The Effect of Land Subsidence to Changes in The Most Extensive Puddle in Semarang

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Abstract - Semarang city can generally be divided into two areas, namely urban areas over the hilly soil conditions, loud and reaches a height of 350m above sea level, and the lower town is a fine-grained alluvial plains. In the area, under the terms of the geography, the terrain is flat, water-saturated, its location is on the waterfront and is traversed by several rivers, most of the land in the form of settlements that grows naturally and irregularly, the land suffered subsidence (land subsidence) because of the extra load on it and excessive groundwater, based on current conditions, in general most alluvial Semarang is frequent inundation of rain and tides. To be able to plan land use and economic activities well, it is necessary to note changes in broad pools of the region because of land subsidence due to consolidation.The purpose of this study is intended to create a map of inundation due to land subsidence and predicting the area inundation will occur from time to time. This study focuses on getting the data of land subsidence due to the consolidation of the land that became the main cause of subsidence resulting in the addition of extensive flooding. From these data, it is converted between land subsidence with water level inundation occurred.This research is conducted by conducting land drilling with drill machine in 24 points to a depth of 30m to obtain soil samples in five sub-districts of North Semarang, Semarang Genuk, East Semarang, Semarang Gayamsari and Central Semarang. Samples are obtained and then tested the mechanical properties of the soil and the soil in soil mechanics laboratory of Unissula. From the lab test results are then analyzed to determine the amount of land subsidence due to consolidation. Finally, the writer conducts extensive analysis of changes in inundation as a result of subsidence by using GIS.

Implementation of this research will result a map of inundation area in Semarang and amended from time to time. This study is planned for three years. In the first year on the stage of 70% has been implemented with the drilling machine on 8 points with a depth of 30m. Furthermore, the sample has been tested and mechanical properties of the soil in Soil Mechanics Laboratory of Unissula. From the analysis it appears that the more north (toward the ocean) the greater the decline, but the decline in the longer time.

Keywords: consolidation, reduction in area, large puddles.

1. Introduction

Semarang city is among big cities in Indonesia and the capital of Central Java province. The area of the administration of 373.4 km2 with a population of 1,481,460 inhabitants, Semarang is composed of 16 districts and 117 villages with a growth rate of 1.86% per annum [1, 9]. Semarang City consists of two units of morphology, in the southern part (the upper city) is composed of hills, which is the foot of Mount Ungaran that stretches from east to west from Tembalang, Tanah Putih, Tegalsari, Siranda until Gajah Mungkur, while the alluvial plain beach located in the northern part (lower town). Among the 16 District in the city of Semarang, Semarang District of North and Central Semarang is a region densely populated with as many as 11 556 inhabitants and a density of 12 089 inhabitants per km2 [5, 11].

With increasing number of people in Semarang, the need for shelter has increased. In this connection one of the efforts undertaken by the Government of Semarang since 1994 authorize settlement construction (real estate), which is located to the west of the port of Tanjung Mas Semarang of ± 361.44 Ha. Preparing land for settlements made with reclaimed, namely by landfill embankment height of 2m to 3m. One of the residential areas of development impacts causing changes in coastal ecosystems, mangrove which initially serves as a barrier wave is replaced with buildings like groin and revetment with the same function. With the change of land use from farms into residential areas then cause environmental problems, among others, has led to the inundation occurred in dense settlements that low topography during the rains and tides. This inundation caused by rain and sea water collected in ponds that formerly flowed into dense residential areas [12].

The addition of load on alluvial soil would be a decrease in the land because of the consolidation which resulted in subsidence (land subsidence) of land in most Semarang be a serious problem because the area is generally a residential area. Land subsidence due to residential areas to be lower, partly because of the location of settlements close to the beach, when the tide of sea water is overflow to the mainland via rivers and drainage canals subsequently pooled on settlements [3, 10].

Based on the above, the land subsidence in the alluvial plains and its influence on a vast pool of Semarang area under water due to rain and sea water should be known by stakeholders.

