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The Prediction of Broad Puddle Change Based on Land Subsidence Analysis in Semarang

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Abstract - Semarang is the capital city of Central Java that has a population about 1.3 million people, the position of Semarang is very strategic as a regional transport. Semarang is divided into 2 parts namely Semarang Upper area and Semarang lower area. The soil layer of Semarang lower area is dominated by soft alluvial soil layers that continue to occur compression. These conditions effect this area most likely get the environmental impact caused by land subsidence. The objective of this study was to determine the large and duration of land subsidence that occurred in Semarang Barat district and its influence towards the area of inundation. The analysis of this research used 1D terzaghi method and plaxis software which then in overlay using GIS which yielded map of subsidence in the area. The calculation results that used 1D Terzaghi, the land subsidence of Mediterranean Housing was 91.11 cm for 27.11 years, Ronggolawe area subsidence was 24.40 cm for 18,50 years, and Jendral Sudirman area was 10 cm for 15,94 years, while using plaxis 8.2 software, the Perum Mediterania was 93.40 cm, Ronggolawe area was 26.22 cm, Jendral Sudriman area was 13.68 cm. Changes in the area of inundation in 2017 to 2047 amounted to ± 924,74 ha.

Keywords: *Land Subsidence, 1D Terzaghi, GIS, Plaxis*

1. Introduction

Along the development and construction of Semarang, it has caused a change in the physical condition of the city, i.e. land use change. It surely incur its own problems in the city.

Semarang is divided into 2 parts namely Semarang Upper area and Semarang lower area. The soil layer of Semarang lower area is dominated by soft alluvial soil layers that that continue to occur compression. These conditions effect this area most likely get the environmental impact caused by land subsidence. Floods often occur in the Semarang lower area, and in some areas, sea water (rob)/ Coastal flood is the cause.

Coastal flood is an interesting phenomenon that floods occur without any rain or in other words the flood caused by tidal seawater that inundate the lower land of sea water. This process occurs because of the load on the ground that is too large so that there is a decrease or land subsidence then causing inundation of water. Land subsidence itself can be several factors, such as excessive groundwater causing underground cavity that causes land subsidence. This study provides limitation of the problem that is:

1. The research location is located in Semarang Barat Sub-district on Mediterania Housing Housing, Ronggolawe Street, and Jendral Sudirman Street.
2. Land Subsidence which is calculated only based on the land consolidation occurs.
3. Analyzing the causes of land subsidence in Semarang Barat Sub-district at T90%.

4. Identify the amount of land subsidence, the duration of subsidence and the width of inundation in the District of Semarang Barat at T90%.

2. Methodology

Based on the research objectives, as well as the estimated data required then used laboratory analysis, calculation and field inspection. The research method used in this study was Experimental Research. This kind of research study aimed to analyze or investigate the magnitude and duration of the land subsidence and its effect on changes in the width of inundation that occurred in Semarang Barat Sub-district manually or calculated by comparing the amount of the subsidence with the use of special applications of geotechnical.

Soil analysis test was obtained by laboratory calculation based on sample and primary data. The calculation was done in two ways: 1D Terzaghi approach and the use of PLAXIS software. The results of the used of plaxis software were large and duration of land subsidence with different load and mechanical conditions of soil. The results of manual calculations (Terzaghi) and Plaxis were compared to obtain the final result of large and duration of subsidence and the tendency of subsidence.

The changes in the width of the inundation area were determined using the GIS (Geographic Information System) software, the analysis of the change in the inundation area obtained by assigning the categories of values for the four variables i.e. the soil load, the decrease of the groundwater surface, the thickness of alluvial sediments, and the carrying capacity of the soil. The four variables were overlaid and the result was a prediction map of land subsidence and then that map was overlaid with topographic maps (secondary data) and the result was a predicted map of changes in inundation area

