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Comparison Of The Asaoka And Hyperbolic Methods In Coastal Reclamation Settlement Prediction. "A Case Study Of The Patimban Port Project"

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Abstract

The land subsidence that occurred in the Patimban Port project was caused by the consolidation process, so it was necessary to improve the subgrade to ensure the safety of the main structure in the future and prevent premature damage such as cracks or even building collapse due to unstable soil. The soil improvement was carried out by applying a preloading load in on top of subgrade to accelerate the consolidation process. The purpose of this study was to determine the comparison of the final settlement using the asaoka and hyperbolic methods. The research method used a quantitative approach with observation in the field through settlement plate installed. Based on the results, of the 8 settlement pipes installed, the largest actual settlement occurred in settlement plate 02, which reached 92 mm within a period of 2 months. Based on the Asaoka method analysis, all settlement pipes have reached the consolidation settlement target of over 90%, so the settlement is considered stable. However, there is a difference with the analysis using the Hyperbolic method, where two pipes have not yet reached the 90% consolidation settlement target on settlement pipe SP 01, which has only reached 66.0%, and SP 02, which has only reached 80.9%. A comparison of the two methods shows that the Asaoka method is stable and simple in determining the final settlement at the end of the construction process, whereas the Hyperbolic method is more responsive to changes in instantaneous data.

Keywords: *Settlement Plate, Preloading, Asaoka Method, Hyperbolic Method*

INTRODUCTION

The Patimban Port project is a coastal reclamation project that uses fill as the foundation for the main structure. The use of fill for reclamation projects is typically unstable due to settlement caused by soil consolidation[1], the process of pore water drainage takes a considerable amount of time when occurring naturally. Consolidation is the process by which the volume of saturated soil decreases as pore water is forced out under static loads over a certain period of time. The soil consolidation process significantly impacts the sustainability of reclamation projects, as it can lead to soil settlement. Soft soils can be problematic in construction projects due to their low bearing capacity[2], if this is not addressed, it may result in damage to the main structural elements of the construction, such as cracking, differences in height at concrete joints, or even severe damage leading to the collapse of the building[3]. Therefore, a soil improvement method is employed by applying a preloading load at a specific height above the construction area of the subgrade. Preloading is a method that involves placing temporary loads on top of the area being repaired, with the aim of accelerating the consolidation process[4]. The primary objective is to accelerate the soil consolidation process before the main structure is built[5]. The success of implementing the preloading method is highly dependent on accurate and continuous field monitoring and control. The completion time for the preloading period[6] can be determined after reviewing evaluation data on the rate and magnitude of elevation settlement via the settlement plates that have been installed. The method of collecting field research data involves conducting direct inspections at the sites in question to obtain primary and secondary data. Previous research has indicated that analysing the settlement of embankment projects using the Asaoka method yields a more accurate final settlement value than other methods[7]. However, in previous studies, few have compared the two methods to analyse accuracy levels under identical soil conditions. Although qualitative analytical methods have been widely used in reclamation planning, their predictions often differ from actual field conditions due to variations in soft soil types and interactions with preloading systems. Observational methods, such as the Asaoka and Hyperbolic methods, offer effective alternatives for estimating final settlement based on settlement plate monitoring data. Therefore, this study compares the two methods to determine which is more representative in predicting ground settlement under specific conditions and to analyse the final settlement period using the hyperbolic method. The aim of this study is to compare which method more closely approximates actual ground subsidence in the field, so that it can be used as a basis for further analysis. The originality of this study resides in its comparative evaluation of their performance using real-time field instrument monitoring data from a strategic national infrastructure project. The results of this research are expected not only to enrich the literature on applied geotechnical engineering but also to provide practical guidance for practitioners in determining the optimal settlement monitoring.

METHODOLOGY

This research uses a quantitative approach, collecting data on actual settlement from settlement plate installed on 8 pipes as the basis for analyzing final settlement using the Asaoka and hyperbolic methods[8]. In which the measurement results are tied to benchmark points as a reference for base elevation to determine the settlement elevation of the installed settlement plate pipes. Meanwhile, the settlement analysis methods the Asaoka and hyperbolic methods were used to determine the total settlement when the degree of consolidation reached 90%. The following is a flowchart of the research process.

