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Geosynthetic Encased Column — An Alternative of Technical Solutions in Soft Soil Improvement in Viet Nam

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Abstract: Several technical solutions such as prefabricated vertical drain (PVD), surface and deep compaction, vacuum drainage, preloading as well as stone column with/without geotextile have been available in soft soil improvement for the construction of structures such as a heavy load building — power plant, storage tanks — petroleum refinery and so on. One of efficient solutions is to use geosynthetic encased columns transferring the loads of the large and rigid structures to stronger soil layers which reduce significantly not only settlement but also consolidation time. The paper presents a study on the use of geosynthetic encased column as an alternative solution for the land reclamation in cases of an extension of fabrication yard PTSC-MC and power plant Nhon Trach 2 (NT2) project. The proposed solution is also compared with other methods and the results are shown.

Key words: geosynthetic encased column, soft soil improvement, settlement

1. Introduction

Vietnam has a large coastline area exceeding more than 3260 kms and the Mekong Delta is known as an area of complex river systems and is one of the areas with very poor subsoil. Soft soil is one of the biggest challenges for engineers because of low bearing capacity, high compressibility, low permeability etc. A lot of industrial parks, petroleum refinery, thermal power plants and infrastructure are under construction in the Mekong Delta and along-shore. Many ground improvement techniques are considered and applied in practice in these areas. These methods include precast drainage (PVD), surface and deep compression, vacuum drainage, preloading, stone/sand columns etc. Ground improvement techniques must be carefully investigated to provide the required performance, constructability, time and overall cost. A further development of well-known stone/sand column foundations is the geotextile encased stone/sand column, in contrast to conventional column foundations, encased columns can also be used as a ground improvement and bearing system in very soft soils with undrained shear strength cu < 5 kN/m². This method is used successfully worldwide in Germany, the Netherlands, Sweden, Italy, Russia, Brazil and Poland[1] but has not been researched and applied in Vietnam. This paper summarizes the results settlement of prefabricated vertical drains combined with vacuum and surcharging for improvement of foundation clays at a land reclamation site in powerplant NT2 and settlement of stone/sand columns for ground improvement at fabrication yard of PTSC-MC. Analytical settlement calculation of the encased stone/sand columns were made and compared with those methods above.

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[1] Dimiter Alexiew, Marc Raithel.

2. Methodology

The principle treatment stratums almost are soft clay or marine clay with high water content, and large void ratio, which has low ground bearing capacity and need to be improved. According to experiences, this stratum present poor drainage property, long consolidation duration and time for strength gain. Particularly, because of low permeability, long consolidation time will be expected. To meet all these highly requirements, some ground improvement technologies are widely applied in Vietnam as below:

2.1 Vertical Drain + Surcharge and Vacuum Consolidation

Vertical drains are inserted into the soft soil layer and a sand blanket (draining layer) is installed above to convey water to the periphery of the treated zone before discharge in the environment.

Surcharge material is then added to accelerate the consolidation process, but care shall be taken to the raising speed of the height of the embankment. At various stages of the consolidation, the consolidation layer can only stand a certain load bearing capacity and the critical raising speed shall never be exceeded for risk of general slope failure.

Vacuum preloading consolidation method is applicable to soft soils, especially deep soft soils with a high demand of post-treatment settlement. In this method, vacuum efforts are used to complete the consolidation of most soil masses, controlling post-treatment settlement of deep soils.

Vacuum consolidation method is a proprietary system used for preloading and consolidation soft and very soft saturated impervious soils. The procedure consists of installing vertical and horizontal drainage under an airtight impervious membrane and evacuating the air below the membrane thus imposing an atmospheric pressure on the soft soil.

This vacuum loading process creates an accelerated isotropic consolidation in the soil mass in a relatively short time thereby eliminating the need for long-term and potentially unstable surcharge loads.

