Mega Infrastructure Soil Improvement Technology and Case Study

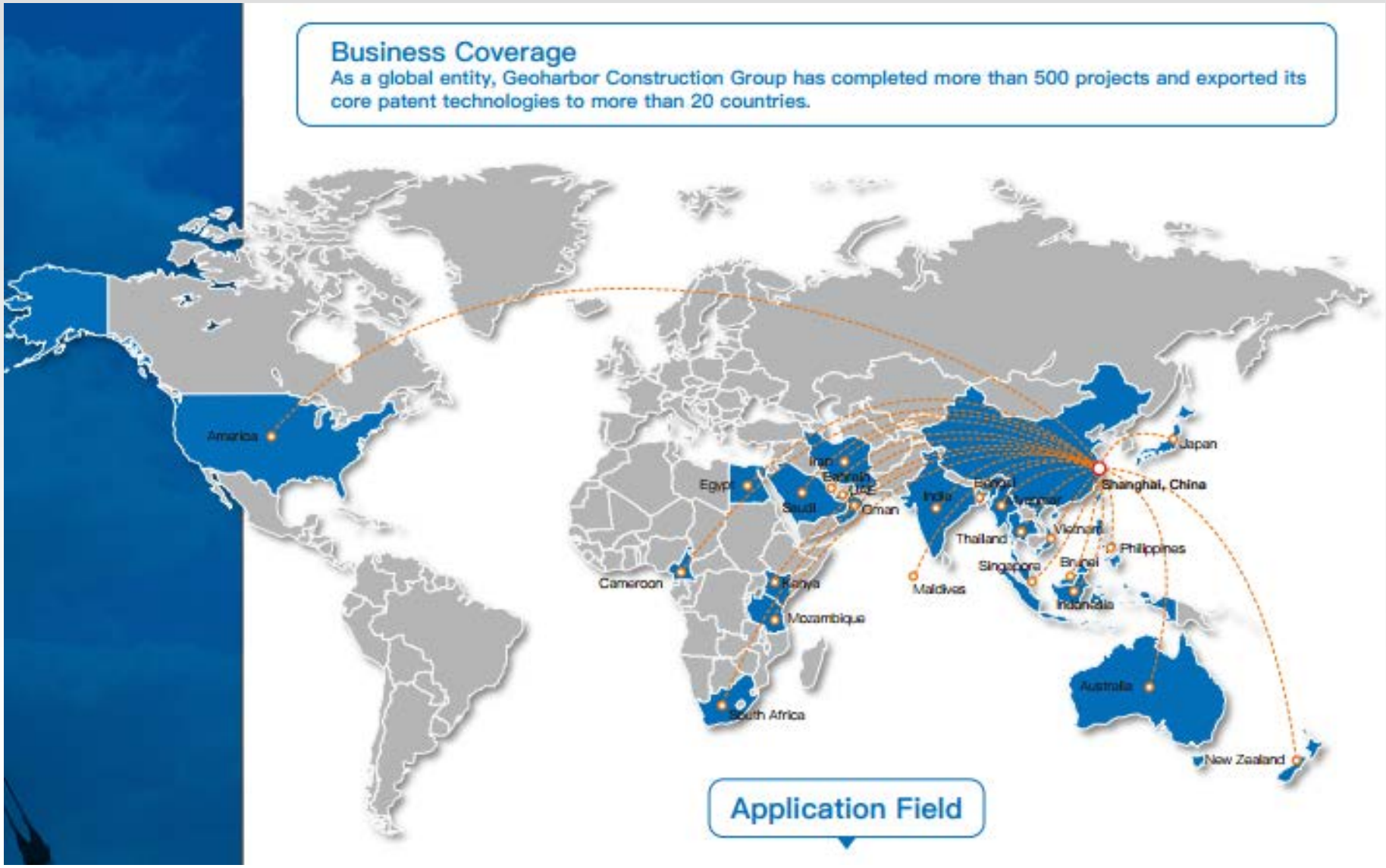
Liu Yu

Geoharbour Group

- **Founded Date: Jan. 28th, 2000.**
- **Professional entity specializing in Geotechnical Research, Design, Construction and Consultancy.**
- **Chief Editor of Chinese National Code for Reclamation Soil Treatment.**
- **Director member of Technical Committee of China Soft Soil Treatment.**
- **Vice President of China Association of Inventions.**
- **More than 30 patents for ground improvement method.**
- **Over 10 subsidiary companies: Singapore, Indonesia, Malaysia, Vietnam, Myanmar, Thailand, Middle-East Area, Australia, Panama, India, Iran...**
- **Over 500 large-scale projects (including China).**
- **Soft Soil Treatment more than 15,000 Ha (Include China).**
- **50+ ongoing projects.**

Business Coverage

As a global entity, Geoharbor Construction Group has completed more than 500 projects and exported its core patent technologies to more than 20 countries.