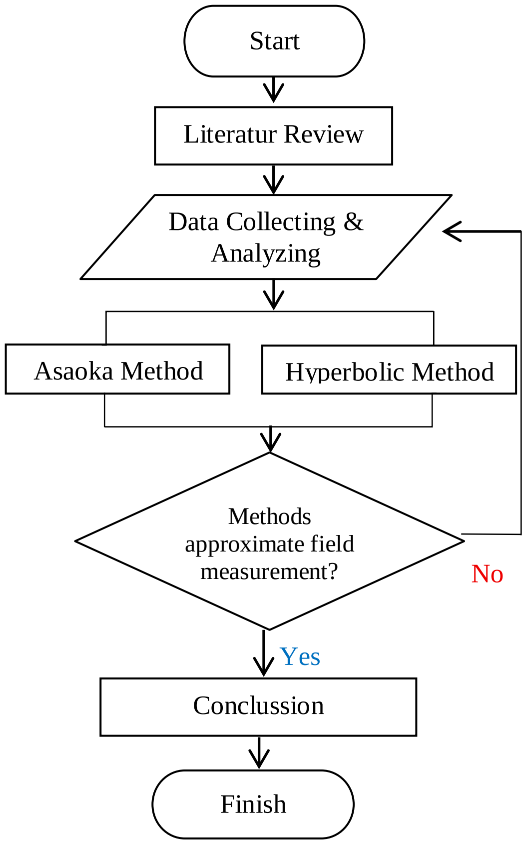

Figure 1. Research Flow Diagram

Specimen Details

When collecting data on final settlement, it is necessary to monitor actual settlement in the field using settlement pipes installed at eight points within the reclamation area of Patimban Port, Package 6 such as maps below.

Figure 3. Research Location Maps

The settlement pipe is made of steel, with a diameter of 3 inches and a length of 4 metres, connected to a plate measuring 1.2 m². The pipe is 5 mm thick and the plate is 5 mm thick. The settlement pipe joints are fully welded to ensure the joints remain strong during installation. In addition, to protect the settlement plate pipe, a protective layer is installed by fitting a PVC pipe inside the steel pipe to act as a protective cover.

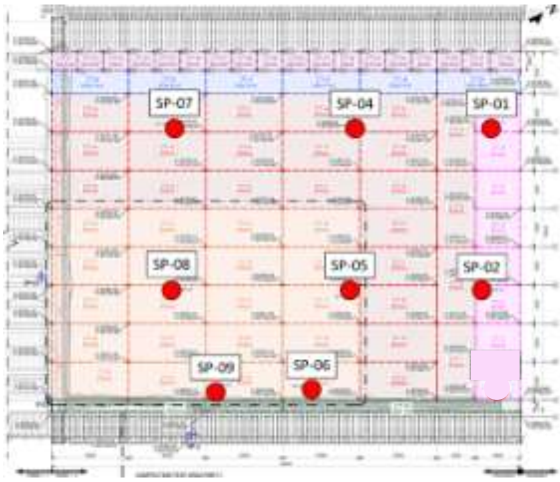

Figure 2. Layout of The Settlement Plate

In addition, to accelerate the soil consolidation process, a preloading method is employed, with loads applied to the settlement plates that have been installed[9], as shown in the following figure, so that consolidation can be achieved more quickly. The position of settlement determined by the following coordinates below.

Table 1. Coordinate Of Settlement Plate

Code	X Coordinate	Y Coordinate
SP-01	821891.628	9311675.534
SP-02	822080.408	9311580.002
SP-04	821817.960	9311513.965
SP-05	822008.835	9311423.044
SP-06	822104.914	9311322.526
SP-07	821721.773	9311302.949
SP-08	821913.069	9311212.998
SP-09	822057.124	9311210.464

A preload of 1.4 metres was applied above the sub-base using sandy soil with a sand content of 83.38%, fine aggregate of 4.46% and gravel aggregate of 12.15% and the qualified is sand material[10] with the calculate of preloading system.