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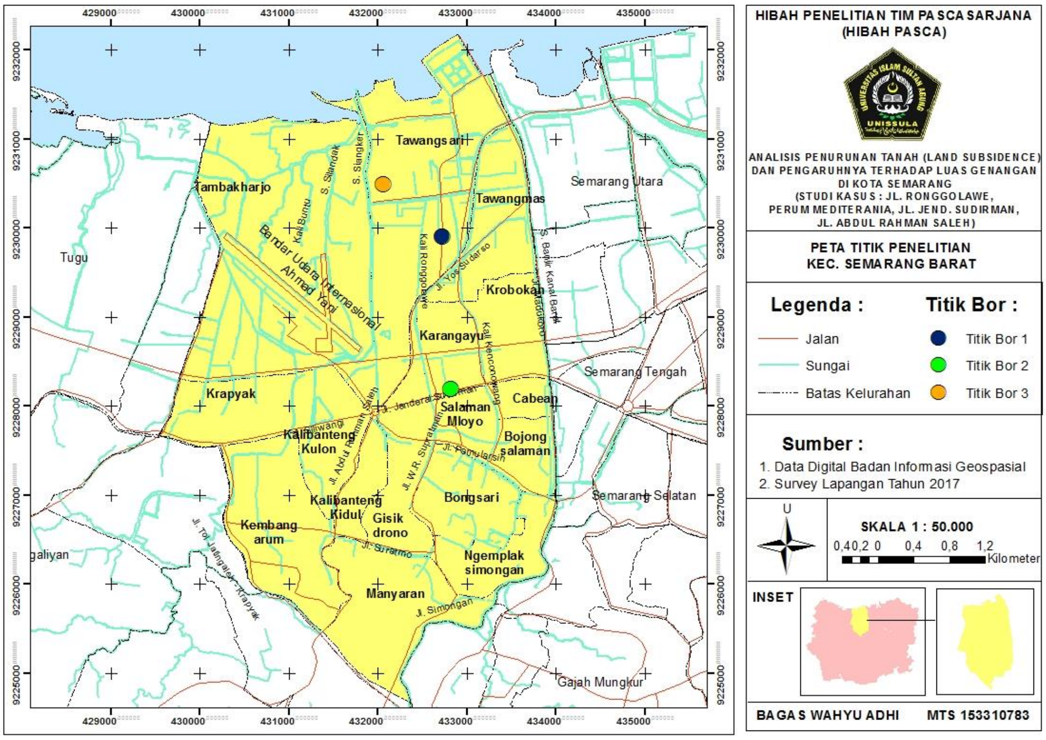
3. Result and Discussion

The results of this analysis had objectivity to test the primary hypothesis, i.e. the load on the land, land mechanical properties affect the large and duration of land subsidence in alluvial land spatially and temporally. At the location of this study there were 3 drill points scattered on alluvial plains with a depth of about 25-30 m, seen in Figure 4.1. The predicted rate and duration of land subsidence were calculated by the 1 consolidation theory approach developed by Das (1998) and Weslay (1997). The physical and mechanical properties of the soil used to calculate were: γ (original land weight), γ (dry land weight) σ' (effective stress) Cc (compression index), Cv (coefficient of consolidation) and e_o (pore number).



Picture 1. Drill location map (Land sample in research area)

Table 1. Prediction of Large and duration of Land subsidence Achieve T90% with 1D Terzaghi Approach

No.	Location	The Large of Subsidence (cm)	The Duration of Subsidence (Year)
1	Perum Mediterania	91,11	27,11
2	Ronggolawe	24,40	18,50
3	Jendral Sudirman	10,00	15,94

Source: Analysis result and calculation result, 2017

The land subsidence prediction map was made from drill spots predicted to occur subsidence in the research area. Interpolation used ArcGIS software with IDW (Inverse Distance Weighted) method. From these results, the prediction of ground subsidence could be calculated. Based on the result of land mechanical analysis at the drill points, it was obtained 5 classes range of land subsidence depth value in Table 2 level I was the level showed the smallest depth while the level V showed the largest depth of land subsidence.

Table 2.The Depth of Land Subsidence Level Reaches T90 with 1D Terzaghi Approach

The depth level	The value of Subsidence Depth	Location
Level I	0 - 20 cm	Jendral Sudirman
Level II	21 - 40 cm	Ronggolawe
Level III	41 - 60 cm	-

The depth level	The value of Subsidence Depth	Location
Level IV	61 - 80 cm	-
Level V	> 80 cm	Perum Mediterania

Source: Analysis result and calculation result, 2017

- The Analysis Uses Plaxis Software

  The next analysis calculation used Plaxis 8.2 software. From the calculations using the Terzaghi method, it can be compared with using Plaxis 8.2 software. The soil parameters included in Plaxis 8.2 modeling were by using data input consists of:

  E (*Modulus Young*), *poisson's ratio*, *cohession*, dan *shear strength*.

  Final result used *software Plaxis 8.2* at Perum Mediterania is:

Table 3. Prediction of Land Subsidence Large with *Plaxis 8.2 Software*

No.	Location	Subsidence Duration (Year)	Subsidence Large (cm)
1.	Perum Mediterania	27,11	93,40
2.	Ronggolawe	18,50	26,22
3.	Jendral Sudirman	15,94	19,54

Source: Analysis result and calculation result, 2017

Modeling with Plaxis 8.2 software yielded in a larger subsidence than Terzaghi, since the Terzaghi method did not use parameters such as Young Modulus and Poisson Ratio. So that it influenced the results obtained. Plaxis calculation was more accurate because it calculated the subsidence from many dimensions.