Application Field

Services	Techniques
Ground Improvement	DC > VCM > HVDM > DCM > SC
Piling Foundation	PC > BP
Deep Foundation Pit	SMW > Diaphragm Wall > Soldier Pile Retaining Structure
Slope Protection	Grid Beam > Anchor Cable > Anchor Bolt > Turf Planting > SNS
Reclamation	Cutter Suction > Pump-convey-hydraulic Fill
Harbor Construction	High Pile > Counterfort Wall > Gravity Retaining Wall

PEMBANGUNAN INFRASTRUKTUR

LOKASI 15 BANDARA DAN 24 PELABUHAN

- Jalan baru **2.650 Km**
- Jalan tol **1.000 Km**
- Pemeliharaan jalan **46.770 Km**

- Pembangunan Jalur **KA 3.258 Km** di Jawa, Sumatera, Sulawesi dan Kalimantan terdiri dari: KA Antar kota 2.159 Km, KA Perkotaan 1.099 Km

- Pembangunan **15 Bandara baru**
- Pengadaan **20 Pesawat Perintis**
- Pengembangan Bandara untuk
- pelayanan **Cargo Udara di 6 Lokasi**

- Pembangunan Pelabuhan Penyeberangan di **60 Lokasi**
- Pengadaan **Kapal penyeberangan perintis sebanyak 50 unit**

- Pembangunan **24 Pelabuhan baru**
- Pengadaan **26 Kapal** Barang Perintis
- Pengadaan **2 Kapal Ternak**
- Pengadaan **500 unit Kapal rakyat**

- Pembangunan **BRT di 29 kota**
- Pembangunan angkutan massal cepat di kawasan perkotaan (6 Kota metropolitan, 17 Kota besar)

SUMBER: BAPPENAS

- **Soft clay area** : west part of Sumatera, north part of Java, most of Kalimantan, south part of Papua

- **Loose sand area** : south and north part of Sumatera, part of Sulawesi, NTT, NTB, Maluku

