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Option Soil Improvement based on soil condition (Study case on cibitung, Bekasi)

Dwi Agrina*,

Tangerang Raya University, Tangerang, Indonesia

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Abstract: *Soft soil problems are common in Indonesia. This study is based on a case study of soft soil problems in Cibitung, Bekasi. The determination of treatment to improve the soil needs to be done based on field data results. Determination of repair options includes the type of construction, soil type conditions, time, cost and feasibility of a method. Based on soil conditions with a soft soil thickness more than 2m, need such as PVD or slab on pile treatment. If it is less than 2m, soil mixing or replacement can be option.*

*e-mail: dwi.agrina.da@gmail.com

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INTRODUCTION

General

Regional Geology in Project Area

Regional geology of case study location refers to The Geology of the Karawang Quadrangle, Java, at scale of 1:100.000, issued by Direktorat Geologi 1976 as shown in the Figure 1 below.

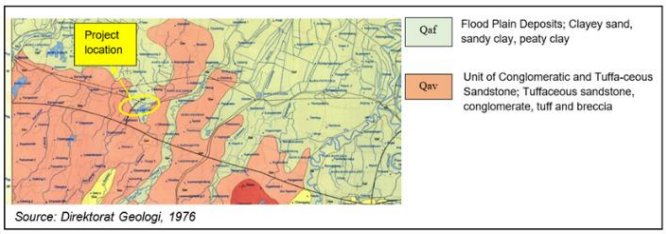


Figure 1. Regional geology map of the Karawang Quadrangle, Java

Geomorphology

Geomorphology of research area necessary to know how in general, groundwater flow direction,

It was found that the research area Bekasi Regency is at an altitude an average of 6-115 meters above the surface sea with a slope of 0-250. Regionally, this territory is divided into two geomorphological units,

- The northern part of Bekasi Regency, is a region with morphology coastal alluvial plains, that are formed by alluvial sized rivers clayey, this northern part is the alluvial zone West Java. Project location is classified as this part.
- The southern part Bekasi Regency, is the morphology hills formed from a variety Quaternary sedimentary rock types and tertiary, local forming a field.

Based on The Geology of the Karawang Quadrangle, Java Bekasi Regency, from top to bottom has a hydrogeology property as follows:

- Ac (Cs) clay, sandy clay 2-15m thick, 1x10-5 low permeability up to> 1x10-7 depth groundwater level 1-3m,
- R (ct) (ms) silt-silt clay and 2-12m thick sandy silt, permeability 1x10-3-1x10-5
- Depth groundwater level of 5-7m, and
- CG, SS conglomerates & sandstones tuff, groundwater level 5-7m in some places not encountered

METHODOLOGY

Data Collection

Data Collection Review and Applied Assumption based on Site Survey

Coordinate Location	Documentation	Observation Result
Project Location Lat : -6°18,171'S Long : 107°04.172'E		Very soft consistency, reddish brown in color
Crossroad Location Lat : -6°18,865'S Long : 107°04.028'E		**Some road failure was found:** -alligator cracking (fatigue) -Consolidation of pavement layers (rutting) **Possibly Causes:** -Inadequate surface or subsurface drainage -Settlement of foundation of embankment -Heavy rain
Near River Location Lat : -6°18,868'S Long : 107°04.085'E		Very soft consistency, very high moisture content
Slope Near River Location		V:H 1:2 With slope height 5 m

Based on Existing Data

Based on existing data provided by Proving Ground there are 80 points of CPT (Cone Penetration Test). The points location spreader on whole area of Proving Ground at intervals every 100 m to mapping the soil types in the area mentioned as a reference for analyzing the foundation and pavement of the road. The location of CPT can be seen on Figure 2 and the depth of hard soil can be seen on Table 1.