2. Literature

2.1 Geotechnical of Semarang

Semarang is geographically located between 60 55 '22 "LS - 70 7'13" LS and 1100 16' 21 "BT - 1100 30 '36" East. Semarang city lies at an elevation of +0 to +350 m dpal, there are even areas under +0 m elevation. Semarang city every rainy season is always flooded, especially in areas of low, even in low lying areas and its location near the beach although it does not rain flooding inundation tide. According Soedarsono [19] cities in the northern part (lower town) bordering the Java Sea had some problems related to topography. Physical environmental problems - problems that arise in the north coast include abrasion, sedimentation, inundation, salt water intrusion, sedimentation wind, wind erosion, soil salinity and soil contamination [2].

2.2 History of the Land Subsidence

Research from Setyarini and Agarsugi [16] explains the decline in soil (land subsidence) is a natural phenomenon that occurs in many large cities located around the beach or alluvial plains, such as Jakarta, Semarang and Surabaya. Land subsidence associated with natural phenomena and human built environment such as flooding, sea water intrusion, changes in river flow and arrangement of building construction that are destructive. While in developing countries such as Indonesia industrial development started in 1980, followed by a decrease in the land until now. The pace and depth of soil subsidence in many different places, depending on the load and the condition of geology, hydrology, ground water and the intensity of the compression mechanical properties of soil or rock [20, 22, 23].

2.3 Consolidation and Land Decline

According to Das [6] consolidation is a process of downsizing the content of saturated soil slowly with low permeability due to the release of pore water. The process continues until the excess pore water pressure caused by the increase in the total voltage has been completely lost. According to Bullard R [7], consolidation is the process of pore water discharge from the water-saturated soil due to loading. In general, consolidation will take place in one department, namely the Department of vertical because layers are exposed to an additional burden it can not move in a horizontal major as retained by the soil around it. Under these conditions the water drainage will run, especially in the vertical direction, this is called the consolidation of one dimension (one-dimensional consolidation) and the calculation of consolidation is almost always based on one dimension consolidation theory. At the time of consolidation takes place, the constructions above ground layers are impaired [18].

2.4 Large Primary Consolidation One Dimension

Sikor T [4], affected by the consolidation of the balance of the earth element, the pull and pressure of minerals and pore water flow. Consolidation of primary land consolidation occurs when the pore water pressure on the ground is more than zero. Land consolidation can be calculated from the magnitude of the decline due to primary consolidation with the presumption that such consolidation is the consolidation of the dimensions that can be formulated as follows [6, 13, 15].

$$S = H\,\frac{\Delta e}{1+eo} \qquad (1)$$

For normal-consolidated clay then:

$$\Delta e = Cc\,\{\log\,(po+\Delta p) - \log po \qquad (2)$$

In this case :

Cc = index compression so that the equation becomes

$$S = \frac{CcH}{1+eo}\log\left(\frac{po+\Delta p}{po}\right) \qquad (3)$$

For a thick layer of clay, the soil layer is divided into multiple sub-layers and decline calculations performed separately for each sub-layer. So decreases in total for the entire layers are:

$$S = \sum\{\frac{CcHi}{1+eo}\log(P\,\frac{Po(i)+\Delta p(i)}{po(i)})\} \qquad (4)$$

Where:

S = Large primary consolidation
Hi = Thickness sub-layer (i)
Po (i) = effective overburden pressure for sub-layer (i)
$\Delta p(i)$ = Addition vertical pressure to sub-layer (i)
eo = initial void ratio
Cc = Compression index
Δe = Change void ratio
H = Thickness of the soil layer

2.5 Consolidation Time

Terzaghi [17, 27] who first introduced the theory of one-dimensional consolidation rate for water-saturated clay soil with the following assumptions:

1) Soil (clay water system) homogeneous
2) Soil completely saturated

3) The ability to compress water negligible
4) The ability to compress the soil grains are ignored
5) The water flow only in one direction (the direction of compression)
6) Darcy's law applies

Variations of the average degree of consolidation of the dimensionless time factor (Tv) are given in the table. Tv can be calculated $Tv = \frac{Cv \cdot t}{d^2}$. The price of the factors of time and degree of consolidation (U) (Das 1988) can be expressed as follows:

For U = 0 to 52.6%, T*v* = $\frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$ ………………………………………........…(5)

For U = > 52.6%, T*v* = 1781 - 0,933 log (100-U%)………..……………….........…(6)

In the state of U = 50% of pore water to flow in one direction, $T_{50} = \frac{Cv \cdot t_{50}}{Hdr^2}$ ....(7)

Where:

T_{50} = Length of the consolidation of 50%.
Cv = the coefficients of consolidation.
t_{50} = To the consolidation of 50% (Table).
Hdr = Length of pore water flow during the consolidation process.