PLTU III Teluk Naga, Banten


2015-06-01 08:39
Sinarmas Pulp and Paper Industry, South Sumatera

Palembang – Indralaya Toll Road, South Sumatera

Sarulla Geothermal Power Plant, North Sumatera

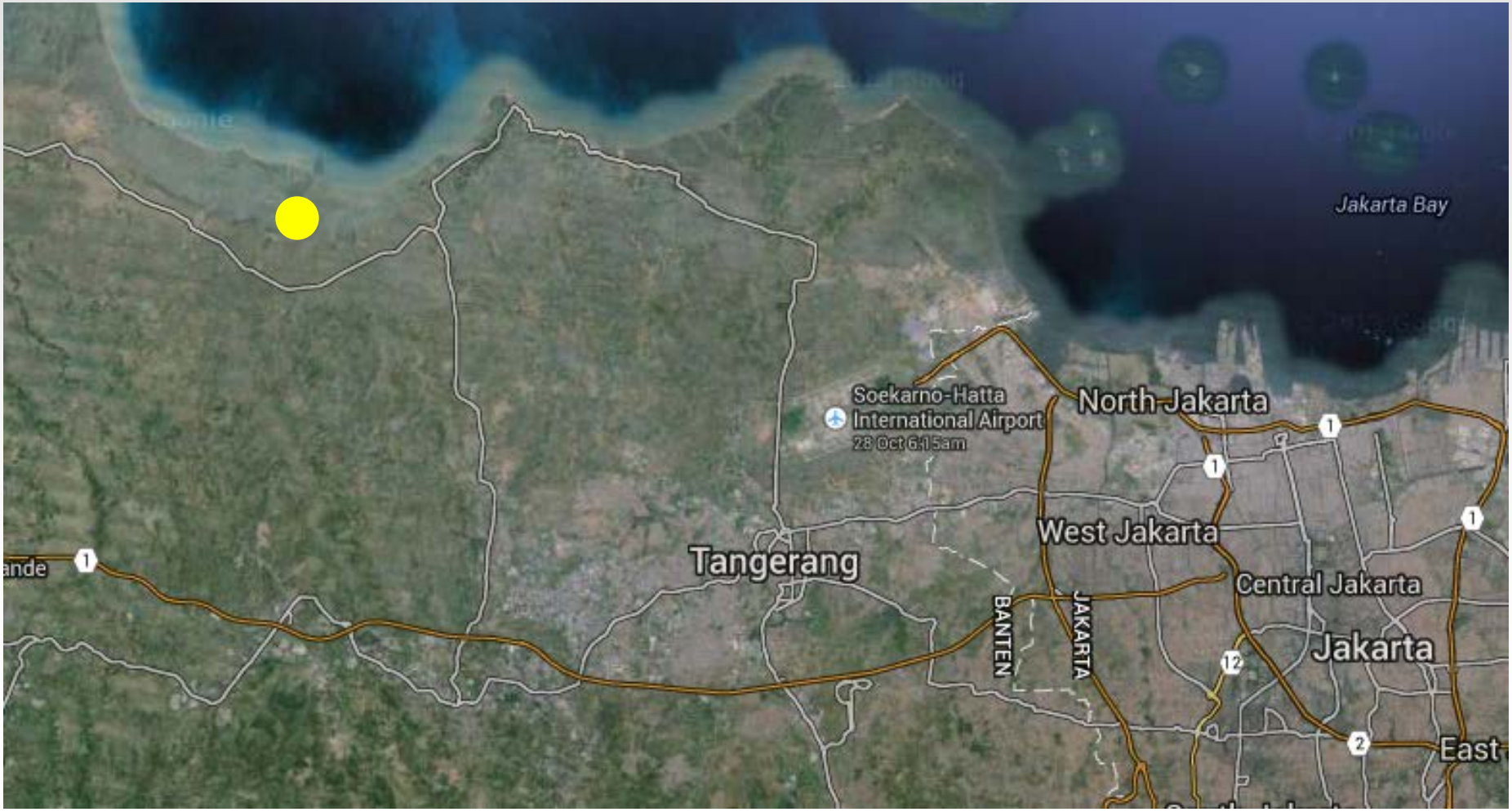
GEOTEKINDO

GROUND IMPROVEMENT SPECIALIST

2008

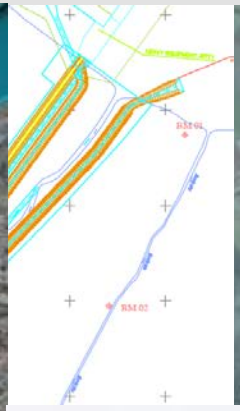
GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

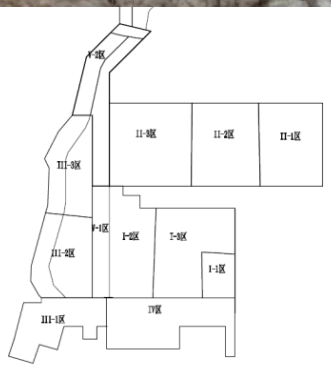
PLTU III Project, Teluk Naga, Tangerang, Banten (2008)



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

PLTU III Project, Teluk Naga, Tangerang, Banten (2008)