2.2 Stone/Sand Column

Stone/sand column acts both as a drainage column as well as an inclusion, with a modulus higher than the surrounding clay layer. The application of a surcharge is necessary to mobilize the friction and dissipate the pore pressure that is formed during the installation process. A layer of granular material of sufficient thickness is necessary between the underface of shallow foundation and the top of the inclusion, so that an arch can develop.

2.3 Encased Stone/Sand Column

To keep the drainage function, and to improve the stone columns as reinforcing elements, geosynthetics are used for column encasement. Encasing stone/sand column with geosynthetics was recommended to enhance the lateral column confinement which resulting on increasing load-bearing capacity. Additionally, encasement prevents the lateral squeezing of stones into the surrounding soil and vice versa.

3. Behaviors of Stone Column/Encased Stone Column, PVD/Encased Stone Column: A Case Study

3.1 Stone Column/Encased Stone Column at Fabrication Yard of PTSC-MC

3.1.1 Introduction of Project

The ground improvement works are to provide a steady platform to support the operation of SL6000 (Kobelco) and the CC2800 (Terex Demag) cranes on the designated routes, which can support up to 500 kPa of transient loads and long term primary settlement should be less than 250 mm. The soft clay is reinforced by the stone column with a diameter of 0.6 to 1.0 m and depth of treatment from 8 to 14 m. The stone columns are arranged in square grids with spacing from 2.2 to 2.4 m.

For settlement analysis, the loading is based on service ability stage which is 370 kPa at ground surface. The corresponding stress level at the top of soft clay layer, i.e., 125 kPa.

