Geoharbour Construction Group

Solution for Infrastructure Construction in soft clay area by Vacuum Consolidation Method

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2019.9.19

Content

1 Geotechnical Problems for the Soft Soil Ground

For the soft soil ground, there will be some Geotechnical problems, mainly include:

1.1 Ground Settlement Problem

1.2 Ground Stability Problem

1.3 Problem of Negative skin friction for Pile

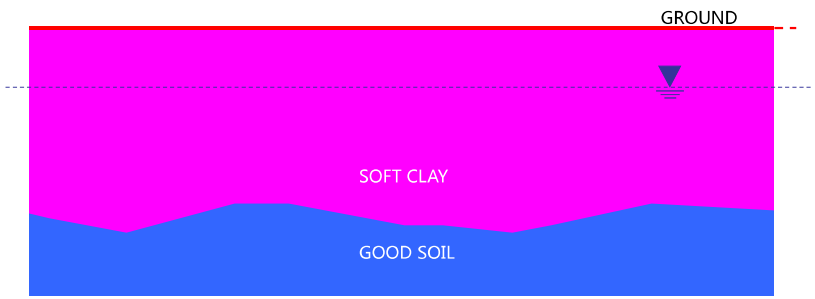
With the underground envionment change widely, make this problem more serious.

1.1 Ground Settlement Problem

Problem of Settlement for Road

1.1 Ground Settlement Problem

Settlement Problem Without Improvement



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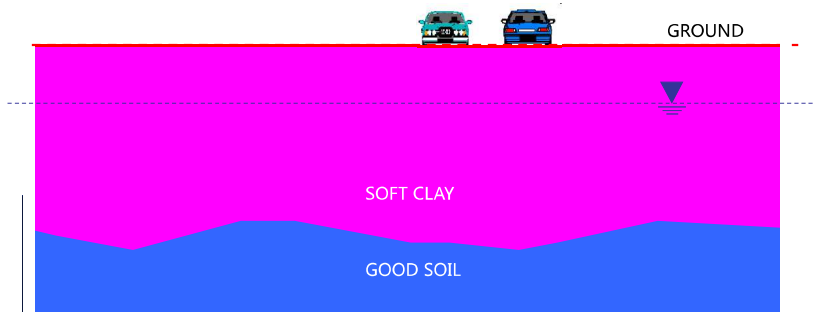
1.1 Ground Settlement Problem

Settlement Problem Eliminated by Improvement



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1.2 Ground Stability Problem

Before Improvement

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1.2 Ground Stability Problem

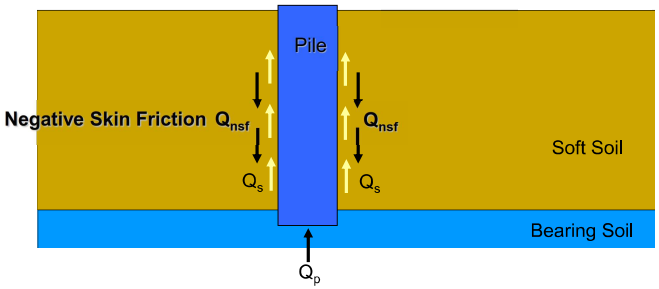
After Improvement

1.3 Problem of Negative skin friction for Pile

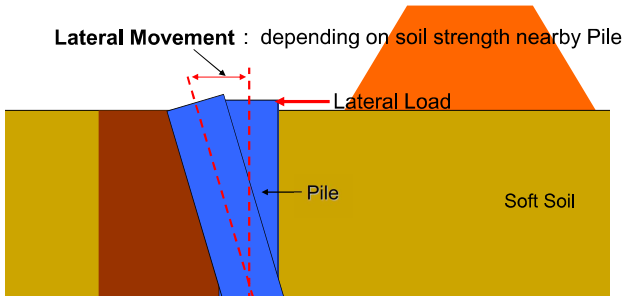
For Pile Vertical Bearing Capacity

Pile Vertical Bearing Capacity = $Q_p + Q_s$

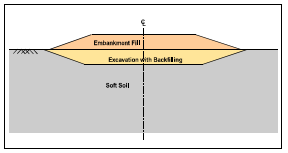
Pile Vertical Bearing Capacity will **decrease because of Q_{nsf}**



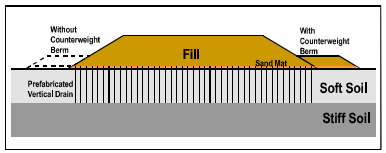
For Pile Lateral Bearing Capacity



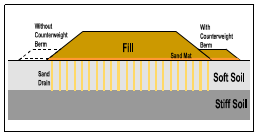
2 Traditional Method for Soft Soil



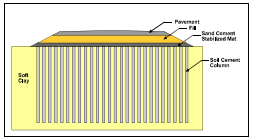
Soil Replacement



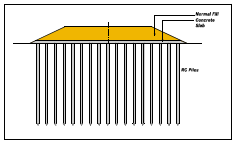
PVD + Surcharge



Sand Drain + Surcharge



Soil Cement Column (SCC)



RC Piled Slab

2 Traditional Method for Soft Soil

Overall Comparisons – During Design Stage

Method	Technical Difficulty	Fill Material	Time	Cost
1. No Ground Improvement				
2. Conventional PVD				X
3. Vacuum Consolidation				1.1~1.2X
4. Soil Cement Column				2~3X
5. Pile Slab				3~4X

Depend on the surcharge price

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Why it is VCM?