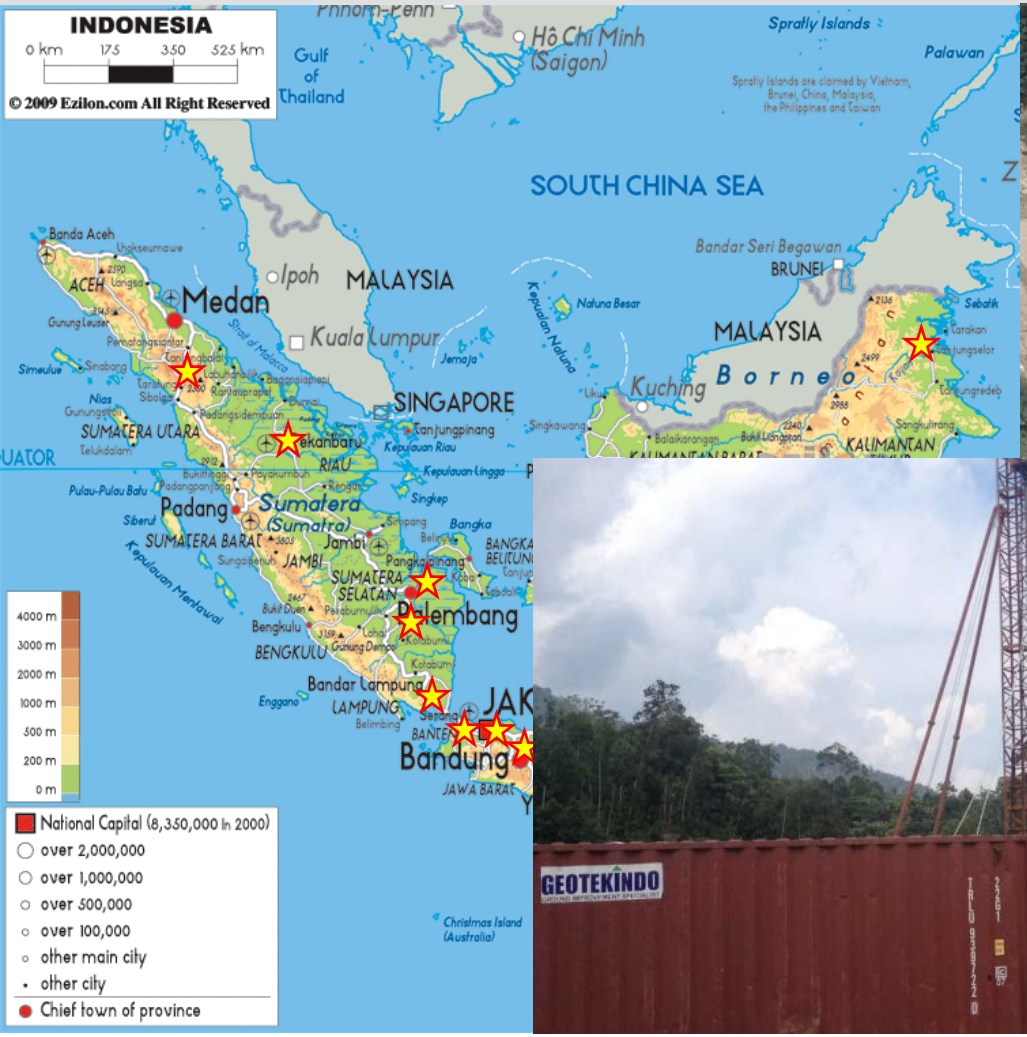




GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

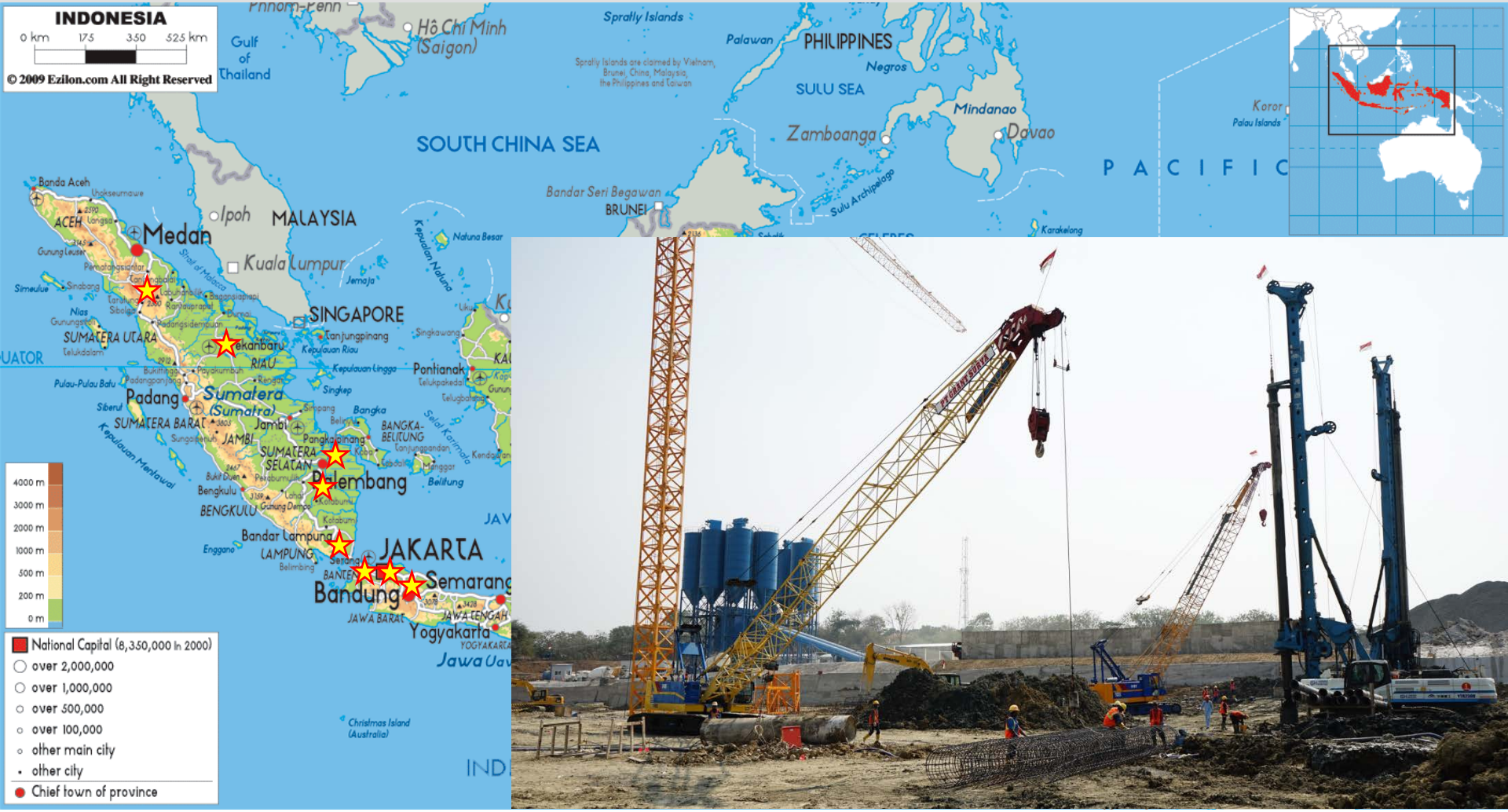
GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Case 1
Jawa 7 Power Plant Project

