JURNAL ONLINE SKRIPSI
MANAJEMEN REKAYASA KONSTRUKSI POLINEMA

EVALUATION COEFFICIENT OF CONSOLIDATION IN PVD AND SOIL PRELOADING IN CLUSTER F SUMMARECON BANDUNG

Zhafira Anggraeni Nurwanda[1], Moch Sholeh[2]

Mahasiswa Manajemen Rekayasa Konstruksi, Dosen Jurusan Teknik Sipil, Politeknik Negeri Malang

zhafiraangnur@gmail.ac.id, moch.sholeh@polinema.ac.id

ABSTRACT

This thesis evaluates the horizontal coefficient of consolidation (Ch) in a soft soil improvement project using Prefabricated Vertical Drains (PVD) and preloading techniques. The study was conducted at Cluster F, Summarecon Bandung, where the subsurface is dominated by soft clay characterized by high compressibility and low shear strength. These conditions require proper soil improvement to ensure safe and stable construction. The main objective of this study is to compare the assumed Ch value used during the design phase with the actual Ch value obtained from field monitoring data. The assumed Ch was determined from laboratory consolidation test results and applied in the initial settlement analysis using Barron's radial consolidation theory. During the preloading process, settlement plate data was collected over time. The actual Ch was then calculated through back-analysis using the Asaoka method, based on the observed settlement behavior. The analysis revealed a significant discrepancy between the assumed and actual Ch values. The assumed Ch was 2.93 × 10⁻⁴ m²/s, while the actual Ch obtained from field data was 1.60 × 10⁻⁴ m²/s, resulting in a deviation of -45%. This finding suggests that the design Ch value was too optimistic. A revised consolidation analysis using the actual Ch value produced more accurate and realistic settlement predictions. The results emphasize the importance of validating design parameters using actual field data. Relying solely on laboratory values can result in misleading predictions and design inefficiencies. Back-calculating Ch using settlement monitoring provides better insight into real soil behavior and allows for improved decision-making in future soft soil improvement projects. This approach helps minimize construction risks and ensures more effective ground improvement designs.

Keywords *: horizontal coefficient of consolidation (C_h); back-calculation; prefabricated vertical drain (PVD); settlement monitoring; preloading*

1. BACKGROUND

The foundation is a critical component in any construction project, as it transfers structural loads to the ground and ensures stability. Its performance is highly influenced by subsurface soil conditions. Soft clay soils, in particular, pose major challenges due to their low bearing capacity, high compressibility, and tendency to settle excessively under load. Without proper treatment, these conditions can lead to uneven settlement or structural failure.

To improve soft clay, consolidation is used to expel pore water and strengthen the soil. However, natural consolidation is slow, often taking years. To accelerate the process, Prefabricated Vertical Drains (PVD) and Prefabricated Horizontal Drains (PHD) are installed to shorten drainage paths and speed up water dissipation. The effectiveness of this method largely depends on the horizontal coefficient of consolidation (C_h), which governs the lateral flow of water toward the drains.

Inaccurate estimation of C_h can lead to significant discrepancies between predicted and actual settlement. This issue arose in a soil improvement project at Cluster F, Summarecon Bandung, conducted by PT Teknindo Geosistem Unggul. Although PVD and PHD were used, the observed settlement differed from the predictions, likely due to incorrect assumptions about C_h.

This study aims to evaluate the assumed C_h value by comparing it with the actual C_h derived from settlement plate monitoring. The analysis includes calculations using both design and back-calculated C_h values, followed by a revised consolidation plan based on actual site conditions.