1) VCM method is consolidation method, soil body itself can be improved basicly and soil strength increased;

2) The improved soil itself can be high-compacted Integrity, greatly increase the resistance to the external environment, such as underground water level changing;

3) VCM method is the technical reliable, quality guaranteed, while cost-saving comparing with traditional method.

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3 Vacuum Consolidation Method (VCM) Development

Vacuum Consolidation Method (VCM) is for soft ground improvement, using atmospheric pressure as a temporary surcharge for Soil Consolidation.

1) The Method was proposed by Kjellman in 1952;

2) China started to apply this Method widely for soft clay improvement since 1958, it has been a mature technique.

3) In the past 10 years , Geoharbour Group successfully finished 100 projects (about 20 Million sq.m) in roadways, airport runways, port stack yards, petrochemical facilities, ground reclamation, power plants and industrial parks etc fields with VCM , Covering China , Indonesia , Vietnam , Singapore , Thailand , etc

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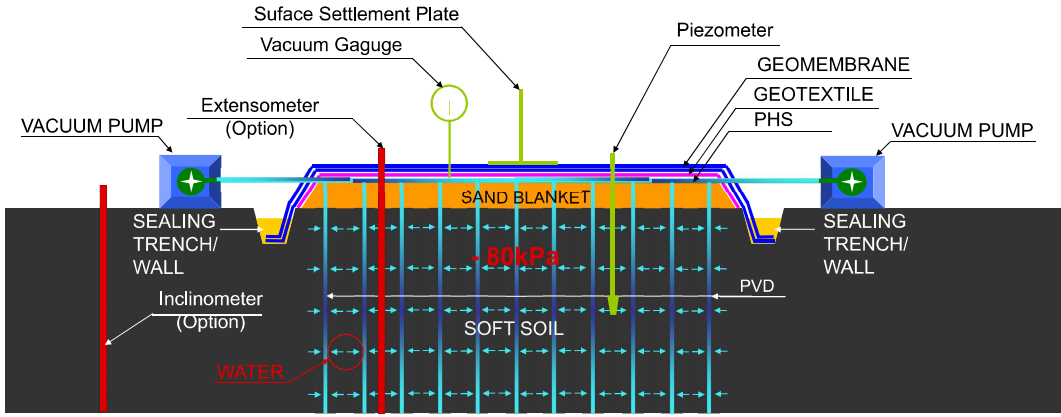
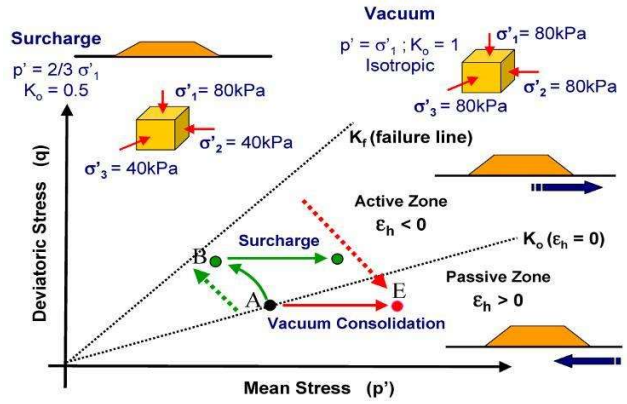
3 Vacuum Consolidation Method(VCM) Development

TYPICAL VCM SYSTEM – Geomembrane Type



3 Vacuum Consolidation Method (VCM) Development



3 Vacuum Consolidation Method(VCM) Development

Consolidation Degree Calculation:

$$U = 1-(1-U_v)*(1-U_h)$$ Carrillo formula (Das, 1985)

U: Consolidation degree,

U_v: Vertical component of consolidation U_h: Horizontal component of consolidation

Type	C_h (m^2/yr)	k_h/k_s
PVDs (SP-W5-001T)	2.62	9.2
PVDs (SP-W5-031T)	2.37	10
Vacuum-PVDs (MSA-ZB36)	3.56	7.3
Vacuum-PVDs (MSA-ZB42)	4.83	10

By Prof.D.T.Bergado (2002)

Consolidation time can be greatly shorten by VCM method, due to its effectively improve the consolidation drainage capacity of the soil.

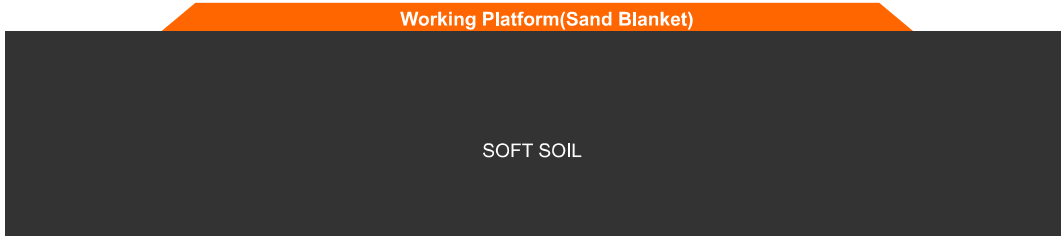
3 Vacuum Consolidation Method(VCM) Development

Comparative Item	*Vacuum-surcharge preloading*	*Conventional surcharge preloading*
Surcharge height	Vacuum pressure (70 kPa), equivelent to 4m sand surcharge Usually consider settlement compensation	H= **6.0-7.0m** Surcharge removal
Improvement period	Total about **5-6 months**	Total about **12-18 months**
Loading phases	One time of surcharging	Layer by layer Carefully control the surcharge height and cycle time
Sliding Stability	No sliding	Potential sliding risks

