sand	0,9586
	(96% contribution)

Table 5 Contribution of BCL against settlement

Soil Type	Contribution
Clay	0,3458
	(35% contribution)
Silt	0,0941
	(9% contribution)
Silt-Sand	0,5152
	(52% contribution)
Sand	0,4142
	(41% contribution)

Table 6 Contribution of land settlement to DOD

Soil Type	Contribution
Clay	0,9264
	(93% contribution)
Silt	0,3690
	(37% contribution)
Silt-Sand	0,0879
	(9% contribution)
Sand	0,2560
	(26% contribution)

The study results indicate that the general relationship between variables is classified as meaningful to high for all types of land in Semarang City, which means that the independent variable is relatively influential on a dependent variable. In a type of silt soil for a relationship between the bearing capacity of the land to settlement is classified as low. This is very possible because the character of the compressive coefficient of soil volume (Mv) is inconsistent due to grain size gradations, gaps and thickness of the potential sinking layer (deformation) are heterogenous. Likewise in silt sand soils for the relationship between settlement and duration of decline has a very low level of relationship. This is because the coefficient of consolidation (Cv) is inconsistent. After all, the mass density of sand material is not homogeneous [27]. However, overall all independent variables affect the dependent variable and have a contribution to fluctuations of the dependent variable.

4. CONCLUSION

From study results, it can be concluded that there is a relationship between bearing capacity of the land to settlement and duration of decline for a type of clay and sand. In silt soil types, the relationship between the bearing capacity of the land to settlement is classified as low with a contribution of 9% due to inconsistent compressibility coefficient of soil volume (Mv) caused by grain size gradation, there are gaps and thickness of the potential sinking layer (deformation) is not same. Also on sand silt soil types, the relationship between settlement and duration of decline has a very low level of correlation with a contribution of 9% due to the consolidation coefficient (Cv) is inconsistent because the mass density of sand material is not homogeneous.

Parameters distribution of soil engineering properties can describe bearing capacity of land in Semarang city which can be used as an instrument to determine the bearing capacity of the environment and evaluation of spatial use from aspects of land-use suitability and land capability.

Land loading exceeds bearing capacity of land will occur the failure of land stability in the form of deformation/subsidence, collapse.

5. ACKNOWLEDGMENTS

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