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project

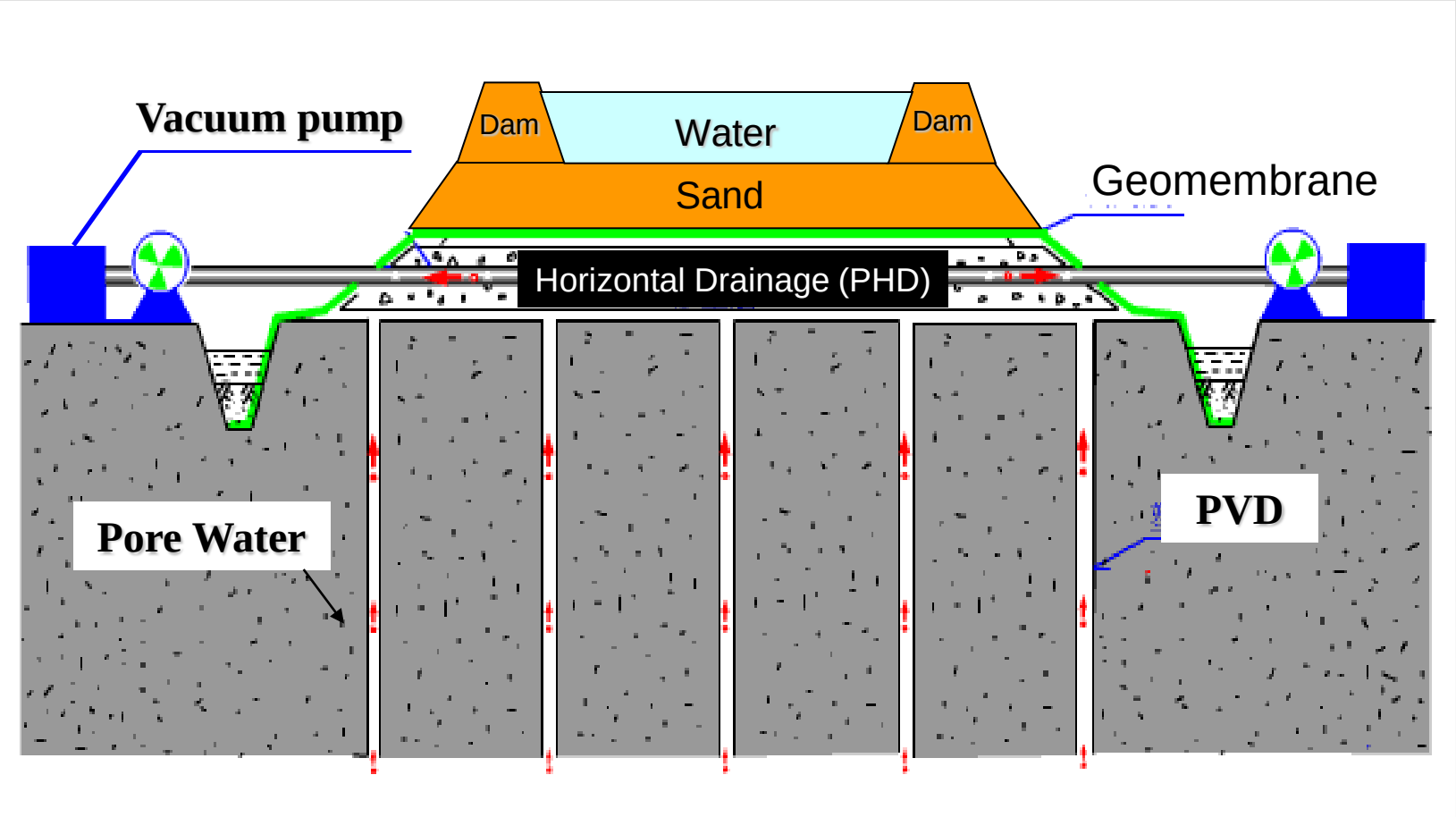
Challenge:

- 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

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge



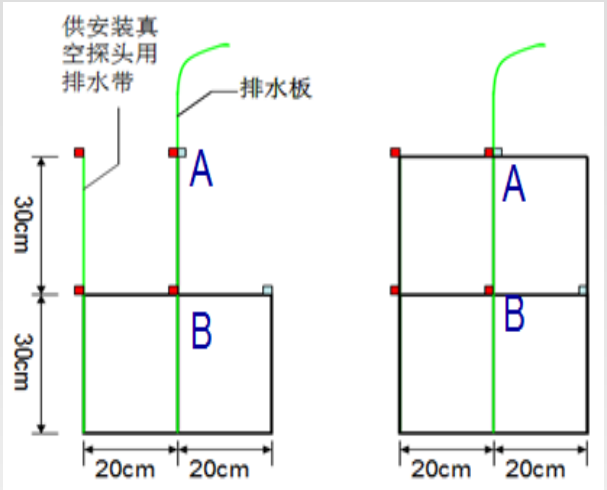
Vacuum System provided 80 kPa preload
Water surcharge provide additional 20 kPa preload
Sand backfilling is for leveling purpose

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Indoor Trial Test

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Indoor Trial Test

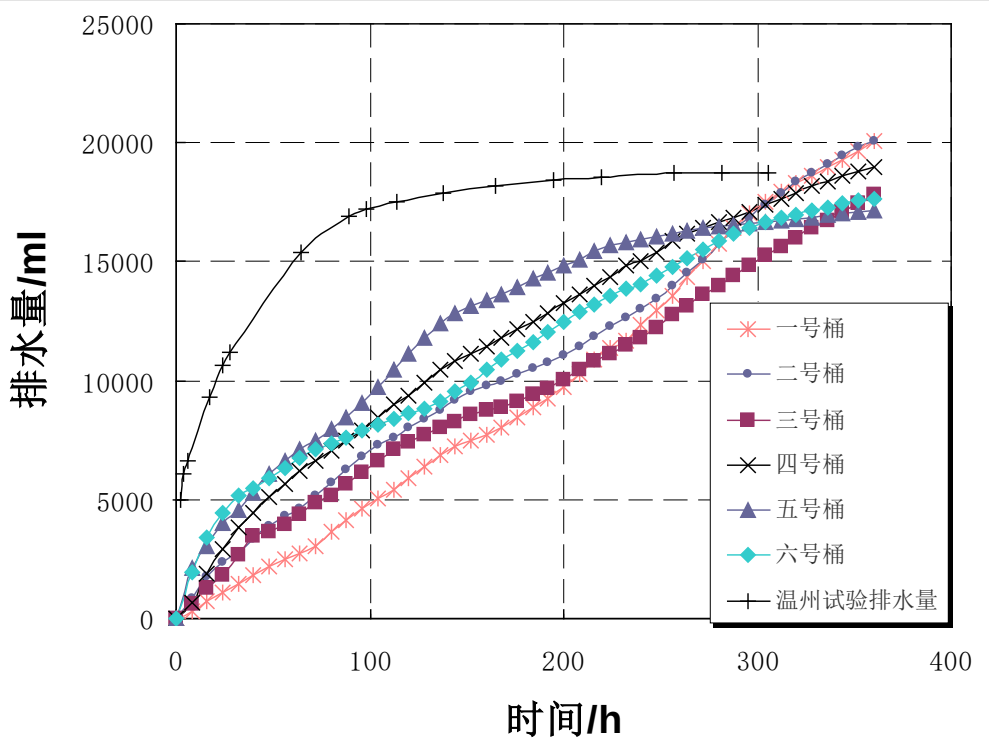