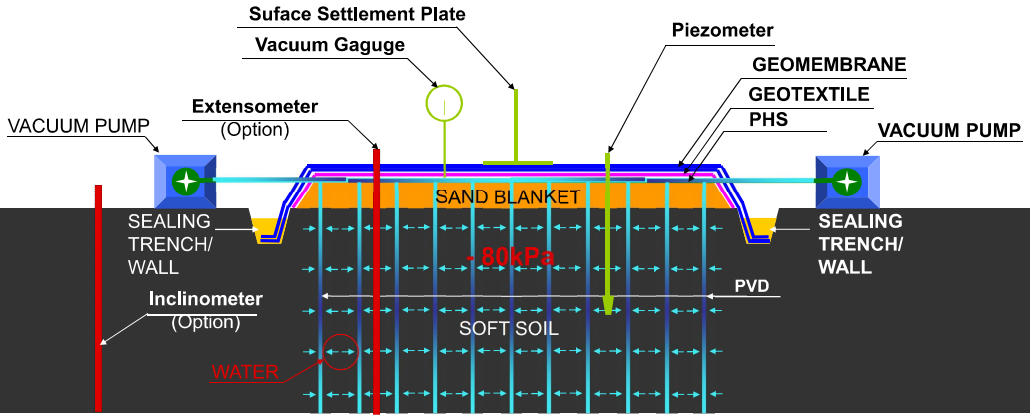
By Prof.D.T.Bergado (2002)

4 Typical VCM Construction Sequence

Stage 1 : Working Platform (Sand Blanket)



Stage 2 : VCM System Install



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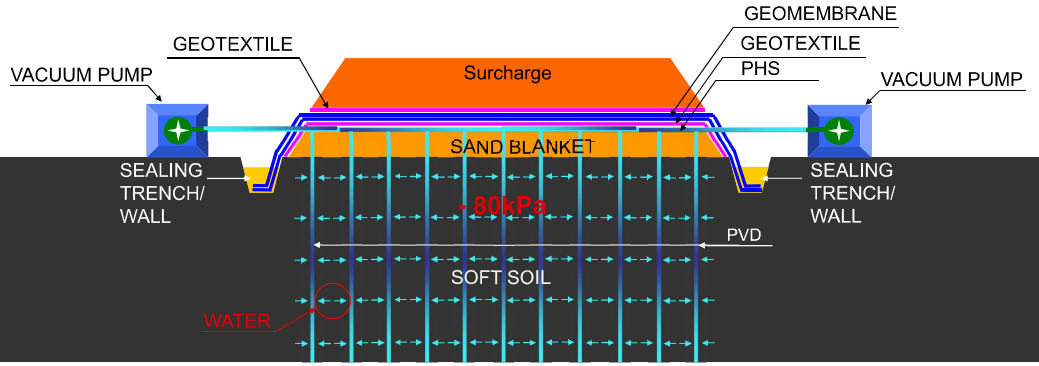
Stage 3 : Fill Surcharge During VCM



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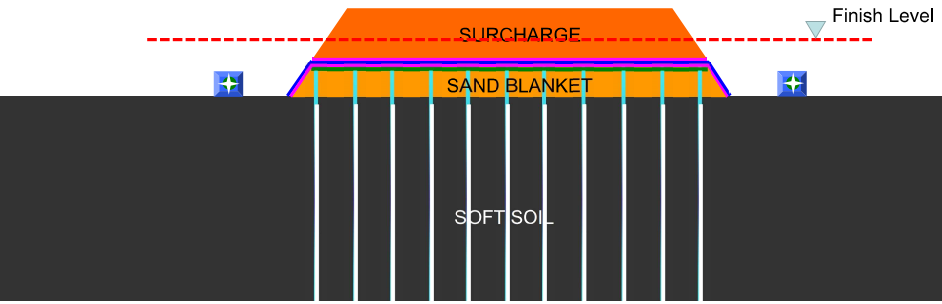
Stage 4 : Consolidation settlement by VCM



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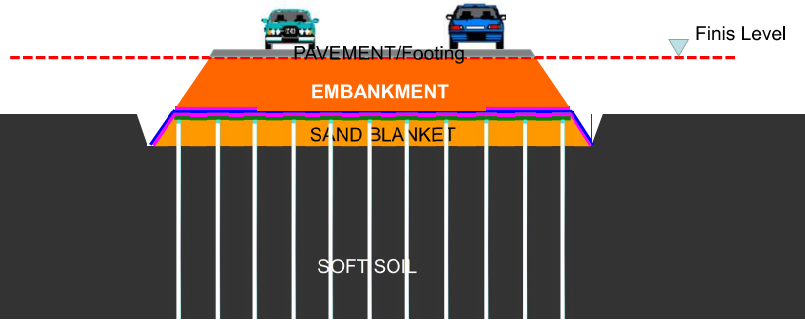
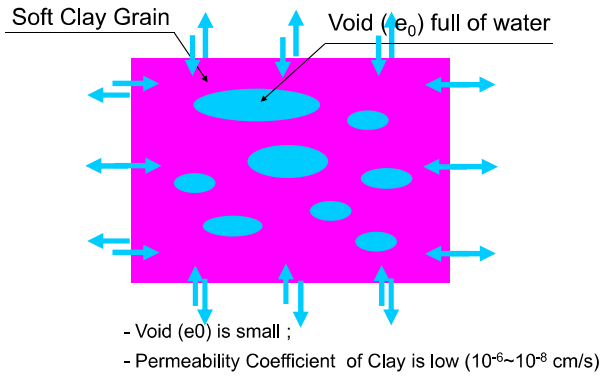
Post Construction after VCM Finish



Why the improved soil can have the high resistivity to the effect of underground water ?