3. Research Methods

3.1 The Research

The study was conducted in Semarang alluvial plain at the bottom, include: Northern District of Semarang, East Semarang, Genuk District, Central Semarang and Gayamsari District. Research areas experiencing subsidence generally consist of young alluvial rock arrangement. It is only hundreds of years so it continues to experience compression. Land subsidence is a problem because the study sites are experiencing subsidence settlement besides its location near the beach are also traversed by several rivers consequently frequent flooding due to rain and tides. Samples in the form of land drilling results from the study site and then tested in the laboratory of soil mechanics at Unissula.

3.2 Instrument for Sampling and Testing Laboratory of Soil

1) The instrument used for sampling is a set of mechanical drill consists of a drill machine completes with motion control devices (prime mover), ground-penetrating tools (bits), and tripod to help insert and remove the drill rod. Soil samples are taken every depth of 100 cm, while the depth of drilling up to 30m.
2) Tool used for laboratory testing, soil mechanics laboratory is to obtain data mechanical properties of soil and soil for each soil sample.

3.3 Method of Decrease Analysis of Soil Samples

Based on the research objectives to be achieved, as well as estimates of the availability of the necessary data then there are two ways the sample analysis. The land subsidence research laboratory analysis as follows:

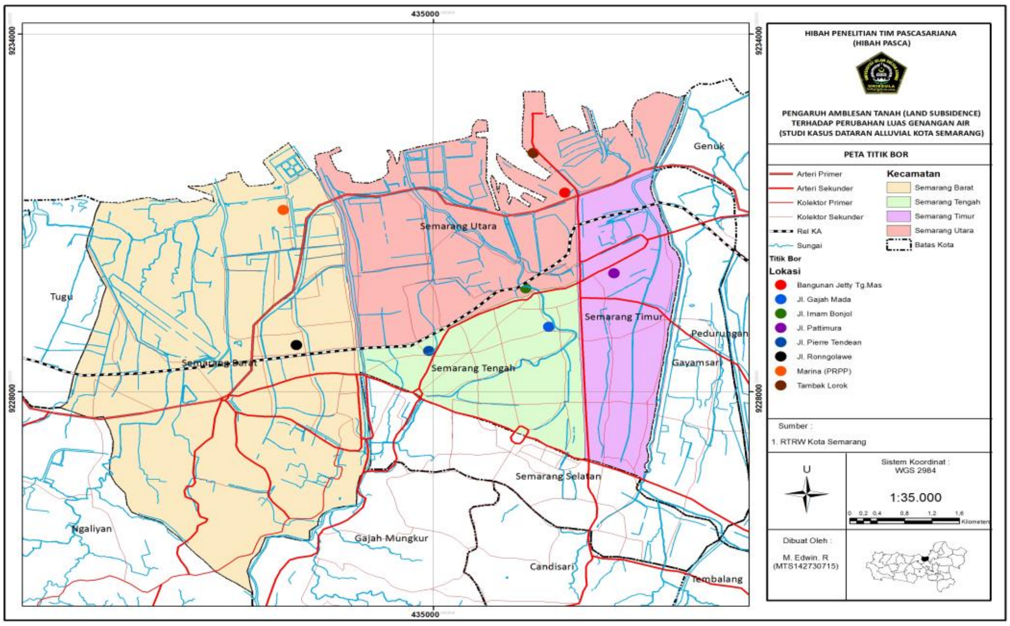
1) Analysis of Soil Mechanics Laboratory results are used to calculate / predict large and duration of land subsidence. Obtained from analysis and calculation of the amount of γ, LL, Ø, c, Cc, Cv, and e_0, as calculated using a physical model can be seen a large and ever-decreasing due to the load on the ground and the mechanical properties of the soil. Soil samples in the form of data from drilling in 8 point spread in 5 districts, further analysis of drill set at 8 points with consideration of the amount is sufficient to represent the research area as a whole.