Figure 2. CPT Points location on case study area which been reviewed

Table 1. Summary of CPT Result

Points	Date	Location	Coordinate (X, Y)		Qc 200 kg/cm2 (m)	Type of Soil
S1	30/10/2018	STA 0+100	728775.284	9302616.805	4.8	
S2	30/10/2018	STA 0+100	728861.834	9302566.713	4.4	
S3	29/10/2018	STA 0+100	728948.384	9302516.622	3.2	
S4	29/10/2018	STA 0+100	729034.933	9302466.530	2.8	
S5	29/10/2018	STA 0+100	729121.483	9302416.438	4.4	
S6	30/10/2018	STA 0+200	728825.376	9302703.354	4.2	
S7	30/10/2018	STA 0+200	728911.926	9302653.263	4	
S8	28/10/2018	STA 0+200	728998.475	9302603.171	8.8	
S9	28/10/2018	STA 0+200	729085.025	9302553.080	9.2	
S10	29/10/2018	STA 0+200	729171.574	9302502.988	10.8	
S11	30/10/2018	STA 0+300	728875.468	9302789.904	4.4	
S13	28/10/2018	STA 0+300	729048.362	9302689.603	9.4	
S14	28/10/2018	STA 0+300	729135.116	9302639.629	9.6	
S15	12/10/2018	STA 0+300	729221.666	9302589.538	11.4	
S16	26/10/2018	STA 0+400	728925.559	9302876.454	5.8	
S18	26/10/2018	STA 0+400	729098.658	9302776.270	8.4	
S19	26/10/2018	STA 0+400	729185.208	9302726.179	11.6	
S20	13/10/2018	STA 0+400	729271.758	9302676.087	11	
S21	26/10/2018	STA 0+500	728975.651	9302963.003	2.8	Silty Sand
S23	26/10/2018	STA 0+500	729148.750	9302862.820	7.4	
S24	26/10/2018	STA 0+500	729235.300	9302812.728	7.8	
S25	27/10/2018	STA 0+500	729321.849	9302762.637	14.6	
S26	25/10/2018	STA 0+600	819025.742	9303049.553	2.6	
S27	26/10/2018	STA 0+600	729111.361	9303000.000	2.6	
S28	24/10/2018	STA 0+600	729198.842	9302949.370	4.4	
S29	26/10/2018	STA 0+600	729285.391	9302899.278	8	
S30	14/10/2018	STA 0+600	729371.941	9302849.186	11.8	
S31	25/10/2018	STA 0+700	729075.834	9303136.102	2	
S32	25/10/2018	STA 0+700	729162.384	9303086.011	2	
S33	24/10/2018	STA 0+700	729252.874	9303038.189	5.2	
S34	27/10/2018	STA 0+700	729335.483	9302985.828	11.2	
S35	14/10/2018	STA 0+700	729422.032	9302935.736	11.6	
S36	24/10/2018	STA 0+800	729125.926	9303222.652	2.4	
S37	25/10/2018	STA 0+800	729212.475	9303172.56	2	
S38	24/10/2018	STA 0+800	729299.025	9303122.469	6.6	
S39	27/10/2018	STA 0+800	729385.574	9303072.377	11.8	
S40	18/10/2018	STA 0+800	729472.124	9303022.286	12.4	

Interpretation of depth of soft soil thickness

From the data above, the interpretation of soft soil thickness can be defined as zone bellow.