Just like soft Tofu contents water

After dehydrated just like dried Tofu

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5 Typical VCM Project Case for Road By Geoharbour

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5.1 General Introduction

Typical VCM for Road Project (2011 ~ 2016)

No.	Project	Duration	Area	Location	Method	Status
1	Kayu Agung-Palembang Toll Road section 1	2016	450,000	Indonesia	Vacuum Preloading	On going
2	Kayu Agung-Palembang Toll Road section 2	2016	330,000	Indonesia	Vacuum Preloading	On going
3	Palembang - Indralaya Toll Road	2015	850,000	Indonesia	Vacuum Preloading	On going
4	Nakhon Si Thammarat Airport (Taxiway)	2015	40,000	Thailand	Vacuum Preloading	Completed
5	Guihua 8th road、jiangbei road、jinger road、wanyunroad、hexu road、changhe south road、 heping south road soft ground improvement project	2014	652,929	China	Vacuum Preloading + HVDM	Completed
6	Yunlong Road (W Binhe Road-Huayuan Road), Wufang Road (W Binhe Road-Huayuan Road), Xingchuanhe Road (Yunlong-Nanliu Road), Shengxin Road (Xingchuanhe Road-S Zhongshan Road), Zhilu 3 (Yunlong Road-Wufang Road) Ground Improvement	2013	189,137	China	Vacuum Preloading + HVDM	Completed
7	Municipal Road Phase 4 Ground Improvement	2013	332,059	China	Vacuum Preloading + HVDM	Completed
8	Formosa Ha Tinh Steel Mill E0506 temporary road project	2012	285,719	Vietnam	Vacuum Preloading,HVDM,Dynamic compaction	Completed
9	Formosa Ha Tinh Steel Mill public road zone 1 ground improvement projec	2012	411,568	Vietnam	Vacuum Preloading,HVDM,Dynamic compaction	Completed
10	Fujian pingtan jinjing harbour district ruyi road K0+960-K2+400 soft ground treatment project	2012	113,177	China	Vacuum Preloading	Completed
11	Formosa Ha Tinh Steel Mill N22 temporary road project	2012	149,784	Vietnam	vacuum preloading,HVDM,Dynamic compaction	Completed
12	North-South Expressway Construction Project	2011	110,000	Vietnam	Vacuum Preloading	Completed
Total			**3,914,373**			

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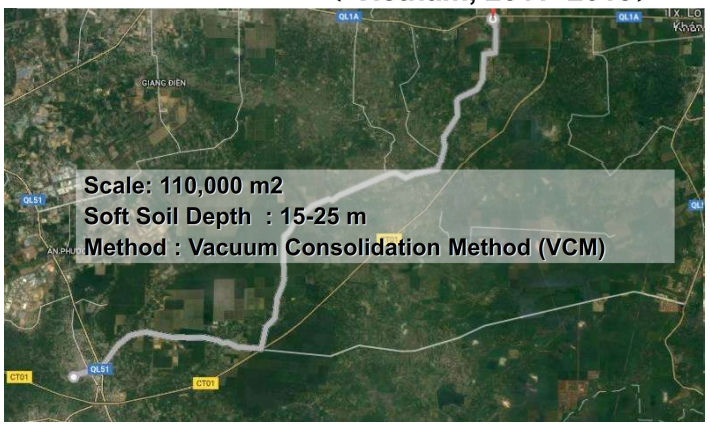
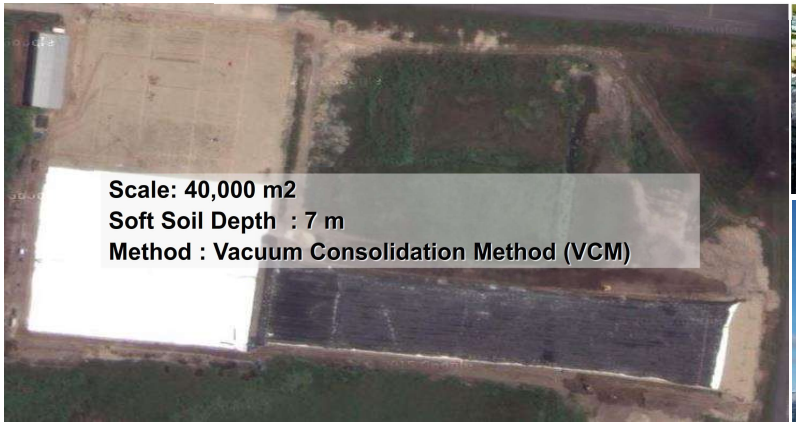
North-South Expressway Construction Project HCMC-DauGiay

（ Vietnam, 2011~2013）



Nakhon Si Thammarat Airport (Taxiway)

（Thailand, 2015~2016）



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Palembang-Kayu Agung TOLL ROAD

（Indonesia, Under Construction ）

Scale: 13 KM
Soft Soil Depth : 10-25 m
Method : Vacuum Consolidation Method(VCM) + Surcharge

