Lessons Learned From The Land Subsidence Problem at Coastal Area in North Jakarta

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Abstract: Jakarta is growing fast such that the development on the Northern part of the City has been done by reclaiming the coastal area in an expeditious manner. The reclamation projects for housing, recreation area, ports, etc., are subject to settlement of the marine soft clay, sea level rise and land subsidence. Sea level rises is due to global warming and has a minor impact compared to land subsidence. Land subsidence is caused by significant changes of land uses because of urbanization and excessive extractions of ground water. The rapid growth of population in Jakarta has forced an excessive extraction of ground water. As a result, part of the coastal area in North Jakarta is flooded during the high tide. This paper provides lessons learned from the land subsidence problems at Pantai Mutiara, Pantai Indah Kapuk, Jakarta Fishing Port and Tanjung Priok Port. Several design key parameters used for coastal structures are highlighted, i.e. elevation of coastal structures and type of coastal structures.

Keywords: Land subsidence, coastal structures, reclamation

1 Introduction

Population in Jakarta is growing fast resulting in ever growing land needs for development toward north of the City only can be satisfied by reclaiming coastal area. As a consequence, coastal structures in North Jakarta are susceptible to poor soil condition of soft marine clay, land subsidence (LS), and sea level rise (SLR).

According to Hanzawa (1984), coastal area in the world, where main industrial and transportation facilities are located, mostly consists of soft marine clay. Construction in this coastal area is challenging because marine clay is weak in term of the degree of compressibility. It is an important task to find out the best method for treating this weak and non-compressible material at minimum cost.

Abidin et al (2009) introduced a downward land movement phenomena in Jakarta called land subsidence, and based on his investigation it is caused by urbanization and excessive extractions of ground water. Moreover, global warming contributes to sea level rise which should be taken into account when determining the elevation of coastal structures.

Combination of these three phenomenas makes it complex for Engineers to determine a safe coastal structures elevation. Geotechnical Engineer has been long known for treating soft clay by soil improvement and predicting the amount of soil consolidation. While the amount of SLR is negligible over the years, LS on the other hand is concerning due to its uncertainty. For this reason, this paper focuses only on LS problems encountered at several coastal structures which are located on reclamation area in North Jakarta such as Pantai Mutiara, Jakarta Fishing Port and Tanjung Priok Port, and how each and every single development protects themselves from these on-going problems. Proper crest elevation and certain type of coastal structures selection which could mitigate the impact of LS are also discussed in this paper.

2 Marine Soft Clay at coastal area of North Jakarta

Coastal area in North Jakarta, like most coastal area in the world, consists of Marine Soft Clay. According to PT Diagram Triproporsi (2009), at Tanjung Priok Port the upper layer consists of very soft clay with N value of approximately 1 to 2 for depth up to 12 m below sea bed. Hard layer starts at approximately 20 to 25 m below sea bed. Similar soil stratum exists across coastal areas in North Jakarta. Soil settlement is typical accelerated by implementing soil improvements such as the use of vertical drain and bamboo piles.

3 Land Subsidence

LS occurs when large amounts of ground water have been excessively withdrawn from an aquifer. The clay layers within the aquifer compact and settle, resulting in lowering the ground surface in the area from which the ground water is being pumped. Figure 1 illustrates LS mechanism. Figure 2 illustrates a LS case in San Joaquin Valley, California, United States of America.

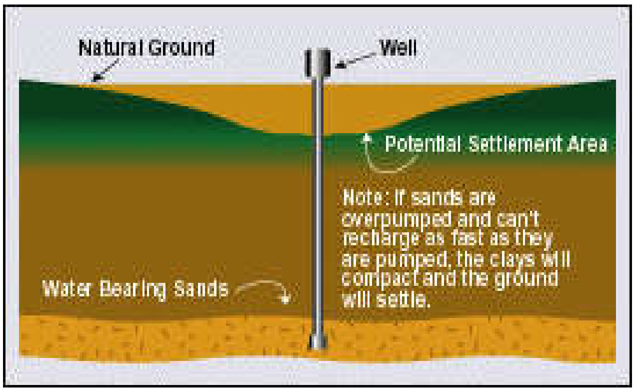

Figure 1. Land Subsidence mechanism.

Source: United States Geological Survey.