Table 2. Weight of Preloading System

Preloading Location	Materials	Weight (Ton)
Sp 01	Sand	4.900 Ton
Sp 02	Sand	7.864 Ton
Sp 04	Sand	6.336 Ton
Sp 05	Sand	7.899 Ton
Sp 07	Sand	7.695 Ton
Sp 08	Sand	9.622 Ton

The use of sandy soil facilitates compaction and, due to its high porosity, accelerates the drainage of pore water resulting from the compaction process.
This preloading was carried out using sandy soil to a height of 1.4 metres above the base fill. Settlement was recorded by monitoring the settlement plate using an auto-level waterpass with the open-polygon method, referencing a single benchmark point[11].

Collecting Data Methods

Data measurement was conducted directly starting on 01 December 2025 until 31 January 2026 at the Patimban Port Package 6 project site by measuring ground settlement with the installed 8 pipe of settlement plate pipes, the readings were then entered into the monitoring data to serve as the basis for analyzing the predicted final settlement, supported by secondary documentation from PT. PP Persero Tbk. The following is data from the monitoring of the land subsidence that occurred.

Table 3. Monitoring Data of Settlement Plate

Date	SP 01 (m)	SP 02 (m)	SP 04 (m)	SP 05 (m)	SP 06 (m)	SP 07 (m)	SP 08 (m)	SP 09 (m)
01/12/2026	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
02/12/2026	0,000	0,000	-0,012	0,000	-0,012	0,000	0,000	0,012
03/12/2026	-0,002	-0,003	-0,003	-0,003	-0,002	0,000	-0,012	0,012
04/12/2026	-0,007	-0,007	-0,003	-0,007	-0,002	-0,012	-0,002	0,000
05/12/2026	-0,125	-0,122	-0,004	-0,007	-0,002	-0,012	-0,002	0,000
06/12/2026	-0,127	-0,124	-0,003	-0,008	-0,002	0,004	0,000	0,000
07/12/2026	-0,128	-0,128	-0,003	-0,009	-0,003	0,004	0,012	-0,012
08/12/2026	-0,129	-0,129	-0,004	-0,121	-0,003	0,003	-0,012	-0,012
09/12/2026	-0,023	-0,022	-0,006	-0,123	-0,012	0,004	0,000	0,012
10/12/2026	-0,023	-0,129	-0,003	-0,123	-0,004	0,004	0,002	0,000
11/12/2026	-0,025	-0,022	-0,012	-0,125	-0,003	0,005	0,012	0,012
12/12/2026	-0,027	-0,024	-0,002	-0,126	-0,004	0,005	0,000	0,012
13/12/2026	-0,026	-0,024	-0,002	-0,126	-0,004	0,004	-0,003	0,012
14/12/2026	-0,026	-0,024	-0,003	-0,127	-0,005	0,003	-0,003	0,012
15/12/2026	-0,027	-0,025	-0,004	-0,127	-0,004	0,004	-0,004	0,012
16/12/2026	-0,027	-0,024	-0,004	-0,127	-0,006	0,004	-0,004	0,000
17/12/2026	-0,027	-0,024	-0,003	-0,126	-0,006	0,003	-0,004	-0,005
18/12/2026	-0,027	-0,024	-0,002	-0,128	-0,007	0,004	-0,004	-0,008
19/12/2026	-0,029	-0,025	-0,007	-0,129	-0,007	0,004	-0,004	-0,121
20/12/2026	-0,029	-0,026	-0,006	-0,129	-0,007	0,004	-0,004	-0,126
21/12/2026	-0,038	-0,036	-0,123	-0,028	-0,008	0,004	-0,004	-0,022
22/12/2026	-0,040	-0,043	-0,126	-0,035	-0,008	0,003	-0,004	-0,026
23/12/2026	-0,047	-0,051	-0,022	-0,043	-0,008	0,003	-0,006	-0,029
24/12/2026	-0,047	-0,052	-0,020	-0,043	-0,008	0,002	-0,007	-0,033
25/12/2026	-0,048	-0,053	-0,020	-0,047	-0,009	0,012	-0,007	-0,033
26/12/2026	-0,048	-0,054	-0,020	-0,047	-0,009	0,000	-0,007	-0,033
27/12/2026	-0,048	-0,054	-0,020	-0,047	-0,009	0,000	-0,007	-0,032
28/12/2026	-0,050	-0,055	-0,022	-0,047	-0,120	0,000	-0,007	-0,032
29/12/2026	-0,052	-0,058	-0,022	-0,048	-0,121	-0,012	-0,007	-0,031
30/12/2026	-0,052	-0,058	-0,022	-0,048	-0,123	-0,002	-0,007	-0,031
31/12/2026	-0,052	-0,058	-0,022	-0,048	-0,123	-0,002	-0,007	-0,031
01/01/2026	-0,053	-0,058	-0,024	-0,050	-0,014	-0,002	-0,009	-0,032
02/01/2026	-0,053	-0,061	-0,025	-0,052	-0,015	-0,003	-0,009	-0,033
03/01/2026	-0,056	-0,063	-0,027	-0,054	-0,015	-0,002	-0,011	-0,033
04/01/2026	-0,056	-0,063	-0,028	-0,054	-0,015	-0,002	-0,010	-0,033
05/01/2026	-0,055	-0,063	-0,029	-0,055	-0,015	-0,002	-0,010	-0,033
06/01/2026	-0,056	-0,064	-0,029	-0,055	-0,016	-0,002	-0,010	-0,033
07/01/2026	-0,057	-0,065	-0,029	-0,055	-0,017	-0,003	-0,010	-0,033
08/01/2026	-0,058	-0,069	-0,031	-0,058	-0,018	-0,004	-0,012	-0,033
09/01/2026	-0,060	-0,069	-0,033	-0,058	-0,018	-0,003	-0,012	-0,033
10/01/2026	-0,060	-0,069	-0,033	-0,059	-0,024	-0,003	-0,012	-0,035
11/01/2026	-0,060	-0,070	-0,034	-0,060	-0,027	-0,004	-0,013	-0,035
12/01/2026	-0,061	-0,073	-0,034	-0,061	-0,027	-0,004	-0,013	-0,035
13/01/2026	-0,062	-0,074	-0,036	-0,063	-0,032	-0,005	-0,013	-0,035