2. METHOD

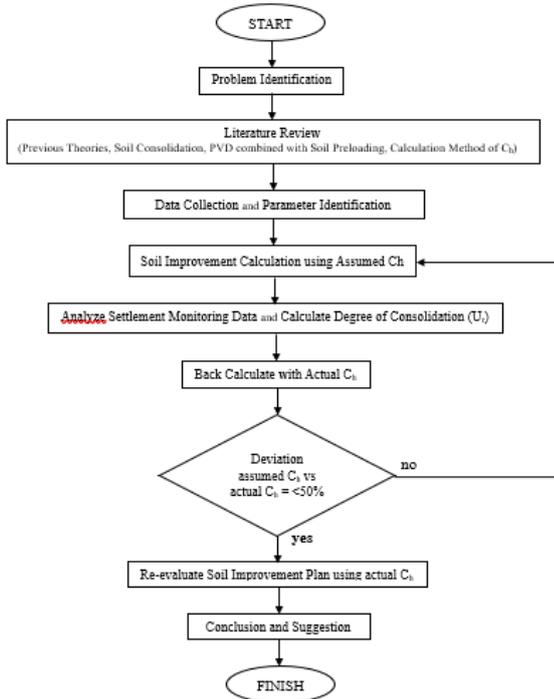The following is the workflow diagram for research:

Figure 1: Flow Chart of the Research

3. RESULT AND DISCUSSION

Here is the analysis of the research:

3.1 Soil Investigation Data Analysis

Based on the soil investigation data obtained from the area, the relevant parameters need to be determined to support the calculation of soil preloading. From the soil investigation, $C_{h\ layer\ 1} = 1{,}91$ cm²/s and $C_{h\ layer\ 2} = 4{,}02$ cm²/s. From C_v value of each layer, $C_{h\ combi}$ also can be determined. $C_{h\ combi} = 2{,}93 \times 10^{-4}$ m²/s.
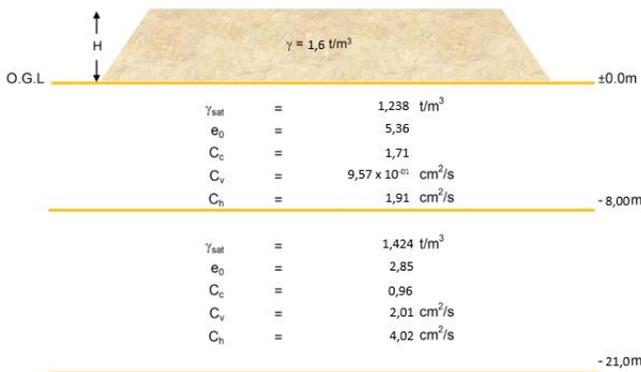

Figure 2: Soil Profile Parameters each Layer

3.2 Preloading Height Calculation

From Figure 3.1, consolidation settlement can be calculated to determine the load of the preloading. The calculation were carried out using q values of 1, 3, 5, 7, 10, 15, and 20 t/m². The following are the results for each q value.

Table 1: Soil Preloading Height Calculation

Load (q) (t/m²)	Soil Settlement Sc (m)	Initial Preloading Height (m)	Final Preloading Height (m)
1	0,119	1	0,881
3	0,672	2	1,328
5	1,398	4	2,602
7	1,941	6	4,059
10	2,569	8	5,431
15	3,337	10	6,663
20	3,912	12	8,088

With the data obtained from the calculation, q determined as 5 t/m². And desired preloading load can be estimated.

Table 2: Desired Preloading Load Estimation

NO	DETAILS	UNIT	VALUE	ELEVATION
A	**DATA INPUT**			
1	Original elevation of soil	m	660,0	660,0
2	γ soil preloading (A)	ton/m³	1,600	-
3	Service load/House load (B)	ton/m²	1,600	-
4	The service load is assumed to be equivalent to 1,0m soil embankment with a unit weight of (g) 1,6 ton/m³ (C)	m	1,000	662,5
5	Elevation Design (D)	m	1,500	661,5
6	Final height of soil preloading (E)	m	2,500	662,5
B	**DATA OUTPUT**			
1	Height application for soil preloading (graph) (F)	m	5,000	665,0
2	Total settlement investigation (graph) (G)	m	2,500	-
3	Consolidation settlement at 90% (H)	m	2,250	-
4	Consolidation settlement at 60% (H)	m	1,500	-