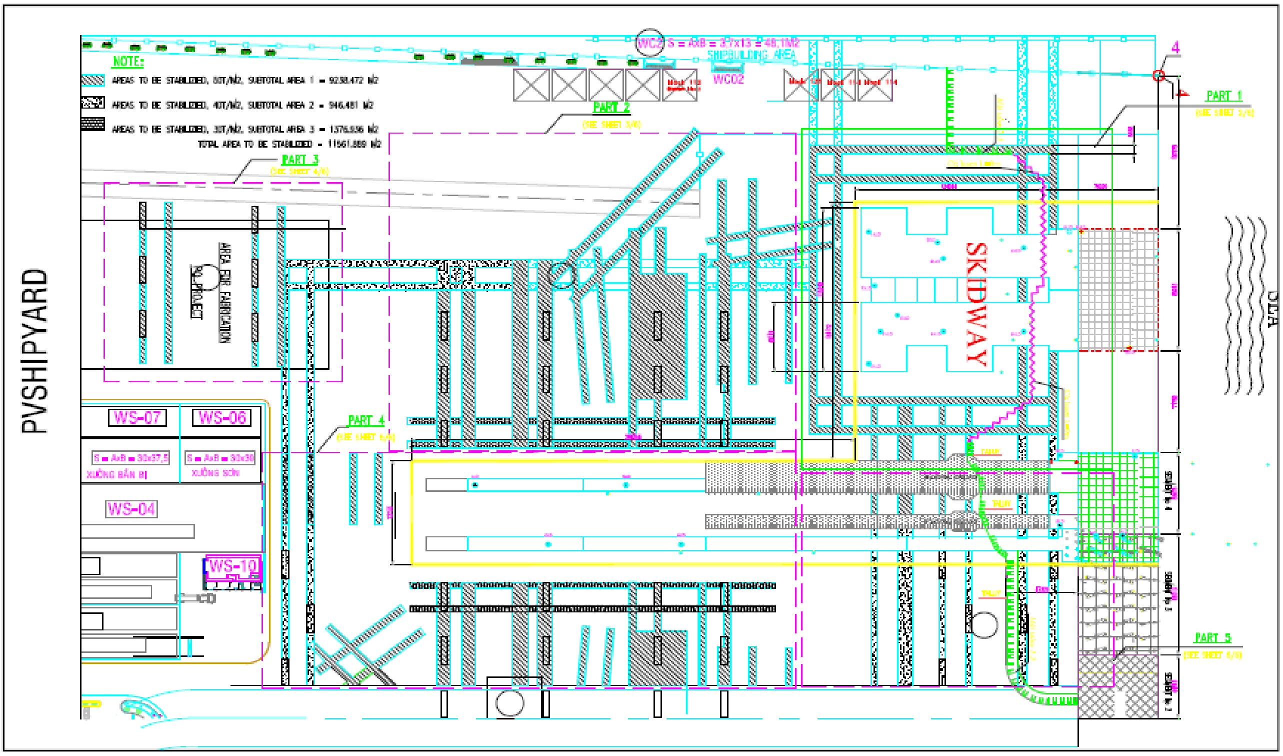

Fig. 1 Crane route path layout and load requirements.

3.1.2 Geological Condition

The soil layers and its parameters are shown in Table 1.

Table 1 Typical subsoil profile.

Depth (m)	Soil Type	φ_{orig}	c'_{orig} (kPa)	Ds_{orig} (kPa)
0 to 0.6	Gravel	40	0	40000
0.6 to 1.5	Sand	30	0	30000
1.5 to 2.5	Crust	0	35	5250
2.5 to 13.5	Soft Clay	0	20	3000

3.1.3 Settlement Prediction of Stone Column

The settlement was calculated based on elastic theory and Priebe's improvement factor [1]. The results are summarized as illustrated in Fig. 2: The settlement without treatment is 370 mm and with treatment is only 175 mm.

3.1.4 Settlement prediction of encased stone column

The settlement was estimated based on Raithel and Kempfert's analytical calculation model [2]. This calculation is conducted using data obtained from stone column and soil parameters above. Based on obtained data by using analytical calculation model of stone column configured using geosynthetic encasement J = 3000 kN/m.

The settlement with alternative encased stone column is 125 mm.

3.2 The Vacuum and Surcharge Preloading with PVD/Encased Stone Column at Nhon Trach 2

3.2.1 Introduction of Project

The project of NT2 is to construct a Combined Cycle Power Plant of 750 MW, comprising two gas turbines and one steam turbine, and is part of a Power generation complex, whose ultimate capacity is meant to be 2640 MW. According to the load conditions 10 T/m^2 (100 kPa), soft soil treatment should improve the ground bearing capacity, control the residual settlement is less than 10 cm in 10 years.