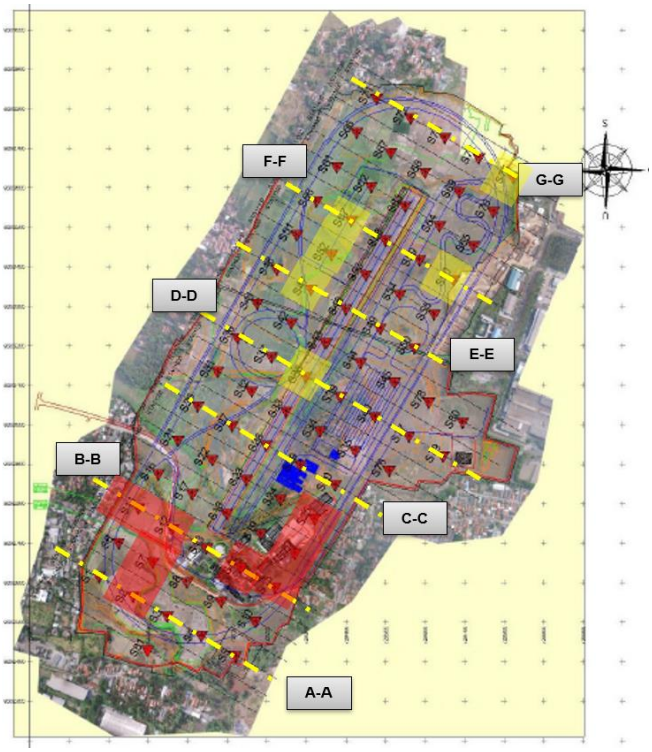


Figure 3. Shown the cross section for CPT location based on depth and Qc (red thick low value, yellow shallow low value)

From the CPT result which been reviewed, there are three soil type on the site location and mostly consists of sandy soil. Based on the value of qc (tip resistance), some of area has very low caused of loose sand. For the further analysis grain size analysis is really needed to classified the soil in detail. Sandy soils of (SW) well-graded sand the highest levels in terms of bearing capacity. The (SC) clayey sand has the lowest values of bearing capacity.

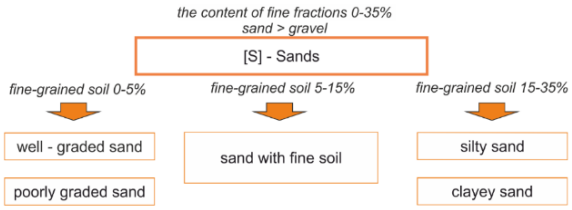


Figure 4. Type of sandy soil

RESULTS

Zoning and Option Study for Treatment

The zoning of soft soil which is based on geological review and CPT can be seen on Figure 5