Tabel 4. Prediction of Land Subsidence Large on the Calculation per Year with Terzaghi Method

No.	Location	Year 2018 (cm)	Year 2019 (cm)	Year 2020 (cm)	Year 2021 (cm)	Year 2022 (cm)
1	Perum Mediterania	3,36	6,72	10,08	13,44	16,80
2	Ronggolawe	1,32	2,64	3,96	5,28	6,59
3	Jendral Sudirman	0,63	1,25	1,88	2,51	3,14

Source: Analysis result and calculation result, 2017

Table 5. Prediction of Land Subsidence Large on the Calculation per Year with *Plaxis 8.2 Software*

No.	Location	Year 2018 (cm)	Year 2019 (cm)	Year 2020 (cm)	Year 2021 (cm)	Year 2022 (cm)
1	Perum Mediterania	3,45	6,89	10,34	13,78	17,23
2	Ronggolawe	1,42	2,83	4,25	5,67	7,09
3	Jendral Sudirman	0,86	1,72	2,57	3,43	4,29

Source: Analysis result and calculation result, 2017

Table 6. Prediction of Land Subsidence Large on the Calculation per Five Year with Terzaghi Method

No.	Location	Year 2018 (cm)	Year 2022 (cm)	Year 2027 (cm)	Year 2032 (cm)	Year 2037 (cm)	Year 2042 (cm)	Year 2047 (cm)
1	Perum Mediterania	3,36	16,80	33,61	50,41	6,22	84,02	91,11
2	Ronggolawe	1,32	6,59	13,19	19,78	24,40	-	-
3	Jendral Sudirman	0,63	3,14	6,27	10,00	-	-	-

Source: Analysis result and calculation result 2017

Table 7. Prediction of Land Subsidence Large on the Calculation per Five Year with *Softwere Plaxis*

No.	Location	Year 2018 (cm)	Year 2022 (cm)	Year 2027 (cm)	Year 2032 (cm)	Year 2037 (cm)	Year 2042 (cm)	Year 2047 (cm)
1	Mediterania Housing	3,45	17,23	34,45	51,68	68,90	86,13	93,40
2	Ronggolawe	1,42	7,09	14,17	21,26	26,22	-	-
3	Jendral Sudirman	0,86	4,29	8,58	13,68	-	-	-

Source: Analysis result and calculation result 2017

- Classification of Subsidence Depth Level

This was a classification made for overlay of subsidence maps in 2018 to 2047:

Table 8. The Depth of Land Subsidence Level with Plaxis *8.2* Sofware Analysis Five Years

The depth level	The Value of Subsidence Depth	Year 2018	Year 2022	Year 2027	Year 2032	Year 2037	Year 2042	Year 2047
Level I	0 - 20 cm	Perum Mediterania, Ronggolawe, Jendral Sudirman	Perum Mediterania, Ronggolawe, Jendral Sudirman	Ronggolawe, Jendral Sudirman	Jendral Sudirman	-	-	
Level II	21 - 40 cm	-	-	Perum Mediterania	Ronggolawe	Ronggolawe	-	-
Level III	41 - 60 cm	-	-	-	Perum Mediterania	-	-	-
Level IV	61 - 80 cm	-	-	-	-	Perum Mediterania	-	-
Level V	> 80 cm	-	-	-	-	-	Perum Mediterania	Perum Mediterania

Source: Analysis result and calculation result 2017

Tabel 9. Relationship between of Land Subsidence and Puddle of West Semarang from 2018 to 2047

No	Location	Land Subsidence (cm)	Puddle (Ha)	Year
1	Perum Mediterania	3,45	285,17	2018
2	Ronggolawe	1,42		

No	Location	Land Subsidence (cm)	Puddle (Ha)	Year
3	Jendral Sudirman	0,86		
1	Perum Mediterania	17,23	443,79	2022
2	Ronggolawe	7,09		
3	Jendral Sudirman	4,29		
1	Perum Mediterania	34,45	570,33	2027
2	Ronggolawe	14,17		
3	Jendral Sudirman	8,58		
1	Perum Mediterania	51,68	675,53	2032
2	Ronggolawe	21,26		
3	Jendral Sudirman	13,68		
1	Perum Mediterania	68,90	781,59	2037
2	Ronggolawe	26,22		
3	Jendral Sudirman	-		
1	Perum Mediterania	86,13	894,02	2042
2	Ronggolawe	-		
3	Jendral Sudirman	-		
1	Perum Mediterania	93,40	924,74	2047
2	Ronggolawe	-		
3	Jendral Sudirman	-		

4. Conclusion

In sum up, the calculation using Terzaghi 1D approach with T90% is obtained the lowest prediction of land subsidence is in the area of Jendral Sudirman, it is 15,94 with value 10,00 cm, while for Perum Mediterania area there is a large land subsidence with the value of 91,11 cm. For calculation using Plaxis 8.2 program, it is obtained the prediction of the smallest land subsidence in the area of Jendral Sudirman reaches 13.68 cm and for the Perum Mediterania area reaches 93.40 cm. Changes in the area of inundation in 2017 to 2047 amounted to ± 924,74 ha. Changes in the area of inundation Five year to ± 185,62 ha, and annually ± 20-30 Ha.

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