14/01/2026	-0,063	-0,076	-0,036	-0,064	-0,032	-0,006	-0,014	-0,035
15/01/2026	-0,063	-0,077	-0,037	-0,064	-0,030	-0,006	-0,014	-0,035
16/01/2026	-0,064	-0,079	-0,038	-0,064	-0,031	-0,007	-0,015	-0,036
17/01/2026	-0,064	-0,078	-0,037	-0,064	-0,031	-0,002	-0,014	-0,036
18/01/2026	-0,064	-0,080	-0,037	-0,064	-0,031	-0,002	-0,014	-0,036
19/01/2026	-0,063	-0,079	-0,037	-0,066	-0,031	-0,002	-0,013	-0,036
20/01/2026	-0,063	-0,079	-0,039	-0,066	-0,031	-0,004	-0,014	-0,037
21/01/2026	-0,063	-0,080	-0,039	-0,067	-0,038	-0,002	-0,013	-0,036
22/01/2026	-0,064	-0,084	-0,041	-0,070	-0,038	-0,002	-0,016	-0,036
23/01/2026	-0,065	-0,085	-0,042	-0,072	-0,045	-0,006	-0,018	-0,038
24/01/2026	-0,066	-0,087	-0,044	-0,073	-0,048	-0,006	-0,019	-0,038
25/01/2026	-0,067	-0,088	-0,045	-0,076	-0,052	-0,008	-0,021	-0,040
26/01/2026	-0,067	-0,088	-0,046	-0,076	-0,047	-0,006	-0,019	-0,038
27/01/2026	-0,068	-0,089	-0,046	-0,076	-0,049	-0,006	-0,019	-0,038
28/01/2026	-0,068	-0,089	-0,046	-0,076	-0,049	-0,006	-0,019	-0,038
29/01/2026	-0,066	-0,090	-0,045	-0,078	-0,051	-0,005	-0,020	-0,041
30/01/2026	-0,066	-0,090	-0,045	-0,077	-0,051	-0,005	-0,020	-0,038
31/01/2026	-0,066	-0,092	-0,044	-0,079	-0,057	-0,002	-0,020	-0,039