3.3 PVD Design

For the pvd design is using triangular pattern and spacing 1,3 m. From this information, the duration of consolidation using PVD and soil preloading can be determined. The consolidation will be last for 7,25 months or 7 months and 1 week.
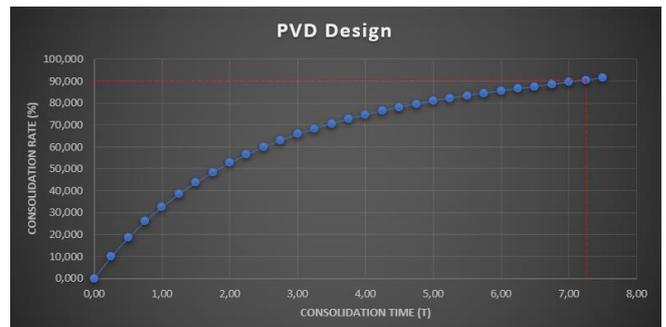
Figure 2: PVD Design Graph

3.4 Estimated Pore Water Discharge

From the previous calculation, Discharge can be calculated.

$Q_{60\%} = 2,698 \times 10^{-7}$ m³/s

$Q_{90\%} = 1,535 \times 10^{-7}$ m³/s

For every point of PVD,

$Q_{each point} = 3,948 \times 10^{-7}$ m³/s

1 PHD = 19 points of PVD = $0,075 \times 10^{-4}$ m³/s

Safety Factor = 32

3.5 Settlement Analysis

From the settlement plate monitoring data, degree of consolidation can be obtained for each settlement plate point using Asaoka method.
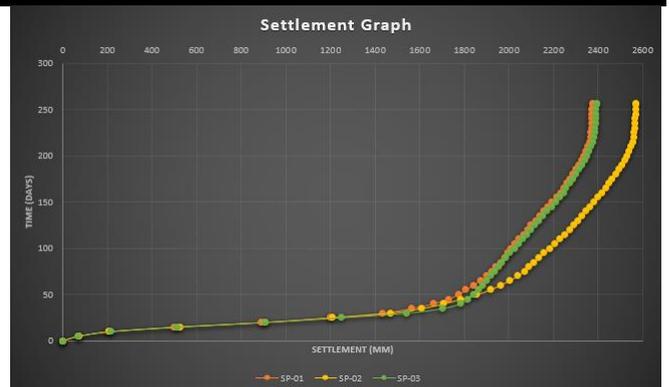

Figure 3: Settlement Analysis Graph

Table 3: Degree of Consolidation Summary

Plate no. SP	Embankment Height	Total duration of Preloading	Observed Settlement	Asaoka method EOP	Achieved Degree of Consolidation (U)
	m	days	mm	mm	%
SP-01	0	33	2376	2342,864	101,414
SP-02	0	35	2569	2550,632	100,720
SP-03	0	35	2393	2350,145	101,823
Average Degree of Consolidation Achieved = U =					101,319

Table 4: Degree of Consolidation Summary

NO	SP CODE	LOCATION	MONITORING DURATION	EMBANKMENT AGE AT TOP PRELOAD	SOIL ELEVATION	EMBANKMENT ELEVATION	EMBANKMENT THICKNESS	TOTAL SETTLEMENT	AVERAGE SETTLEMENT OVER THE LAST 5 DAYS
				(m)	(m)	(m)	(m)	(mm)	(mm)
A	B	C	D	E	F	G	H	I	J
1	SP-01	AREA CLUSTER F	257	33	659,354	667,953	8,599	-2376	0,4
2	SP-02	AREA CLUSTER F	257	35	659,289	668,162	8,873	-2569	0,2
3	SP-03	AREA CLUSTER F	257	35	659,173	667,900	8,727	-2393	0,2

3.6 Back Calculation C_h

From the settlement analysis, back calculation can be done and the actual C_h.