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5.2 Case Study

PALEMBANG – INDRALAYA TOLL ROAD

（Indonesia, Under Construction ）

To be detailed Presentation

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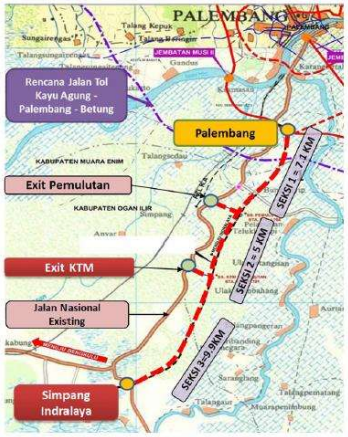
5.2.1 General information - Location

Palembang City, South Sumatra Province , Indonesia

5.2.1 General information - Layout



Length	: 21.93 km
Speed	: 100 km/hr
Initial lane	: 2x2
End lane	: 2x3
Traffic path	: 3.6 m
Shoulder	: 1.5 m
Outer shoulder	: 3 m
Interchange	: 2 pieces

Numbers of Structures

-Underbridge	: 13 pieces
-Underpass	: 3 pieces
-Overpass	: 7 pieces
-Box pedestrian	: 5 pieces
-Box culvert	: 43 pieces
-JPO	: 10 pieces

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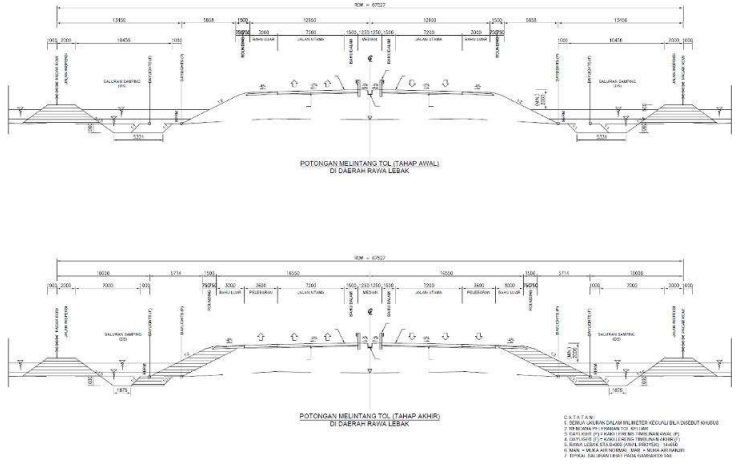
5.2.1 General information - Typical Section



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5.2.1 General information - Soil Condition

Depth (m)	BH-01	BH-02	BH-03	BH-04	BH-05	BH-06	BH-07	BH-08	BH-09	BH-10	BH-11	BH-12	BH-13	BH-14
STA	1+000	1+850	3+650	5+900	7+125	8+050	9+625	12+000	14+100	16+100	17+650	19+000	20+050	21+400
1.5	0	0	0	0	0	0	2	4	0	19	1	5	0	18
3.0	0	1	0	2	0	0	0	8	0	13	0	7	2	16
4.5	1	1	2	2	0	1	0	9	2	16	0	8	6	16
6.0	3	1	0	5	1	5	0	12	2	18	0	7	13	13
7.5	0	1	2	9	1	5	6	9	3	20	4	8	19	14
9.0	0	2	4	17	5	5	6	7	10	17	3	6	31	18
10.5	1	3	7	13	5	2	8	1	7	19	2	11	36	15
12.0	2	4	9	4	7	3	0	1	8	53	2	14	40	18
13.5	6	4	12	9	7	10	2	2	3	56	18	14	40	21
15.0	14	12	14	9	15	11	2	3	10	58	13	32	32	15
16.5	8	13	35	9	20	19	4	8	15	36	14	25	35	16
18.0	10	14	50	23	20	18	5	17	24	41	10	26	38	17
19.5	23	16	50	22	20	25	6	15	24	40	14	27	40	21
21.0	24	18	8	26	50	27	13	16	30	34	15	23	41	20
22.5	28	22	43	29	50	40	31	15	27	49	11	21	39	34
24.0	25	24	27	20	50	62	35	17	36	41	50	21	40	39

STA 0+000 sd 7+000

		SPT (N)
1	Very soft	< 2
2	No	CONSISTENCY
3	Medium Stiff	4 - 8
4	Stiff	8 - 15

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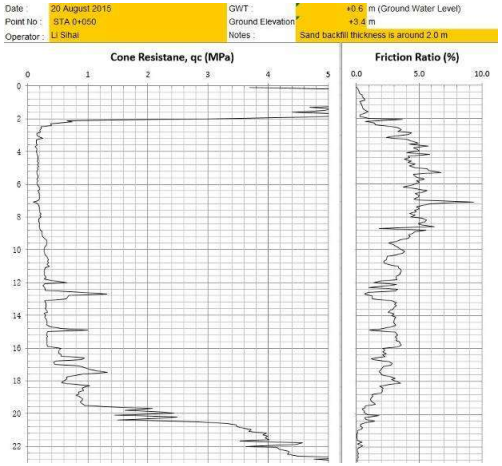
5.2.1 General information - Soil Condition

Cone Penetration Test, CPT

Before Soil improvement process :

Use CPT to verify Soft Clay.



5.2.2 VCM Construction - Original Site Condition

Swampy condition with water about 1.5 – 2.0 m above the ground during rainy season and 17 km of main road area will under water.
Under 5 years flood period the water may increase 1 m more and it may result total 18 km of main road area will under water.
However at dry season the ground water table is about -1m below the ground.