The following are the measurement steps carried out in the field:

- Install the survey instrument an auto-level at a point betwFeen the benchmark and the settlement plate pole to be measured.
- Then, aim the instrument at the backsight target on the survey marker installed above the benchmark, which serves as the reference for the initial measurement elevation.
- Measure the foresight target on the settlement plate post, which is then connected to subsequent posts using the open polygon method meaning the elevation measurements are tied to the benchmark point.

The measurement used open polygon methods because the point of settlement plate is longer distance. The survey measurement method typically used to collect elevation data is the pair measurement method. A leveling survey is used to determine the elevation difference between two or more related points. The keep the telescope axis horizontal. The component that ensures this horizontal alignment is the spirit level a tube filled with liquid containing a bubble.

In leveling surveys, precise positioning is required to sight the front and rear markers, with a maximum distance of 40 meters between the leveling instrument and the markers, a minimum center-line height of 0.3 meters, and a maximum round-trip error of 12 mm √D (where D is in kilometers). The waterpass measurement procedure is as follows:

- Two targets in the form of measuring markers are set up at the front and rear points.
- Set up the waterpass between the two targets.
- Aim at both measuring markers alternately and record the values for the upper, middle, and lower threads.
- Calculate the elevation difference and distance using the following formulas:
- Elevation difference = Back Elevation – Front Elevation
- Distance (m) = (Top Thread – Bottom Thread) × 100
- Calculate the tolerance using the formula 12 mm √D, where "D" is the total distance.

Analytical Methods

Before carrying out the final settlement analysis, daily pipe measurement data covering a two-month period is required. To facilitate the analysis of ground settlement using the Asaoka method and the hyperbolic method, the calculations are performed using Microsoft Excel. Data collection for pipe settlement monitoring is carried out in the morning to minimise measurement errors caused by heat haze, hot weather and strong

winds. The instrument used for data collection is an auto-levelling waterpass with an accuracy of 1 mm, enabling the production of more accurate ground settlement data.
Then from the monitoring data, the prediction of the final settlement was calculated using the Asaoka and hyperbolic observation methods, calculated the value of the degree of consolidation from each method[12]. The use of the Asaoka and hyperbolic methods can determine the extent to which the final estimated decline differs from the actual decline observed in the field, and whether there is a significant discrepancy or whether the estimate is close to the actual field conditions. The Asaoka method uses data parameters over a three-day period, whilst the hyperbolic method uses daily measurement data.
The Asaoka method[13] is the most widely used observational method for unidirectional consolidation, as it not only predicts the final settlement but also allows for the determination of more accurate consolidation parameters. Calculations using the Asaoka method can be performed using the following formula.

$$S_f = \frac{\beta}{(1-\alpha)} \tag{1}$$

Where Sf is the final decline, and α and β are the coefficients of the linear regression line. To determine the target final decline when the degree of consolidation reaches 90%, the following formula can be used.

$$St = Sf \times 0.9 \tag{2}$$

Where St is the final target for the decline at the specified consolidation level of 90%.

$$U90 = \frac{S}{Sf} \times 100\% \tag{3}$$

Where U_{90} is the actual percentage decrease when the degree of consolidation reaches 90%, S_0 is the actual of reduction, and Sf is the final reduction target.