Table 5: Back Calculation C_h

Back Calculation of C_r from Asaoka Line's Scope									
Vertical drainage distance, H =					21	m			
PVD Spacing, S =					1,3	m			
PVD Pattern (1=Triangular; 2=Square) =					1				
PVD influence diameter, D =					1,365	m			
Equivalent PVD diameter, d =					0,066	m			
Drain Spacing Factor, F_n = In (D/d) – ¾ =					2,276				
Known Vertical Coefficient of Consolidation =					8,002E-05	m²/s		2,524E+03	m²/year
Settlemet Plate No.	Asaoka Line Scope	Asaoka Start Time	Asaoka Time Interval	$\dfrac{\pi^2 C_v}{8H^2}$	$\dfrac{-In\beta}{\delta t}$	$\dfrac{8C_r}{D^2 F_n}$	Back Calculation	Time to EOP U = 90%	Estimated Additional Time Required
SP	β		δt				C_r	Th = 0,557359	
		days	days				m²/s	days	days	date
SP-01	0,890	15	5	2,23869E-07	2,33E-02	3,03E-04	1,605E-04	213	Achieved	31-May-20
SP-02	0,896	15	5	2,23869E-07	2,19E-02	3,01E-04	1,598E-04	214	Achieved	31-May-20
SP-03	0,885	15	5	2,23869E-07	2,45E-02	3,01E-04	1,598E-04	214	Achieved	31-May-20
Average C_r =							1,60E-04		

From the calculation, the actual C_h obtained. Actual C_h is $1,60 \times 10^{-4}$ m²/s.

3.7 Deviation Calculation

$C_{h\ assumed}$ = $2,93 \times 10^{-4}$ m²/s

$C_{h\ actual}$ = $1,60 \times 10^{-4}$ m²/s

$$Deviation\ (\%) = \frac{C_{h\ assumed} - C_{h\ actual}}{C_{h\ assumed}} \times 100\%$$

$$Deviation\ (\%) = \frac{1,60 \times 10^{-4} - 2,93 \times 10^{-4}}{2,93 \times 10^{-4}} \times 100\% = -45\%$$

The deviation is -45%.

3.8 Redesign with Actual C_h

With the actual $C_h = 1,60 \times 10^{-4}\ m^2/s$, the redesign should be done. The new consolidation will be last for 3,6 months.
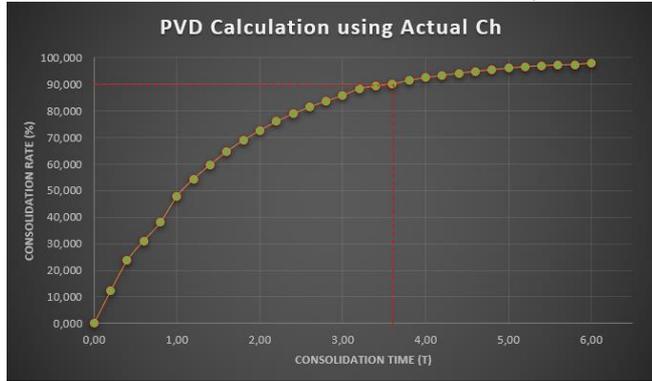

Figure 4: PVD Design Graph with Actual C_h

From the calculation, the pore water discharge can be obtained.