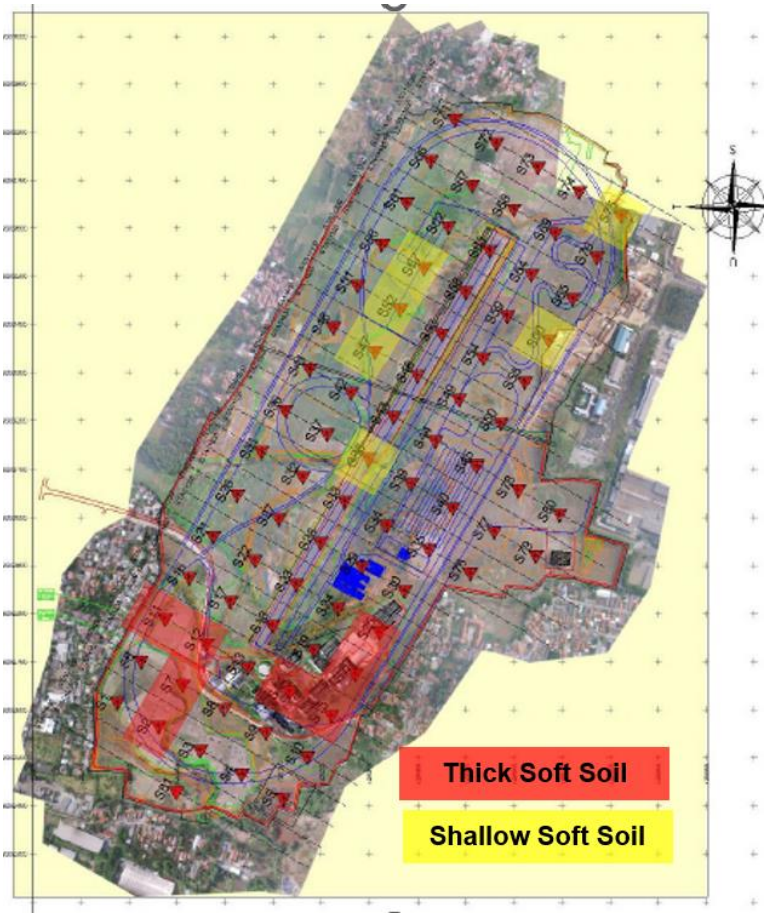
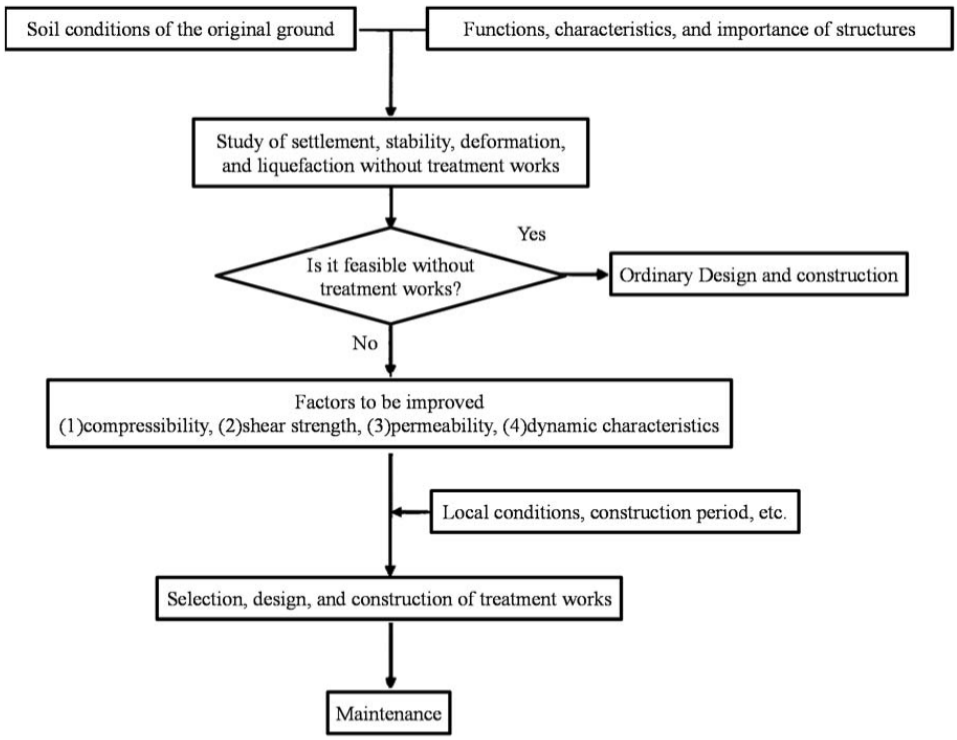


Figure 5. Zoning of soft soil on study Case Location

Option Study of Treatment

Concept of Design and Execution of Soft Ground Treatment



Source: Soft Ground Treatment Manual Japan International Cooperation Agency（JICA）

Figure 6. **Concept of Soft ground treatment**

The basic concepts of soft ground treatment in Manual are shown below:

- The loads applied to the soft ground shall be as small as possible within the permitted conditions.
- Select appropriate treatment work to ensure safety or to satisfy the execution conditions.
- An improvement method that utilizes the inherent characteristics of the ground shall be given a precedence in the study of the preloading method or slow loading method to enhance the strength through consolidation by ensuring sufficient time for execution.
- Conduct design and execution while considering the limitations of current investigation/analysis techniques, and the uncertainty of investigation, design, and execution.
- Conduct adequate execution management and information management based on an understanding of the complicated characteristics and distribution of soft ground.
- Conduct appropriate design and execution considering the ability of maintenance to ensure the intended performance of the earthwork structure