2) Analysis of the computer laboratory used to determine the distribution and widespread changes puddle. Data used include topographic maps and maps alluvial soil subsidence prediction. To determine the distribution and wide puddle, then map is overlay stacking so widely known changes inundation by ground subsidence. The process of overlaying using Geographic Information System (GIS) in the form of digital data that is formatted raster [24].

4. Results And Discussion

4.1 Physical and Soil Mechanics

In this study, the physical and mechanical properties of the soil in the study of primary data as much as 8 drill point spread on alluvial plains with depth varies between 0-30 m drill site. The location of the drill is as shown in Figure 1. For the needs of large prediction calculation and duration of data subsidence and mechanical properties of the soil conducted further analysis. To give more detailed description of the physical and mechanical properties of soil are described in Tambak Lorok one point (drill point no.3). Locations in Tambak Lorok are described in detail with consideration at that location in the category of major subsidence and subsidence is also the longest time. The test results of physical and mechanical properties of the soil in the study is obtained from 8 point drill as samples and lab test results can be seen in Table 1.



Source : Team analysis, 2015

Figure 1. Location of sampling points with a drill machine

Table 1. Results of Drilling and Testing Laboratory of Soil Mechanics

a. Subdistrict of West Semarang

1.	Marina PRPP		0 to -2m	Dump	It is silt material which is sandy and pebbly soil contained dump gravity of soil of 1.70 t / m3.
			Water soil surface -3m -2m to -30m	*Silt* Very soft to soft	silt layers with a variety of shell fragments mix, sand, pebble gray and gray-black. N-SPT value between 2-5 and CPT values ranging from 5 kg / cm2, with a very soft consistency until soft. LL between 60% - 81%, PI between 30% - 50%, (ϕ) 11^o - 18^o, and (c) between 0,07kg / cm2 - 0.21kg / cm2. Cc = 0.119 to 0664. eo = 0, from 980 to 2.469
			-30m to ∞	*Silt & clay* rather hard to hard	No consolidation
2.	Jl. Ronggolawe		0 to -1m	Dump	It is silt material which is sandy and pebbly soil contained dump gravity of soil of 1.70 t / m3.
			Water soil surface -2m -1m to -6m &	*clay* rather soft	Clay layer is composed of sand gray, siliceous sand, clay and shells are separated by rather soft consistency, the value of N-SPT range 2 s / d 50 Cc = 0.350. eo = 1, 136 to 1.391.
			-6m to -12m	*Sand*	Composed of sand layers of gray, sand siliceous, plates and shells are separated by soft to solid consistency. N-SPT value ranges from 2 - 50. No consolidation.
			-12m to -18m	*Silt* rather soft	A layer of very argillaceous silt and sandy coral gravel there. N-SPT value between 7-18, with a rather soft consistency. LL between 60% - 63%, PI between 32% - 41%, this layer can be classified as Inorganic clay of high plasticity. Cc = 0.398. eo = 1, 022 to 1.295
			-18m to -25m	*Sand & gravel*	Comprising a layer of sand and gravel gray, siliceous sand, plates and shells are separated by soft to solid consistency. N-SPT value ranges from 2 - 50. No consolidation.

b. Subdistrict of North Semarang

3.	Tambak Lorok		-1 to -4m Water soil surface -2m	Dump	Layer of silty gravelly material gravelly silty sand, some reclamation embankment material SPT grades 1-4, with a very soft consistency until soft. LL 55% - 80%, PI 23% - 48%, (ϕ) 0.1 t / m3 - 3.0 t / m3.dengan soil density of 1.57 t / m3.