3.2.2 Geological Condition

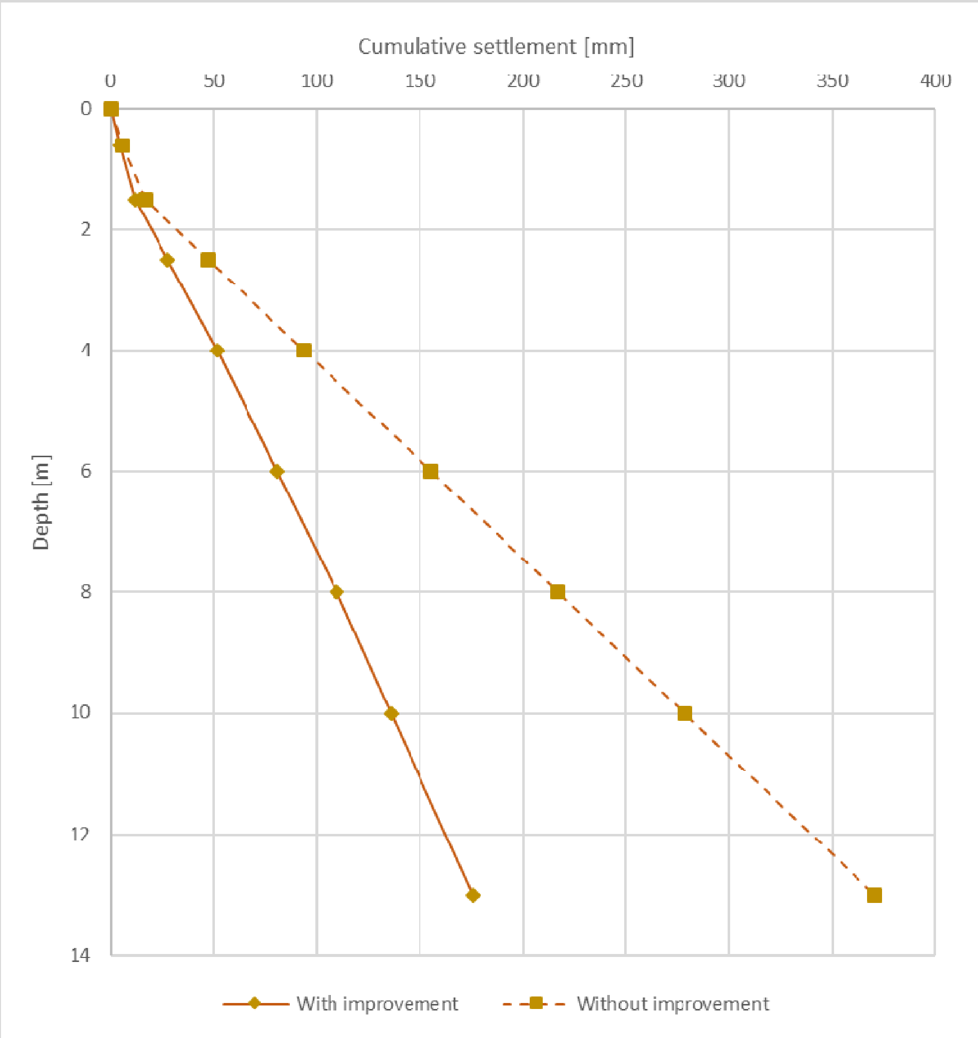

Fig. 2 Settlement with and without Stone Column.

The two soft clay layers of NT2 and calculation data are summarized as follow:

- Layer 2: Fat clay, the average thickness is about 7.7 m
- Layer 3: Silty clay, sometimes with fine sand, greenish grey, bluish grey, yellowish brown, stiff to very stiff. The thickness varies from 5.5 m to 9.4 m.

3.2.3 Settlement Prediction

The immediate settlement and primary consolidation settlement are calculated according to the Vietnam code of practice (TCXD 245:2000) [3]. The design of the settlement and consolidation program is made as per Fig. 5 & Table 2 and as follows:

- Calculation of the consolidation settlement that would occur under operation load if without any treatment during the considered period — immediate settlement as illustrated in Fig. 3;
- Considering the available preloading, calculation of the necessary consolidation ratio to be reached to catch up the primary consolidation settlement — sand backfilling and vacuum load as illustrated in Fig. 4;
- Calculations of the needed vertical drain mesh characteristics considering the available pre-consolidation period with result as per Fig. 6.