内置钢架正面和侧面图（蓝点为孔压探头埋设处）

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Indoor Trial Test

试验桶编号 NO.	1	2	3	4	5	6
直径Diameter（m）	1.2	1.2	1.0	1.0	0.8	0.8



Main Conclusions of Indoor Trial Test：

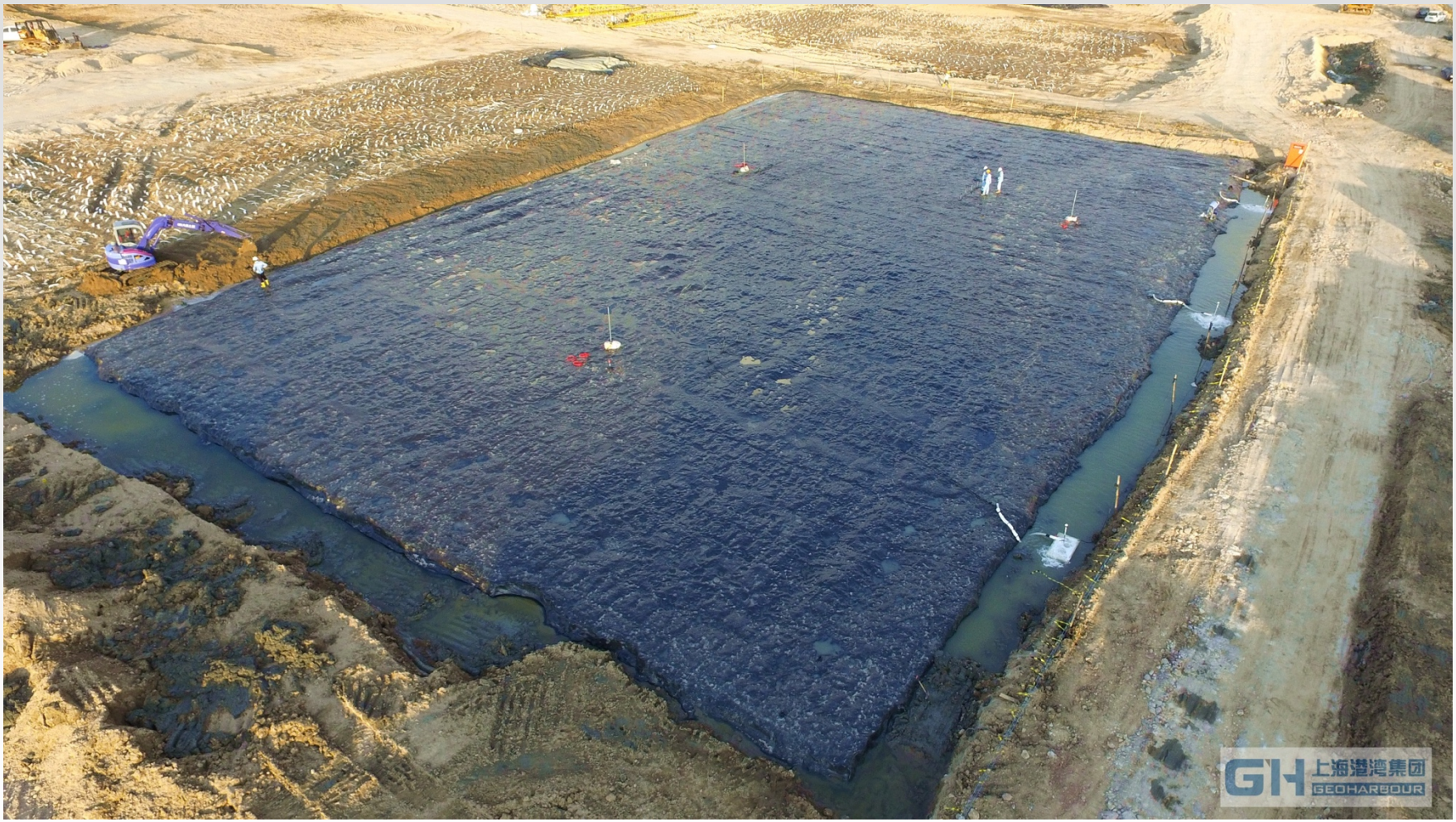
- No clogging was found
- Proper PVD spacing is 1.0 m

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

In-situ Trial Test

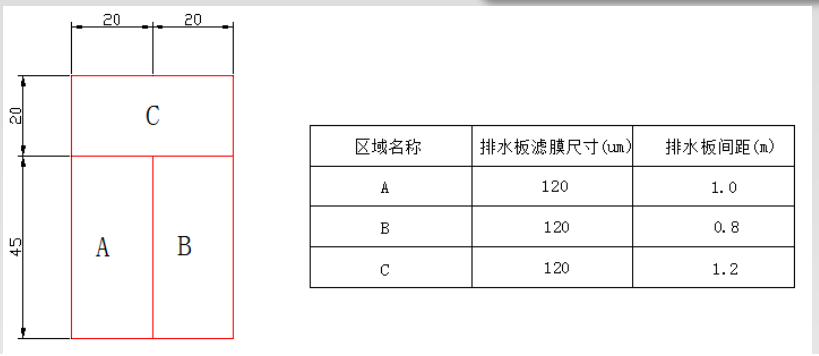
GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