The hyperbolic method[14], on the other hand, assumes that the relationship between time and land subsidence follows a hyperbolic curve. To obtain the final subsidence analysis results using the hyperbolic method, the following formula may be used.

$$Sf = S0 + \frac{1}{\beta} \tag{4}$$

Where Sf is the final decline. α and β is a linear regression line. To determine the extent of the decline when the degree of consolidation reaches 90%, the following formula can be used.

$$St = Sf \times 0.9 \tag{5}$$

Where St is the decrease over time t, and Sf is the decrease.

Where St is the final target for the decline at the specified consolidation level of 90%.

$$U90 = \frac{S}{Sf} \times 100\% \tag{6}$$

Where U_{90} is the actual percentage decrease when the degree of consolidation reaches 90%, S is the actual of reduction, and Sf is the final reduction target.

Calculation of The Settlement

Calculations for final settlement analysis using the Asaoka and Hyperbolic methods were carried out for each settlement pipe, comparing the settlement rates (1/t). Settlement pipe monitoring data was analysed to identify settlement patterns over time. Using this approach, the percentage of consolidation and stabilisation trends in the reclaimed area can be estimated based on the time required to reach final settlement[15]. The analysis requires actual settlement data over a specific period; in this case, settlement data covering a two-month period is used to obtain more accurate results. Below are the settlement data and the regression line for the actual field settlement.

Table 4. Regression Data and Regression Lines Using the Asoaka and Hyperbolic Methods

Code	Initial Settlement (S_0) (mm)	Actual Settlement Cut Off (S) (mm)	Asaoka Method			Hyperbolic Method		
			R^2	α	B	R^2	α	β
SP 01	-7	-66	0,980	0,888	-8,230	0,882	0,366	0,009
SP 02	-7	-92	0,831	0,830	-16,630	0,603	0,355	0,008
SP 04	-3	-44	0,956	0,859	-6,878	0,301	1,304	-0,021
SP 05	-7	-79	0,931	0,780	-16,211	0,901	1,118	-0,011
SP 06	-2	-57	0,975	1,069	-1,391	0,831	3,667	-0,060
SP 07	-1	-2	0,723	0,882	-0,321	0,637	2,508	0,449
SP 08	-2	-20	0,740	0,924	-1,251	0,509	2,731	0,046
SP 09	-11	-39	0,931	0,603	-14,453	0,926	0,716	0,022

Once the regression lines have been obtained, the final settlement value for each pipe is then determined using the Asaoka and hyperbolic methods to establish the end of the loading period[16]. Calculations using both methods are carried out in Microsoft Excel to plot the Asaoka and hyperbolic curves for determining the final settlement to determine which method is more effective and better reflects the actual decline in the field.

RESULT

Soil settlement occurring at the Patimban Port reclamation project, due to unstable soil, could cause structural damage in the future, such as cracks in the concrete or even the collapse of the main building. therefore, soil improvement is necessary. The method employed is the preloading method, which involves adding fill loads to accelerate the consolidation process so that it rapidly reaches 90%. Based on the results of the analysis using the Asaoka and hyperbolic methods, it is evident that the final settlement values obtained show a relatively similar trend, despite differences in values due to the analytical approaches and assumptions employed. The analysis indicates that settlement is achieved more rapidly using the Asaoka method than with the hyperbolic analysis method. The following are the conclusions of the analysis using the Asaoka and hyperbolic methods for each settlement pipe.

Results of the Asaoka Method Analysis

Based on calculations using the Asaoka method, the following are the predicted final settlements based on the presentation of monitoring data on the actual settlement of the pipe settlement plate every 3 days over a 60-day period. The hyperbolic method takes into account the predicted final settlement, the target final settlement, and the percentage of actual settlement, as shown in the following table.