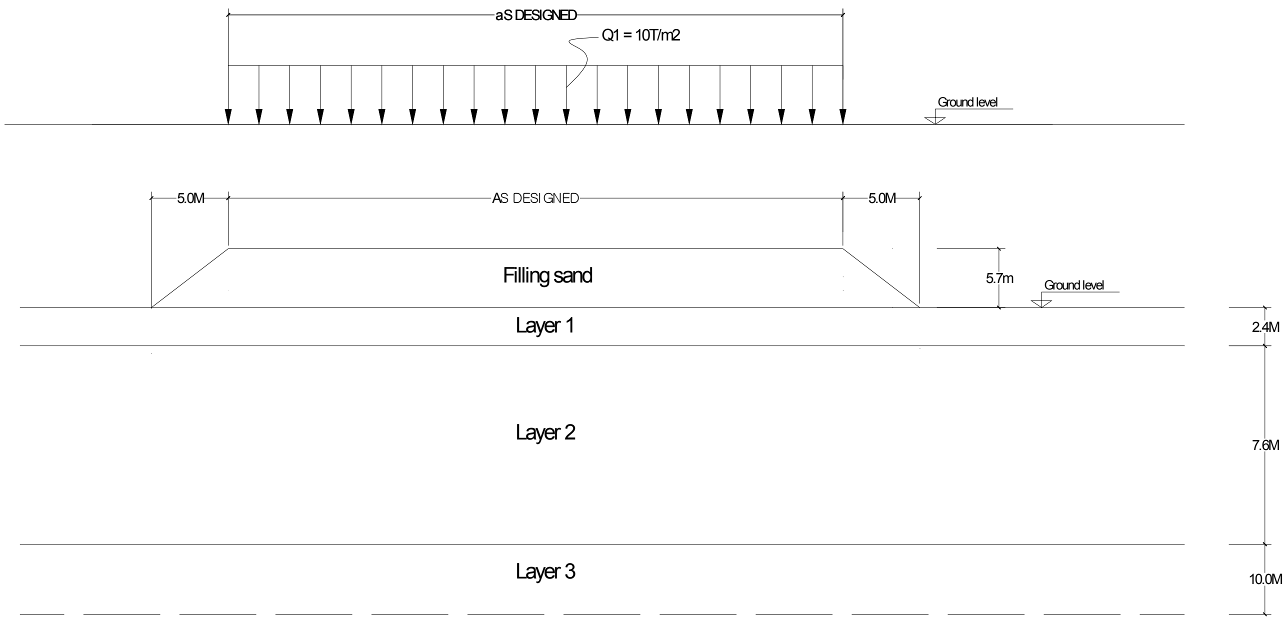

Fig. 3 The calculation model under operation load without treatment.