$Q_{60\%} = 4,947 \times 10^{-7}\ m^3/s$

$Q_{90\%} = 3,092 \times 10^{-7}\ m^3/s$

For every point of PVD,

$Q_{each\ point} = 7,239 \times 10^{-7}\ m^3/s$

1 PHD = 19 points of PVD = $0,137 \times 10^{-4}\ m^3/s$

Safety Factor = 18

Table 6: Soil Investigation Data on Borehole-01

Borehole	Depth (m)	Soil Classification	Soil Consolidation Test			Test Volume			Atterberg Limit		
			e_0	C_v (cm²/s)	C_c	γ_{sat}	W_c	G_s	LL	PL	PI
BH-01	1,0 – 1,5	CH	1,19	6,53E+00	0,252	16,39	42,64	2,56	89,00	36,00	53,00
	4,0 – 4,5	CH	3,49	3,66E+00	2,063	12,28	125,14	2,50	138,00	51,00	87,00
	7,0 – 7,5	CH	5,36	9,57E-01	1,712	11,90	212,20	2,47	219,00	54,00	165,00
	11,5 – 12,0	CH	2,68	3,07E+00	1,365	13,87	99,12	2,61	118,00	45,00	73,00
	19,0 – 19,5	CH	7,44	1,40E+00	2,621	10,79	267,87	2,53	154,00	56,00	98,00
	22,0 – 22,5	CH	2,05	2,05E+00	0,336	14,40	70,39	2,62	112,00	43,00	69,00
	26,5 – 27,0	-	0,84	6,58E+00	0,127	18,29	28,08	2,67	-	-	-
	29,5 – 30,0	CH	4,89	2,61E+00	2,419	11,71	175,40	2,55	196,00	61,00	134,00
	41,5 – 42,0	CH	3,64	4,62E+00	1,316	12,07	120,19	2,59	111,00	41,00	70,00
	44,5 – 45,0	CH	4,50	1,82E+00	1,560	12,08	168,77	2,52	174,00	56,00	118,00
	47,5 – 48,0	CH	1,27	3,57E+00	0,221	16,40	45,05	2,62	82,00	34,00	49,00
	52,0 – 52,5	CH	1,36	2,41E+00	0,263	16,16	47,29	2,64	97,00	39,00	59,00

Table 7: Soil Investigation Data on Borehole-02

Borehole	Depth (m)	Soil Classification	Soil Consolidation Test			Test Volume			Atterberg Limit		
			e_0	C_v (cm²/s)	C_c	γ_{sat}	W_c	G_s	e_0	C_v (cm²/s)	C_c
BH-02	1,0 - 1,5	CH	1,32	3,07E+00	0,283	15,85	47,00	2,55	98,00	35,00	63,00
	4,0 - 4,5	CH	4,60	4,56E+00	3,463	11,42	153,07	2,58	120,00	36,00	84,00
	11,5 - 12,0	-	1,44	3,83E+00	0,488	16,19	46,25	2,75	-	-	-
	13,0 - 13,5	CH	3,20	9,76E-01	1,287	13,54	118,87	2,65	113,00	34,00	79,00
	16,0 - 16,5	CH	2,85	2,01E+00	0,958	13,95	109,22	2,61	184,00	44,00	140,00
	20,5 - 21,0	CH	1,20	2,19E+00	0,752	16,26	40,81	2,59	171,00	45,00	126,00
	23,5 - 24,0	-	1,14	6,46E+00	0,248	16,00	28,24	2,73	-	-	-
	26,5 - 27,0	-	1,38	6,86E+00	0,241	17,50	56,82	2,71	-	-	-
	32,5 - 33,0	-	0,63	6,27E+00	0,680	19,81	22,28	2,69	-	-	-
	41,5 - 42,0	-	0,90	6,67E+00	0,133	17,83	26,22	2,74	-	-	-
	44,5 - 45,0	CH	4,34	3,98E+00	0,269	11,50	144,28	2,56	228,00	34,00	194,00
	46,0 - 46,5	CH	1,24	3,72E+00	0,292	16,74	46,86	2,60	119,00	44,00	75,00