Significant Points of Soft Ground Treatment:

- Conformity with the purpose of usage: The function of earthwork structure constructed on soft ground must fulfill for traffics on the structures. It also includes the serviceability of the structure for the safety and comfort of the road users.
- Reliability: An earthwork structure on soft ground has appropriate safety against various types of influences, such as from traffics, rainfall, and seismic motion.
- Durability: Even an earthwork structure in aging deterioration after long usage should keep original quality and structural safety.
- Quality Control: Earthwork structures should be constructed securely in order to ensure the purpose of usage, safety of the structures and safe execution of works. The structures should be studied carefully in the design stage.
- Easiness of maintenance: Easiness of maintenance such as daily inspection, examination of the materials and repair work should be considered. It is related to durability and economic efficiency.
- Harmony with the environment: Earthwork structures on the soft ground should be harmonized with the social and natural environment, and apply an appropriate landscape to the surrounding area.
- Economic efficiency: It is important to reduce the total cost including for maintenance and repairs to minimize the life cycle cost rather than simply minimizing the construction cost.

Table 2. Summary of typical methods on Soft Ground Treatment Manual Japan International Cooperation Agency（JICA）

Function	Typical methods		Effects																	
			Settlement		Stability			Deformation		Liquefaction										
										Preventing liquefaction										
										Improvement of sand properties										
			Reduction in settlment during service with acceleration of consolidation settlment	Reduction in total settlement	Increase in strength gain due to consolidation	Increase in resistance force	Reduction of sliding force	Isolation of stress	Reduction of stress	Densification	Consolidation	Grading treatment	Reduction of saturation	Increase in effective stress	Dispersion of excess pore water pressure	Control of shear deformation	Measures to mitigate facility damage while tolerating liquefaction	Securing trafficability
Consolidation and drainage	Surface water drainage																		+	+
	Sand mat		+																+	+
	Slow banking method				+															
	Surcharge		+		+															
	Vertical drain	Sand drain	+		+															
		Vertical drain	+		+															
	Vacuum consolidation		+		+															
	Groundwater level reduction		+		+								+	+						
Compaction	Vibratory compaction	Sand compaction pile	+	+	+	+			+	+										
		Rod compaction		+*						+										
		Vibro-floatation		+*						+										
		Vibro-tamper		+*						+										
		Falling weight compaction		+*						+										
	Static compaction	Static compacted sand pile	+	+	+	+			+	+										
		Static pressure-fit compaction								+										

Function	Typical methods		Effects																
			Settlement		Stability			Deformation		Liquefaction									
										Preventing liquefaction									
										Improvement of sand properties									
			Reduction in settlement during service with acceleration of consolidation settlement	Reduction in total settlement	Increase in strength gain due to consolidation	Increase in resistance force	Reduction of sliding force	Isolation of stress	Reduction of stress	Densification	Consolidation	Grading treatment	Reduction of saturation	Increase in effective stress	Dispersion of excess pore water pressure	Control of shear deformation	Measures to mitigate facility damage while tolerating liquefaction	Securing trafficability
Induration	Shallow soil stabilization			+		+		+			+							+
	Deep mixed	Mechanical mixed		+		+		+	+		+					+	+	
		Jet grouting		+		+		+	+		+					+	+	
	Lime pile			+		+				+	+							
	Chemical injection			+		+					+							
	Freezing					+												
Excavation replacement	Excavation replacement			+		+		+				+						
Lowering Pore water pressure	Pore-pressure dispersing														+			
Load reduction	Lightweight embankment	Styrofoam block		+			+		+									
		Bubble-mixed lightweight soil		+			+		+									
		Formable bead-mixed lightweight soil		+			+		+									
	Culvert			+			+		+									
Embankment reinforcement	Embankment reinforcement					+											+	
Structural measure	Counterweight filling					+											+	
	Contiguous wall															+		
	Sheet pile					+		+							+**		+	
	Pile			+		+			+								+	
Laying materials	Laying reinforced materials					+												+

+; Effective for sand ground, +**; Cases with drainage function*

After determining the possible soft soil zone, and knowing the effects of each typical treatment, the next study is to make some option study for treatment.