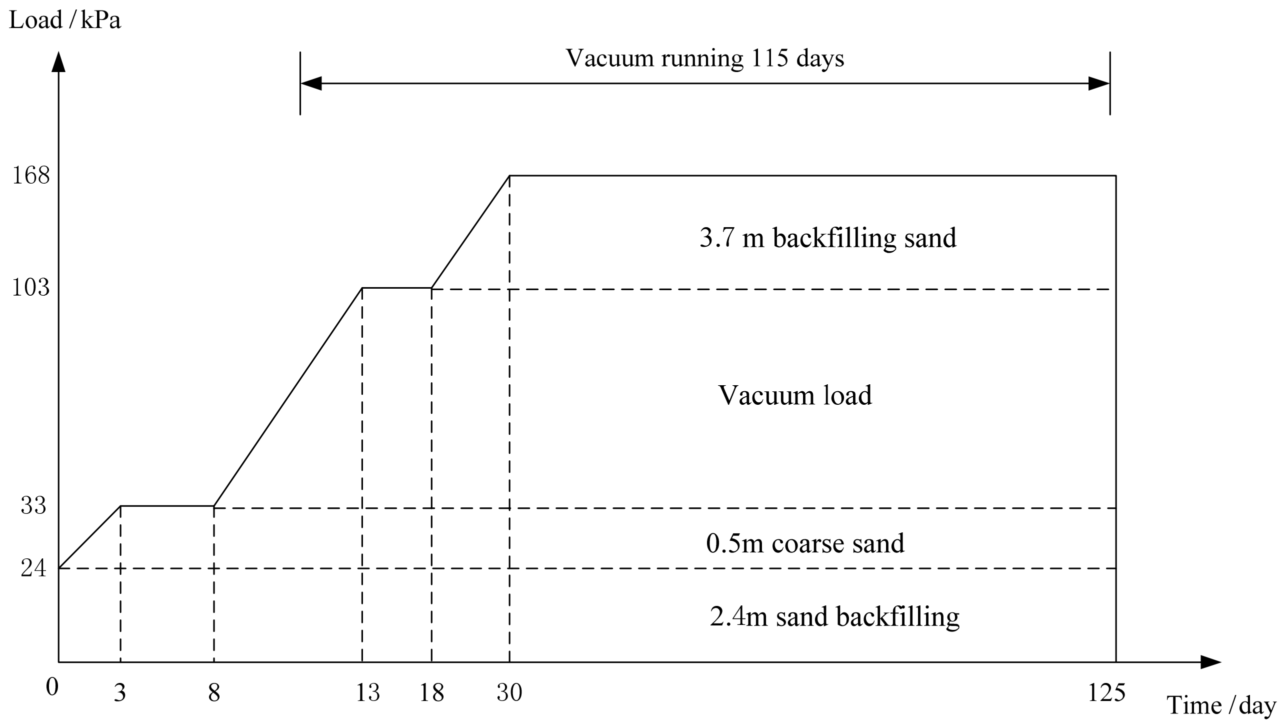

Fig. 4 The calculation model under operation load with treatment.

- The post-construction settlements include two parts: the first is the secondary consolidation settlement of soft clay, the second is the immediate settlement under operation load.

Table 2 Typical soft clay profile.

Soil Properties	Symbol	Unit	Layer 2			Layer 3		
			Average	Max	Min	Average	Max	Min
Moisture content	W	%	103.8	122.8	82.8	28.1	30.2	22.9
Wet Density	w	g/cm^3	1.417	1.48	1.37	1.899	1.98	1.87
Dry Density	d	g/cm^3	0.698	0.81	0.615	1.483	1.611	1.436
Specific Gravity	s	g/cm^3	2.58	2.61	2.56	2.703	2.725	2.7
Void Ratio	e	%	2.715	3.171	2.174	0.823	0.88	0.688
Direct shear test	C	kG/cm^2	0.057	0.065	0.052	0.282	0.315	0.247
		degree	2°19’	3°45’	2°00’	15°37’	18°10’	15°15’
Consolidation test:								
Pre-consolidation pressure	P_C	kG/cm^2	0.534	0.600	0.43	0.693	0.760	0.430
Coefficient of vertical consolidation	C_v	10^{-4} cm^2/s	2.61	4.330	0.195	4.710	6.570	0.387
Compression Index	C_c	-	1.172	1.351	0.933	0.110	0.119	0.076
Coefficient of Permeability	K_{20}	10^{-7}cm/s	0.294	3.330	2.700	0.305	0.386	0.262
Swelling index	C_s	-	0.156	0.166	0.133	0.016	0.017	0.013
Coe. of horizontal consolidation	C_h	m^2/year	1.32	3.05	0.3	0.67	1.01	0.21
Coefficient of Modulus elasticity	$E_{®h}$	kG/cm^2	56	67	49	473	473	473