			-5m to -24m	*Silt* very soft to soft	A layer of silty with a mixture of shell fragments in gray and gray-black. SPT value varies 1-4 with unbelievably soft and malleable consistency, LL between 50% - 80%, PI between 23% - 48%. Cc = 0.448 to 0.962. eo = 1, 62 to 2.213.
			-25m to ∞	*Silt & clay* very soft to rather soft	consolidates
4.	Jl. Jetty Tanjung Mas		0 to -2m Water soil surface -2m	Dump	Layer of gravelly silty material, sand, some reclamation embankment material SPT grades 1-4, with a very soft consistency until soft. LL 55% - 80%, PI 23% - 48%, (ϕ) 0.1 t / m3 - 3.0 t / m3.dengan soil density of 1.70 t / m3.
			-2m to -25m	*Silt* very soft to soft	A layer of silty with a mixture of shell fragments in gray and gray-black. SPT value varies 1-4 with unbelievably soft and malleable consistency, LL between 50% - 80%, PI between 23% - 48%. Cc = 0.448 to 0.962. eo = 1, 422 to 2.213
			-25m to ∞	*Silt & clay* rather hard to hard	No consolidation
5.	Jl. Imam Bonjol		0 to -1m	Dump	It is dump soil, sandy silt material mixture and gravelly soil with a specific gravity of 1.73 t / m3
			Water soil surface -3m -1m to -25m	*clay* very soft to rather soft	A layer of clay with a variety of shell fragments mix, sand, pebble gray and gray-black ,. N-SPT value range 2-7 with the consistency of very soft to moderately soft. LL between 60% - 81%, PI between 30% - 50%, (ϕ) 7° - 11°, (c) 0.04 kg / cm2 -0.25 kg / cm2. Cc = 0.600. eo = 0.600
			-25m to ∞	*Silt & clay* rather hard to hard	No consolidation

c. Subdistrict of Central Semarang

6.	Jl. Gajah Mada		0 to -1m	Dump	It is dump soil, sandy silt material mixture and gravelly soil with a specific gravity of 1.65 t / m3.
			-1m to -2m Water soil	*Silt* very soft	A layer of silt with shell fragments mix variations, sand, pebble gray and gray-black ,. N-SPT value range 2-7 with the consistency of very soft to moderately soft. LL between 60% - 81%, PI between

			surface -2m		30% - 50%, (ϕ) 5º - 11º, (c) 0.04 kg / cm2 -0.25 kg / cm2. 0,959 cc, eo = 1.136
			-2m to -25m	*Clay* soft	The form of soft silt layers with a variety of shell fragments mix, sand, pebble gray and gray-black ,. N-SPT value range 2-7 with the consistency of very soft to moderately soft. LL between 60% - 81%, PI between 30% - 50%, (ϕ) 5º - 11º, (c) 0.04 kg / cm2 -0.25 kg / cm2. Cc-0.3 to 1.189, eo = 0.998 to 1.2
			-25m to ∞	*Silt & clay* rather hard to hard	No consolidation
7.	Jl. Piere Tendean		0 to -1m	Dump	A layer of silt material there is a sandy and gravelly soil contained dump soil gravity of 1.73 t / m3.
			Water soil surface -3m -1m to -25m	*Silt* very soft to rather soft	A layer of silt with a varied mix of fragments of shells, sand, gravelly gray and gray-black. SPT N-values range from 2-7 with the consistency of very soft to moderately soft, LL between 60% - 81%, PI between 30% - 50%. The soil layer can be classified as inorganic clay of high plasticity, (ϕ) 7º - 11º, and (c) between 0,04kg / cm2 - 0.25kg / cm2. Cc = 0.500. eo = 0, from 714 to 1.055.
			-25m to ∞	*Silty clay rather hard to hard*	No consolidation

d. Subdistrict of East Semarang

8.	Jl. Patimura Jurnatan		0 to -2m	Dump	A layer of silt material there is a sandy and gravelly soil contained dump soil gravity of 1.76 t / m3.