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5.2.2 VCM Construction - Site Preparation

Stripping work (Site Cleaning)

Woven-geotextile spreading for Working Platform

Working road as dike (Service Road)

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5.2.2 VCM Construction - working Platform by sand or soil

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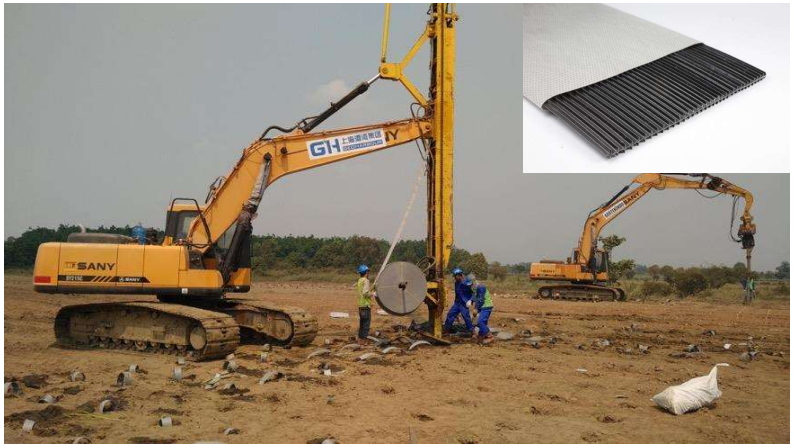
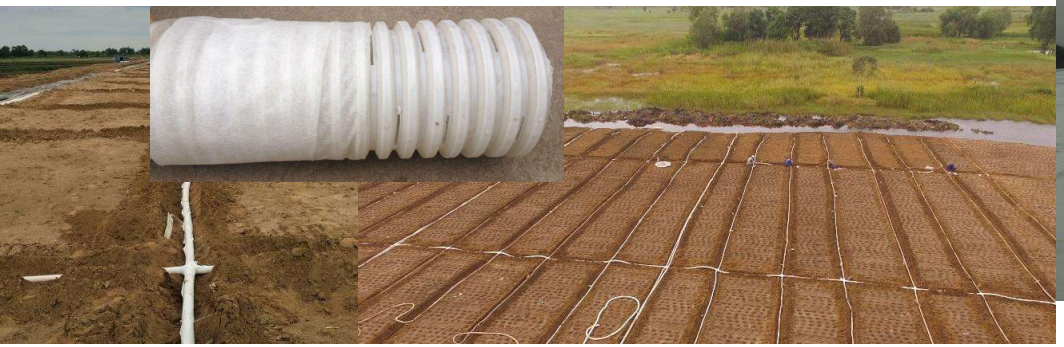
5.2.2 VCM Construction - PVD Installation



5.2.2 VCM Construction - PHS Installation



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5.2.2 VCM Construction - 1st Geotextile Installation

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5.2.2 VCM Construction - Geomembrane Installation

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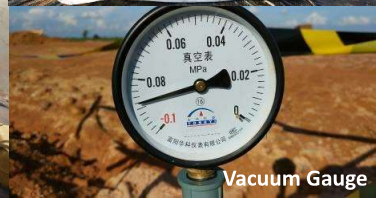
5.2.2 VCM Construction - Bury Geomembrane (Edge Treatment)

5.2.2 VCM Construction - Monitoring Instrumentation Installation



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5.2.2 VCM Construction - Monitoring Instrumentation Installation

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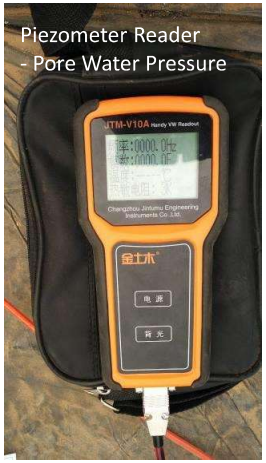

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5.2.2 VCM Construction - Installation and Operation of VCM System

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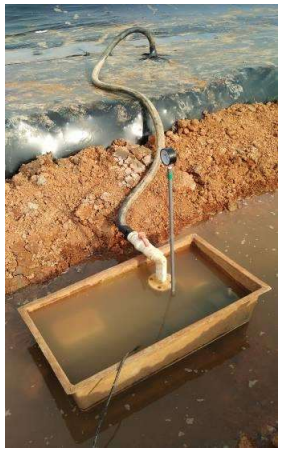

5.2.2 VCM Construction - Vacuum Consolidation Process

5.2.2 VCM Construction - 2nd Geotextile Installation

5.2.2 VCM Construction - Filling Surcharge during VCM period

5.2.2 VCM Construction - Filling Surcharge during VCM period

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5.2.3 Traffic Operation

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5.2.3 Traffic Operation

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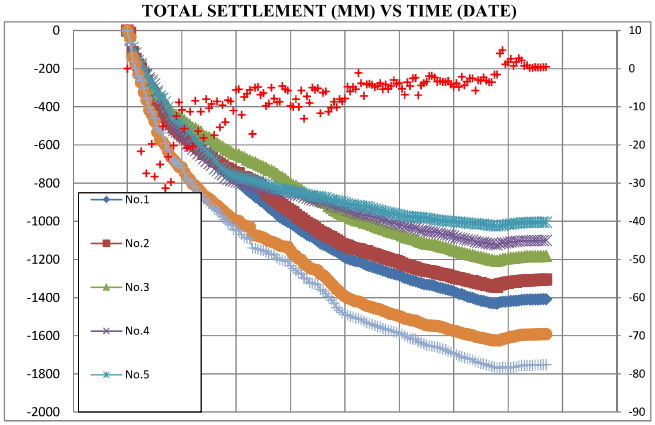
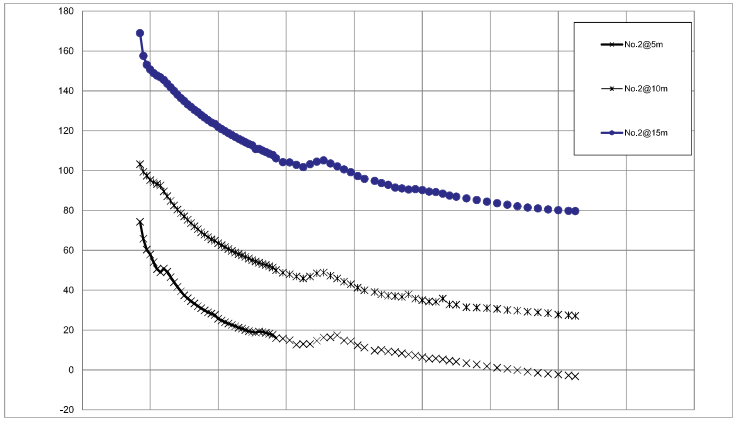
5.2.4 Monitoring during VCM- Surface Settlement