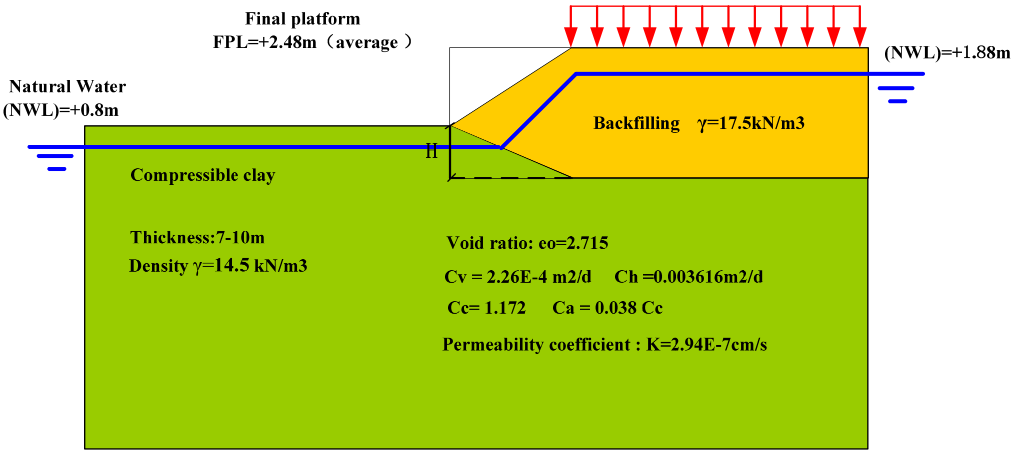

Fig. 5 The calculation input data

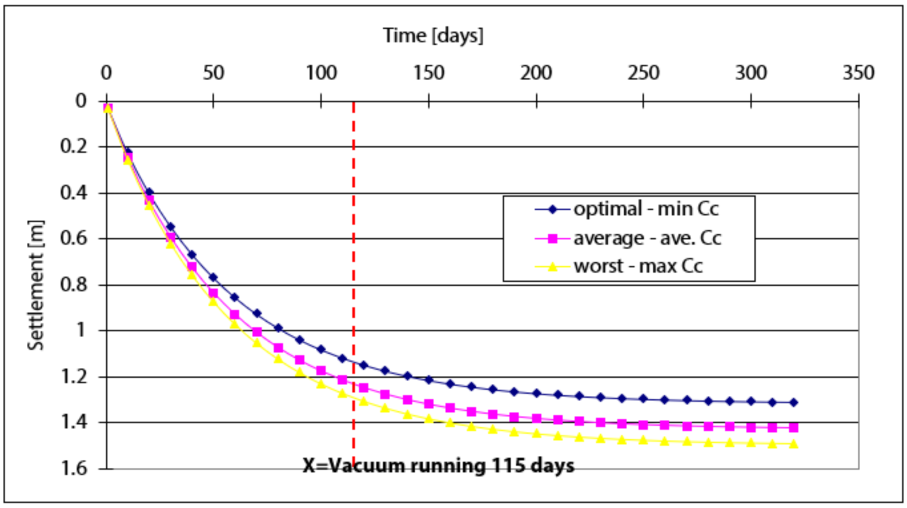

Fig. 6 The consolidation settlement of 10T zone.

$$s_s = C_a \frac{H}{1+e_1} \log \frac{t_{sc}}{t_p} = C_a \frac{H}{1+e_1} \log \frac{t_1 + t_r}{t_1}$$

Case	Unit	Optimal	Base	Worst
P	kPa	132.7	132.7	132.7
h_2	m	8	8	8
Eu_2	MPa	33.5	28	24.5
h_3	m	10	10	10
Eu_3	MPa	283.8	283.8	283.8
Si	m	0.040	0.047	0.052

$S_{post\text{-}construction}$ = 7.6 cm (< 10 cm requirement for soft soil)

3.2.4 Settlement Prediction of Encased Stone Column

The settlement was estimated based on Raithel and Kempfert's analytical calculation model [4]. The settlement with treatment is 84 mm with column diameter 1.0 m, spacing 2.3 m and the tensile stiffness of the geosynthetic encasement J = 3000 kN/m.

4. Results and Discussion

To evaluate the beneficial effects of providing stone columns encased with geosynthetics, a comparative calculation was carried out on encased stone columns/stone column and encased stone column/PVD with vacuum and surcharge preloading.

- Stone columns/encased stone columns and PVD are the most widely techniques used for ground improvement of soft soil in the world.
- Installation of stone columns/encased stone column considerably improves the constrained modulus of the weak soils.
- The case study shows that the settlement of soft soil reinforced with encased stone column is smaller than with stone columns.
- Encased stone columns/Stone columns are found to be an effective method of ground improvement, the time requirement is less as compared to PVD methods.
- Geosynthetic encased columns are optimal solution due to technical, technological and reasons of time for the land reclamation in Vietnam.

5. Conclusions

In this study, the settlement of stone columns encased with geogrid reinforcement was calculated and compared with the result of stone column and PVD with vacuum and surcharge preloading. The result shows that it fits into the studies and researches [5, 64]. Many projects have been successfully executed worldwide [7], the encased stone columns are the new direction research and application for the work of soil improvement in Vietnam.

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