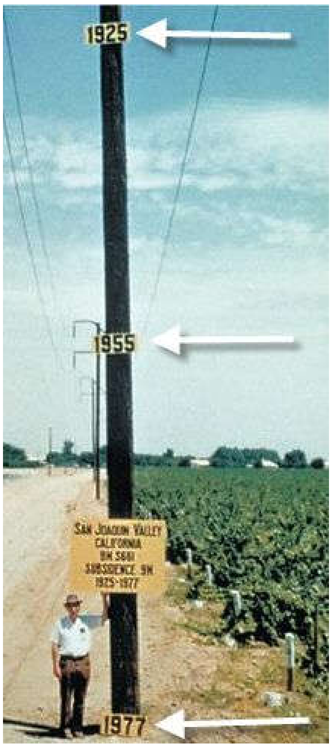

Figure 2. Land Subsidence case in San Joaquin Valley, California dated back in 1925.

A few decades ago, Engineers at Jakarta did not take into account LS into their design works since it was not known. However, starting from 1980's and on, Engineers observed that LS occurred. Abidin et al (2009) did his research on LS in Jakarta by surveying elevations, GPS survey and InSAR technique with the significant discovery. LS measured were from 1 to 15 cm per year, 12 cm per year on average, and could be as much as 20 to 25 cm per year at the certain locations and periods., as indicated in Table 1. In a nut shell, LS in Jakarta is caused by rapid urbanization and excessive extractions of ground water which yield to consolidation of sediment layers.

Table 1. Observed subsidence rates in Jakarta; the rates vary both spatially and temporally.

Method	Period
Leveling surveys	1982-1991
	1991-1997
GPS surveys	1997 - 2008
InSAR	2006 - 2007

Source: Abidin et al (2009)

1.4 Sea Level Rise

Safwan Hadi et al (1990) studied SLR which is due to global warming. The study measured SLR at 4.38 mm per year, which was adopted by Nippon Koei (2006) for the design of Tanjung Priok Port. Another engineering consultant firm, PT Diagram Triproporsi (1996), took account SLR at 5.6 mm/year for its Ancol Baru Reclamation Project based on a literature.

2 PROBLEM SOLVING

2.1 Problem Solving at Pantai Mutiara

Development at Pantai Mutiara mostly consists of residential real estate. Severe LS has been occurred at the sea dike and road just behind the sea wall. Therefore, the developer has constantly elevated the sea dike and road three times in ten years for a total of 1 m elevation increase. This means the rate of LS in the neighborhood is approximately at 10 cm per year.

Interestingly, some houses do not experience LS whereas some others have been exposed to LS, and Home Owners in lieu of the Developer commonly fix their house at own expense. Land value in Pantai Mutiara is much more expensive than the other areas in Jakarta regardless of LS since the Developer provides pumps as part of drainage system which alleviates floods effectively.

2.2 Problem Solving at Pantai Indah Kapuk

Pantai Indah Kapuk is a real estate with one thousand hectares of land which was built with polder system. The impacts of LS have been mitigated as follows:

a) Houses are built on pile foundations.
b) Drainage by pumping system.
c) The Developer maintains roads and elevates sea dikes every several years.
d) The Developer collects maintenance fee from Home Owners. The fee amount for each Home Owner varies and is based on property size.

2.3 Problem Solving at Jakarta Fishing Port

Jakarta Fishing Port experience severe LS problems. According to Pacific Consultants International (PCI) & associates (1996), the crest elevation of the breakwater had been decreased by approximately 50 to 70 cm in 12 years from 1984 to 1996 or equal to approximately 5 cm per year on average. Therefore, rehabilitation projects were implemented a few years ago by means of elevating roads and quay wall and considering polder system.

In 1996, in respond to LS problems PCI and associates prepared a preliminary design as follows:

a) Quay wall floor was elevated as illustrated in Figure 3.

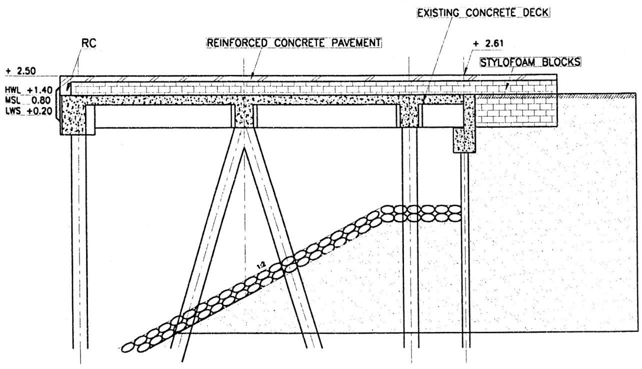

Figure 3. Elevating Plan of Quay Wall Deck.

b) When ground elevation could not be elevated, a dike around the buildings or facilities was constructed to prevent inundation of seawater from coming in. In addition, a pumping system was installed to discharge rainfall water which accumulates inside the dike, as illustrated in Figure 4.