5.2.4 Monitoring during VCM- Pore Water Pressure



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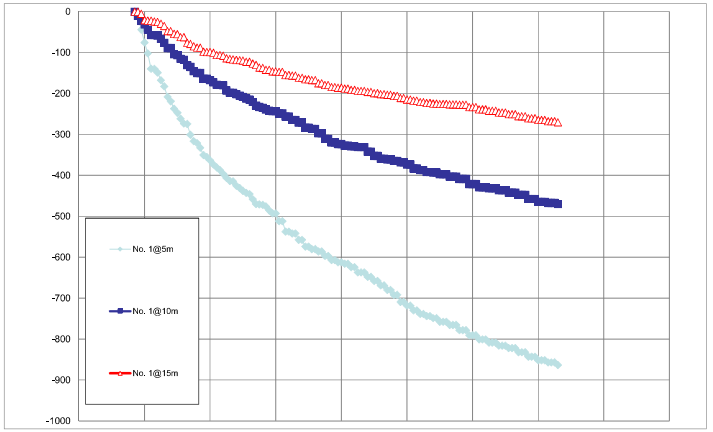
5.2.4 Monitoring during VCM- Layer Settlement



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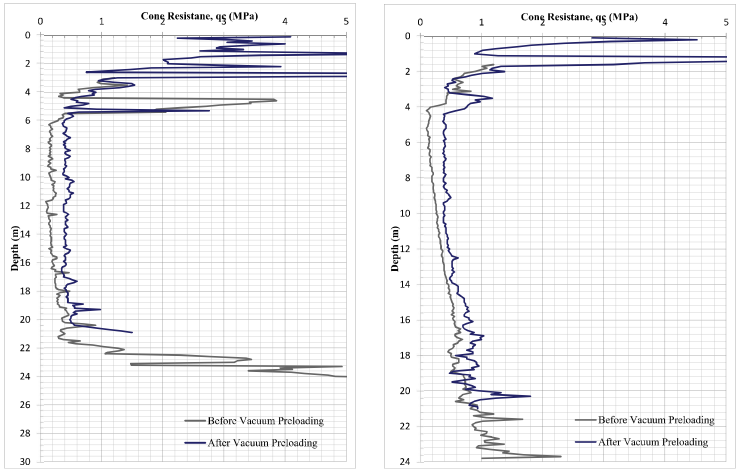
5.2.5 Site in-situ test- CPT result before and after VCM



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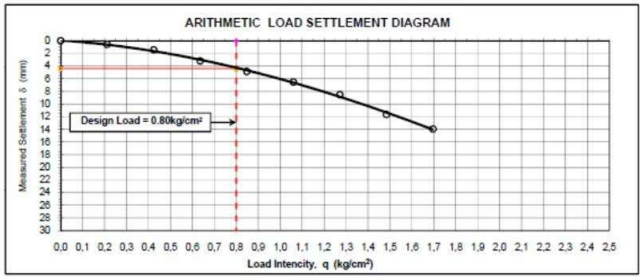
5.2.5 Site in-situ test- Plate Load Test after VCM

NO YIELD POINT :				TYPE OF PLATE :	RECTANGULAR PLATE
Load Intencity (Max Load)	q' =	1,70	kg/cm²		
Load Allowable (Design)	q =	0,80	kg/cm²	Size (d) =	1,00 m
Settlement at q	δ 1 =	4,40	mm	Area =	1550,0 sqin
Zero Correction	δ 2 =	0,00	mm	=	10000,0 cm²
Corrected Settlement	δ = δ 1 – δ 2 =	4,40	mm		
Modulus Subgrade Reaction $K_v = q/\delta$	=	1,82	kg/cm³	Modulus of Elasticity :	Eo = $I_o (1-\mu^2)\, qd/\delta$ Mpa
Soil Description : SANDY	μ =	0,30		Eo =	14,38 MPa



Site conditions in rainy season

5.2.6 Site Condition- in Rainy Season

Water table will be increased to 1.5~2m above ground during rainy season.

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5.2.6 Site Condition- in Dry Season

Water table will be decreased to 1m below ground during dry season.