Figure 5: PVD Layout Plan
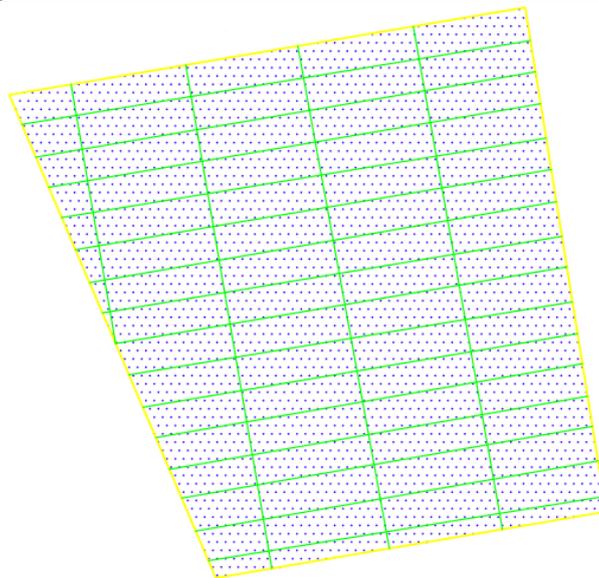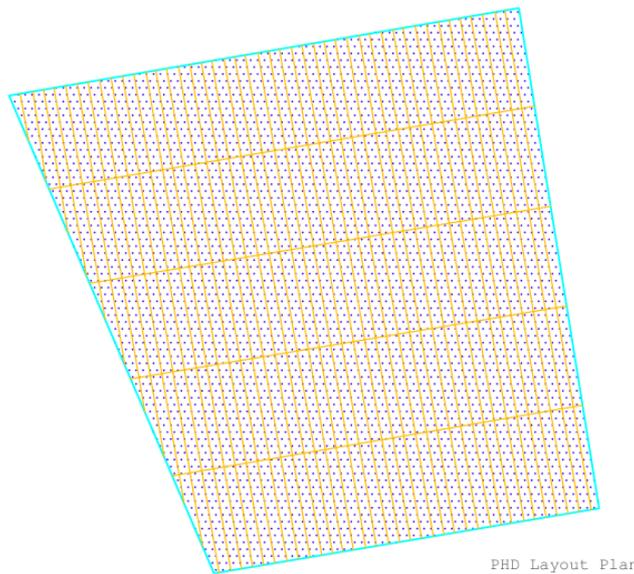

PHD Layout Plan

Figure 6: PHD Layout Plan

4. CONCLUSION

This research focused on obtaining and comparing the horizontal coefficient of consolidation (C_h) from initial soil data and field monitoring results, in order to improve the calculation of consolidation settlement using Prefabricated Vertical Drain (PVD). Here is the conclusion obtain from the problem statement:

1) How different is the C_h value obtained from initial design assumptions compared to the Ch value back-calculated from field settlement monitoring?

The initial design used a consolidation coefficient (Ch) of 2.93×10^{-4} m²/day, while field monitoring showed a lower value of 1.60×10^{-4} m²/day, indicating a -45% deviation. Although a higher Ch typically suggests

faster consolidation, the estimated time based on the assumed Ch was longer than that from the actual Ch. This discrepancy may result from conservative assumptions in the design model. The findings emphasize the importance of validating design parameters with field data, as actual conditions may lead to more efficient consolidation than predicted.

2) What are the possible reasons for the discrepancy between theoretical predictions and actual settlement outcomes in the Cluster F, Summarecon Bandung project?

Several factors could contribute to the observed discrepancy, including soil disturbance during Prefabricated Vertical Drain (PVD) installation (smear

effects), variability in natural soil conditions, and limitations in lab-based Ch estimation methods that may not fully capture in-situ consolidation behavior.

3) How can the back-calculated Ch from field monitoring data be used to enhance future soil improvement planning and design accuracy?

The back-calculated Ch serves as a more realistic representation of site conditions and can be used to recalibrate design parameters for future projects. By integrating field-monitored Ch values, future soil improvement plans can achieve better prediction of settlement rates, more accurate construction timelines, and improved safety margins, reducing the risk of post-construction settlement.

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