Table 5. Calculation Result of Asaoka Methods Analysis

Settlement Plate	Final Settlement (Sf)(mm)	Target of Consolidation > 90% (St)(mm)	Precentage Of Actual Settlement (U_{90}) (%)
SP 01	-73,2	-65,9	90,2%
SP 02	-97,6	-87,9	92,2%
SP 04	-48,7	-43,9	92,3%
SP 05	-73,7	-66,3	104,5%
SP 06	-20,3	-18,3	251,5%
SP 07	-2,7	-2,4	184,2%
SP 08	-16,4	-14,8	121,8%

SP 09	-36,4	-32,7	104,5%

The analysis results show that the consolidation rate for all settlement plate pipes has exceeded 90%; therefore, it can be concluded that the final settlement analysis using the Asaoka method has been achieved to more than 90%.

Different from the Asaoka method, the hyperbolic method uses daily data over a 60-day period for the settlement of the settlement plate. The target final settlement, and the percentage of actual settlement, as shown in the following table.

Results of the Asaoka Method Analysis

Table 6. Calculation Result of Hyperbolic Methods Analysis

Settlement Plate	Final Settlement (Sf)(mm)	Target of Consolidation > 90% (St)(mm)	Precentage Of Actual Settlement (U_{90}) (%)
SP 01	-99,9	-89,9	66,0%
SP 02	-111,3	-100,2	80,9%
SP 04	-45,5	-40,9	99,0%
SP 05	-85,4	-76,9	90,1%
SP 06	-18,6	-16,7	274,5%
SP 07	-3,2	-2,9	154,9%
SP 08	-19,6	-17,6	102,3%
SP 09	-34,6	-31,1	109,9%

Comparison of Analysis Graph

A comparison between the predicted decline based on the Asaoka and hyperbolic methods and the actual decline can be plotted on a graph to make the data easier to read. The following graph compares the actual decline with the predicted final decline.

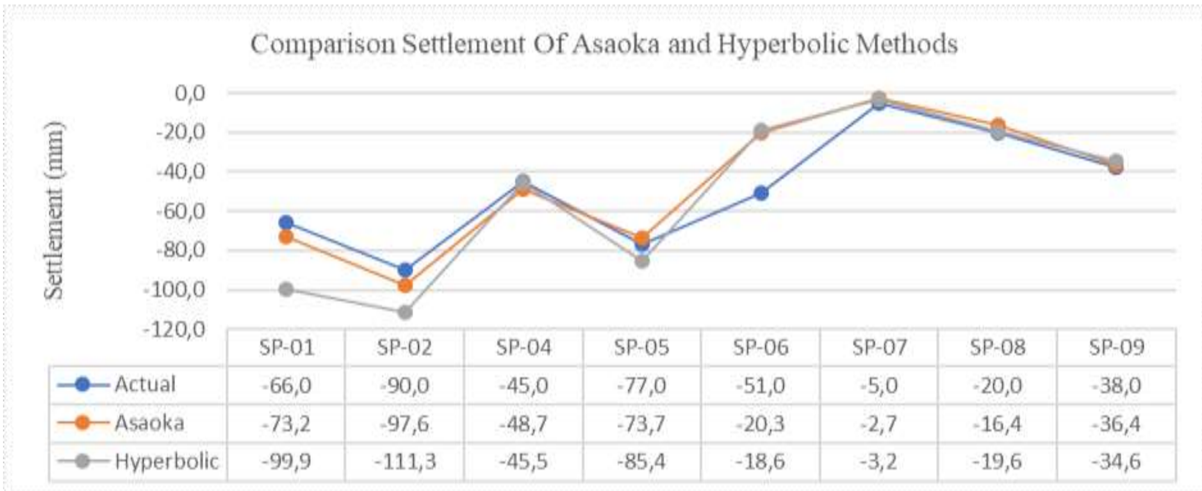

Figure 3. Graph of Comparison Settlement Asaoka and Hyperbolic Method

The comparison graph shows that the Asaoka analysis method provides a closer approximation to the actual settlement in the field compared to the hyperbolic method the largest deviation from the actual settlement 33.9 mm occurred at settlement pipes SP 01 and SP 02, with deviations of 21.3 mm and and 32.4 mm for SP 06. Therefore, a comparison of the two methods shows that the Asaoka method is more stable and simpler for determining final settlement as an initial evaluation of the construction process, whereas the hyperbolic method is more responsive to changes in time and settlement data. The Asaoka method tends to be used to determine final ground settlement because it yields a better approximation compared to the hyperbolic method conversely, the hyperbolic method can be used if the initial data already indicates a large proportion of the total settlement, so it would be less effective when used in the early phases to determine final settlement if data is limited.