Table 3. Option Study based on soft soil thickness

Soil Condition based on site classification	Need / No need Treatment or Reinforcement							
	Fill / Embankment				Cut			
	Road	Buildings	Slope (1:2.5)		Road	Buildings	Slope (1:2.5)	
			<5m height	>5m height			<5m height	>5m height
Medium Soil	No need	No need	No need *control drainage and compaction.	Check Critical height *need additional SPT test	No need	No need	No need *control drainage	Check Critical height *need additional SPT test
Soft Soil Thickness <2m	Need *replacement or soil mixing	No need	No need *control drainage and compaction.	Need	Check soil layer on finish level	No need	No need	Check soil layer on finish level
Soft Soil Thickness >2m	Need *Consolidation acceleration, or use reinforcement if can tolerate settlement (effective to solve differential settlement), or use slab on pile (no settlement)	No need	Need *treat the soil before make an embankment	Need *need additional SPT test to analyze type of protection or reinforcement	Need *Consolidation acceleration, or use reinforcement if can tolerate settlement (effective to solve differential settlement), or use slab on pile (no settlement)	No need	Check soil layer on finish level	Need *need additional SPT test to analyze type of protection or reinforcement

Soft layer Classification:

- ✓ Shallow and thin soft layer.
  When a soft layer is shallow and thin, its consolidation settlement is small and ends in a short time. In general, it is also less subject to slip failure. Therefore, the treatment of these layers is often conducted with a simple subsurface water drainage method. When constructing a very important structure, it is relatively easy to excavate and remove the problem soft layer. Thus, the excavation replacement method is also often used.
- ✓ Thick soft layer.
  When a soft layer is thick, the subsurface water drainage method is used in combination with other methods according to the purpose of application or the soil. Cohesive soil issue will be related on high compressibility, settlement and low bearing capacity. There for the settlement acceleration, soil reinforcement will be the key to solve the problem. PVD or slab on pile can be apply to this case. For loose sand issue will be related on low bearing capacity, low density, and liquefaction. Good compaction, and reinforcement is necessary. Deep compaction, grouting, and slab on pile can be alternative to solve this problem.

SUMMARY

1. Based on regional geology in project data has a hydrogeology property as follows:
   - Ac (Cs) clay, sandy clay
   - R (ct) (ms) silt-silt clay
   - CG, SS conglomerates & sandstones tuff
2. Based on data collection the soil layer properties as follows:
   - Clay (soft soil)
   - Sandy Silt (Very stiff soil)
   - Gravel (Hard soil)
3. Based on site survey, the gradient slope applied on project location is 1:2 (V:H) max height 5m.
4. Based on CPT, mostly soil layer classified as sandy soil. This need to be confirm with sieve grain analysis and hydrometer analysis test. If the low bearing capacity only because of loose sand, so there will be no expansive and high compressible issue.

5. Since the site project location mostly sandy soil and have high GWL, the study about liquefaction analysis is necessary. SPT test is needed for further analysis.
6. For shallow and thin soft layer, the treatment of these layers is often conducted with a simple subsurface water drainage method. When constructing a very important structure, it is relatively easy to excavate and remove the problem soft layer. Thus, the excavation replacement method is also often used.
7. For thick soft layer, the subsurface water drainage method is used in combination with other methods according to the purpose of application or the soil.
8. For each infrastructure will have a varies option treatment based on condition

   Road: if classified as medium soil no need improvement. If soft soil thickness less than 2 so need replacement or soil mixing method. For soil thickness more than 2m need consolidation acceleration using PVD or slab on pile

   Slope : need drainage control and compaction. If slope steeper than 1:2,5 ratio need protection or reinforcement

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