			-2m to -3m Water soil surface -3m	*Silt* very soft to soft	Layers with a variety of shell fragments mix, sand, gravelly gray and gray-black. Value of N-SPT ranges from 2-5 and grades CPT ranges from 5 kg / cm2 with the consistency of very soft to soft, LL between 60% - 81%, PI between 30% - 50%. (ϕ) 11º - 18º, and (c) Among 0,07kg / cm2 - 0.21kg / cm2. Cc = 0,700. eo = 1, 106.
			-3m to -6m	*Sand*	Composed of sand layers of gray, siliceous sand, plates and shells are separated by soft to solid consistency. N-SPT value ranges from 2 - 50. No consolidation.
			-6m to -25m	*Silt* very soft to soft	Layers with a variety of shell fragments mix, sand, gravelly gray and gray-black. Value of N-SPT ranges from 2-5 and grades CPT ranges from 5 kg / cm2 with the consistency of very soft to soft, LL between 60% - 81%, PI between 30% - 50%. (ϕ) 11º - 18º, and (c) Among 0,07kg / cm2 - 0.21kg / cm2. Cc = 0,700. eo = 0, 871.
			-25m to ∞	*Silty clay rather hard to hard*	No consolidation

Source: Mek Tan Lab test results (2015)

Table 2: Decline and duration of the decline in Alluvial Plain 1D of Terzaghi approach

Drill point number	Location	Decline Duration (Years)	Large Decline (Meter)
1.	Marina PRPP	17,354	0,896
2.	Jalan Ronggolawe	15,408	1,247
3.	Tambak Lorok	29,634	1,277
4.	Jetty Tanjung Emas Building	27,241	1,078
5.	Jalan Imam Bonjol	17,780	0,642
6.	Jalan Gajah Mada	10,371	0,559
7.	Jalan PiereTendean	16,147	0,505
8.	Jalan Pattimura (Jurnatan)	19,485	0,744

Source: Results of the analysis and calculation results 2015

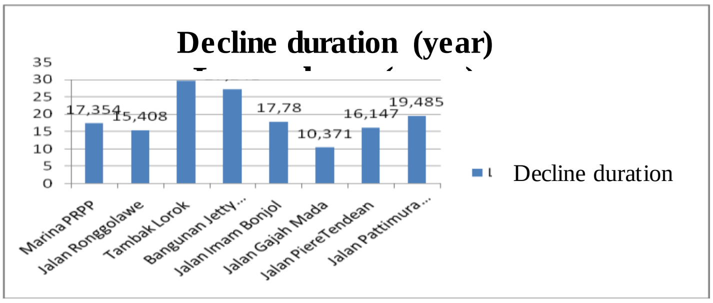


Figure 2. Graph the relationship between decline duration with location of sampling

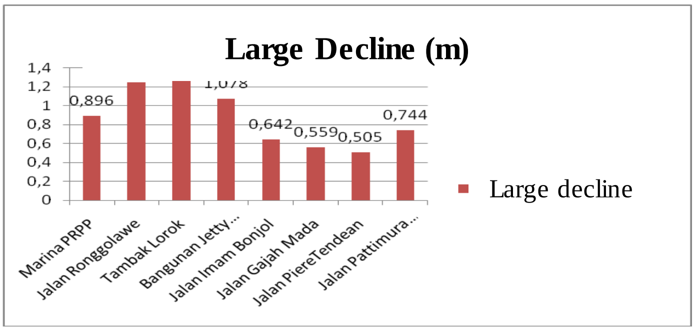


Figure 3. Graph the relationship between large decline with location of sampling

5. Conclusion

1) At a depth of approximately 0 - 2m all soil is a soil embankment, in the form of a layer of silt material there is a sandy and gravelly soil contained specific gravity of soil
2) (γ) 1.45 t/m^3 to 1.76 t/m^3.
3) The ground water level ranged from 1 to 2 m below the ground surface
4) At an average depth of 2-25m in the form of a layer of silt with variations mix fragments of shells, sand, pebble gray and gray-black. Consistency is very soft to soft. LL between 60% - 81%, PI between 30% - 50%, (ϕ) 11o-18o, and (c) between 0,07kg/cm2 - 0.21kg/ cm2. Cc = 0.465 - 0.797.eo = 1, 100 to 1.530.
5) At a depth of over 25m, there is no land consolidation
6) From the analysis of the lab test results, it can be seen that further to the north (toward the ocean), the land subsidence is greater but in the longer time.

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