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5.3 VCM + Water surcharge Case

Jawa 7 Power Plant Project

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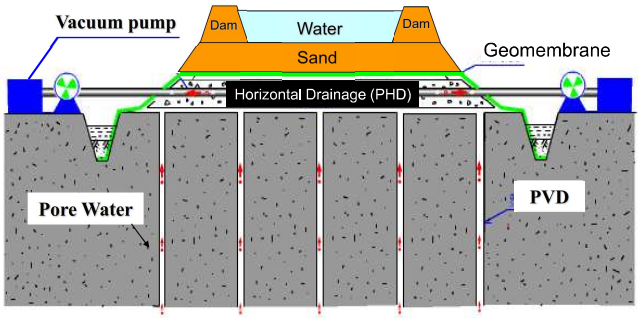
5.3 VCM + Water surcharge Case

Challenge:

- Residual settlement shall less than 10 cm.
- The power plant shall be built in 3 years.
- Ground surface is very soft or extremely soft.
- Traffic limitation for soil/sand transportation.

Soft Clay Parameter:
Initial Water Content 100%~140%
Undrain Shear Strength: 5.3 kPa
Thickness: 6~18 meter



Vacuum System provided 80 kPa preload
Water surcharge provide additional 20 kPa preload
Sand backfilling is for leveling purpose

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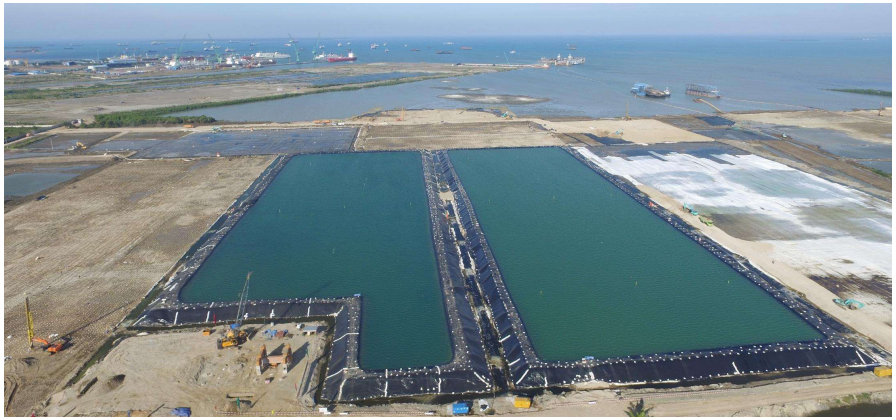

After VCM + Water Surcharge improvement, the ground settle 1.4~1.5 m and the unconfined shear strength Su increase 18~25 kpa

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Excavation up to 6.7 m without retaining wall

6 Conclusion

6.1 VCM method can effectively improve soil itself, shorten the soil particle distance, and soil strength increased;

6.2 The improved soil itself can be high-compacted Integrity, greatly increase the resistance to the external environment, such as underground water level changing;

6.3 VCM method is the technical reliable, quality guaranteed, while cost-saving comparing with traditional method, both construction cost and maintainance cost.

6.4 VCM method has successfully applied in the road project in some countries, such as Indonesia, Vietnam, China, Singapore, and so on. Hope this technique can be applied in the Thailand road project, and support the develpment of Thailand, more or less.

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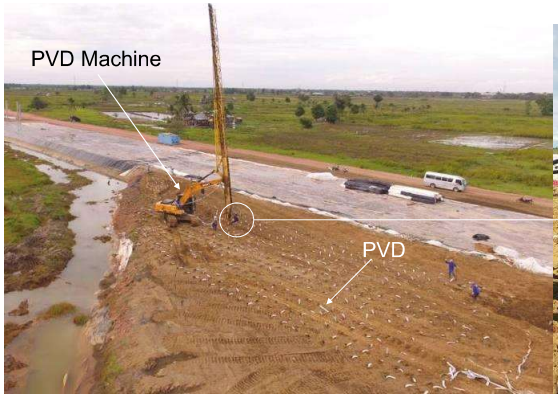
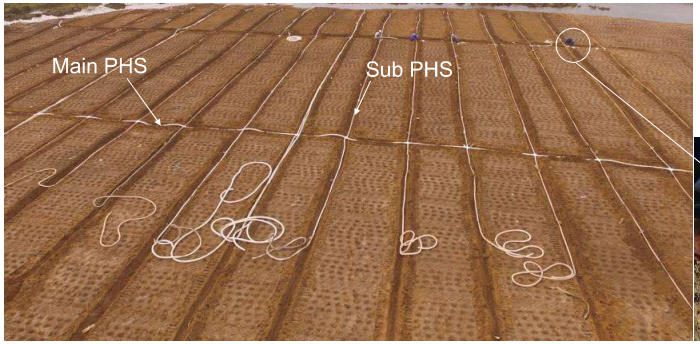
VCM Construction Sequence

Execute PVD (Prefabricated Vertical Drain)



VCM Construction Sequence

Execute PHS (Prefabricated Horizontal System)



VCM Construction Sequence

Execute Geotextile (On Sand Blanket , Under Geomembrane)

- Note : This Geotextile is for protecting Geomembrane

VCM Construction Sequence

Execute Geomembrane

1) The Geo-membrane is prefabricated according to Zone Size , then install at the site immediately, no need connection work ;
2) 20~30 labors could finish one zone in one day without machinery;
3) The installation shall proceed daytime with less than force 5 wind power.

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VCM Construction Sequence

Execute Edge Treatment : Sealing Trench / Wall

To cut off permeable air layer

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VCM Construction Sequence

Execute Vacuum Pump

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VCM Construction Sequence

Vacuum Pump Running

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VCM Construction Sequence

Vacuum Pressure

80kPa

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VCM + Surcharge

Soil Surcharge Fill During VCM

VCM + Surcharge

Water Surcharge Fill During VCM

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VCM + Surcharge

Soil + Water Surcharge Fill During VCM