DISCUSSION

Observations of settlement plate subsidence at the Patimban Port reclamation site, Package 6, show several significant differences in behavior between the Asaoka and hyperbolic methods in predicting final ground settlement. The Asaoka method tends to provide moderate estimates of final settlement and reaches a more rapid convergence once the degree of consolidation exceeds 90%. This is because the nature of the differential equation used in the Asaoka method is heavily influenced by observational data from the final phase of construction. Conversely, the hyperbolic method yields final settlement values that tend to be higher in the early phases of the construction project but stabilize as the time approaches infinity. These results are consistent with previous research by Tan[14], who stated that linear-based observational methods are highly dependent on the maturity of field observation data.

Based on the The Asaoka and hyperbolic methods of analysis were used to compare which approach more closely approximates the actual field settlement observed in the pipes. Based on the research conducted, the results of the analysis using the Asaoka method were closer to the actual settlement in the field because fewer variables were used for the analysis compared to the hyperbolic method. The significant deviation between the actual settlement and the hyperbolic method’s results indicates that the hyperbolic analysis method can be used to support the Asaoka analysis method in determining the final settlement. However, to support the settlement analysis using the Asaoka and hyperbolic methods, comparisons must still be made with several other observational methods, such as the use of piezometers to determine the pore water pressure, as well as with theoretical methods such as the Terzaghi method and the finite element method. Analysis of the settlement of pipes SP 01, SP 02 and SP 05 reveal a significant deviation between the hyperbolic method and the actual settlement. This occurs because the still-unstable ground settlement affects the cumulative settlement due to sub-optimal loading. Factors contributing to significant deviations in the results of hyperbolic method analyses compared to actual water levels may stem from fluctuating and unstable monitoring data, which can be influenced by measurement errors caused by weather conditions, mirages, wind speed, and even data reading errors. Therefore, to mitigate these measurement errors, measurements should ideally be taken in the morning or evening when the weather is not too hot.

CONCLUSSION

The methods selected for soil improvement in the Patimban Port reclamation project include the preloading method which involves adding fill material on top of the subgrade to accelerate soil consolidation and the installation of settlement pipes to monitor ground settlement. The settlement pipe data was used in analyses employing the Asaoka and hyperbolic methods to determine the final settlement. The results of these analyses were compared with actual settlement data, leading to the conclusion that the final settlement estimated using the Asaoka method more closely approximated the actual settlement observed in the field. However, the final settlement analysis using the hyperbolic method is also not too far off when compared to the actual settlement significant deviations from the hyperbolic method were observed only in a few settlement pipes, including SP 01 at 33.9 mm, SP 02 at 21.3 mm, and SP 06 at 32.4 mm. There is a discrepancy with the analysis using the hyperbolic method, as there are still two pipes that have not met the 90% consolidation settlement target: SP 01, which has only reached 66.0%, and SP 02, which has only reached 80.9%.

A comparison of the two methods shows that the Asaoka method is stable and simple in determining the final settlement of the construction process, whereas the hyperbolic method is more responsive to changes in instantaneous data. This is consistent with several previous studies indicating that the Asaoka method provides a more accurate estimate of actual settlement in the field. However, this study shows that the hyperbolic method can also be used as supporting data for settlement planning if the initial data already indicate a significant proportion of the total settlement. The analysis indicates that the significant deviation between the hyperbolic method and the actual settlement is due to the fact that the still-unstable ground settlement affects the cumulative settlement resulting from insufficient loading. The scope of this study is limited to field measurements of settlement data, excluding soil consolidation calculations using analytical and numerical methods such as Terzaghi and Plaxis.

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