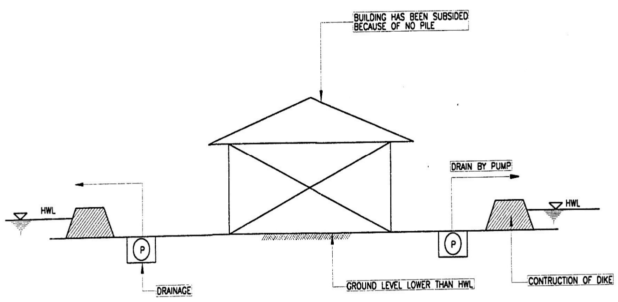

Figure 4. Flood Control System.

2.4 Problem Solving at Tanjung Priok Port

Tanjung Priok Port is an old port. According to Nippon Koei (2006), the first breakwaters were built between 1877 and 1882 by the Dutch. Port Authority schedules repairs and maintenances regularly since Tanjung Priok Port is the biggest port in Indonesia. Soil settlement is insignificant at Tanjung Priok Port since it sits on an old reclamation area in which its soft clay has already been over consolidated. A few latest projects at Tanjung Priok included soil improvements over several foundations.

3 CONCLUSIONS

Based on the above lessons learned, it is recommended for the design of the coastal structures in North Jakarta to consider the following factors:

a) Soil condition in North Jakarta coastal area is very soft clay up to approximately 12 m below sea bed, and then gradually becomes a hard layer at approximately 25 m below sea bed.
b) Soil improvement should be carried out for new reclamation.
c) Crest elevation determination of sea defense structures should follow Equation (1).

$$\text{Crest elevation} = HWS + SS + Ru + SLR + LS \qquad (1)$$

Where HWS is High Water Sea level, SS is Storm Surge – 0.64 m above HHWL for 50 years return period, this means + 1.82 m LWS in total with the HHWL according to Nippon Koei (2006), Ru is wave run up – which depends on the slope and the material of the structure, SLR is Sea Water Level Rise at 5 mm per year, and LS is Land Subsidence at rates from 1 to 25 cm per year depending on the location in Jakarta as described by Abidin (2009).

d) The choice of type of coastal structures is very important for anticipating any future repairs if needed. Example of defense coastal structure in North Jakarta is illustrated in Figures 5a and 5b.

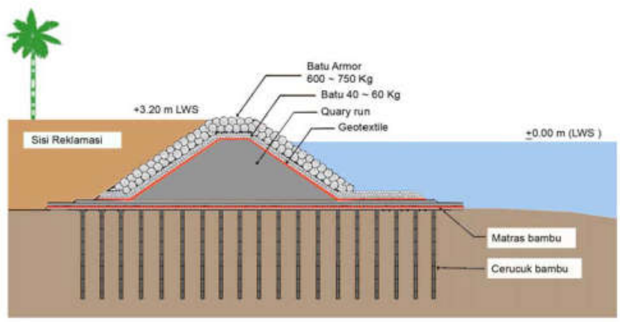

Figure 5a. Revetment at Ancol Baru Project, North Jakarta.

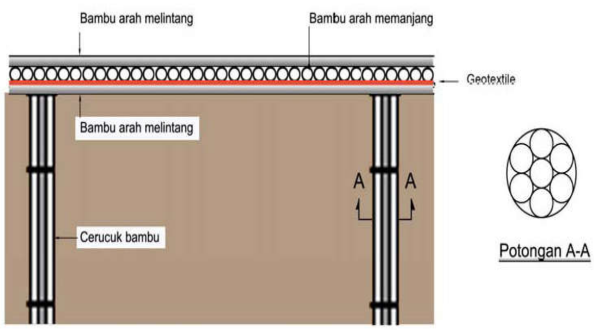

Figure 5b. Bamboo Mat in Detail.

e) Since LS poses significant problems, local government should pay attention to the urban developments by considering land use planning, ground water extractions regulation, building and infrastructure codes, flood management and control, and sea water intrusion control.

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