In-situ Trial Test

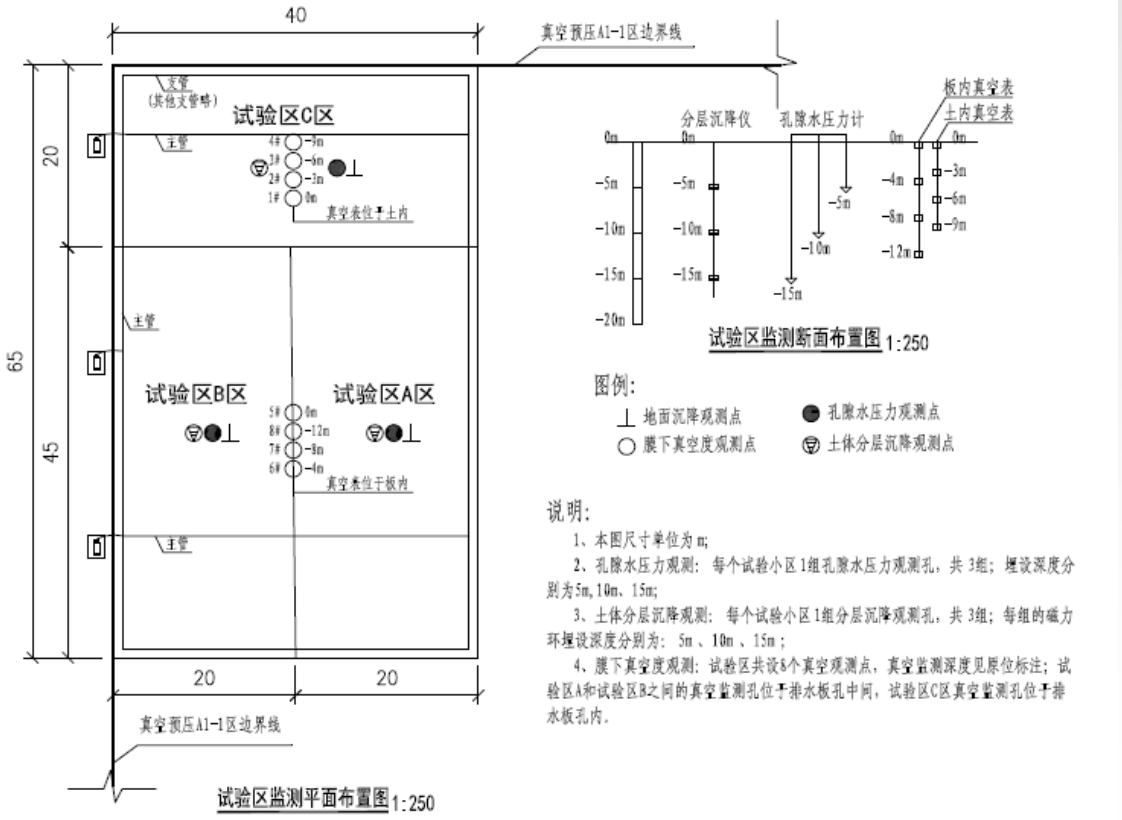


GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

In-situ Trial Test



区域名称	排水板滤膜尺寸(um)	排水板间距(m)
A	120	1.0
B	120	0.8
C	120	1.2



说明:

1、本图尺寸单位为 m;

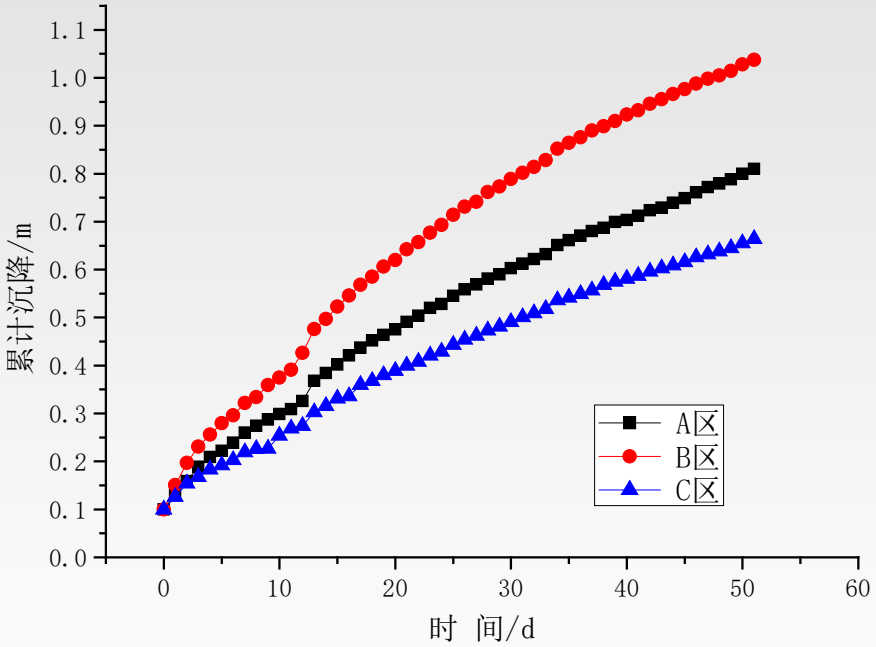
2、孔隙水压力观测: 每个试验小区 1组孔隙水压力观测孔，共 3组；埋设深度分别为5m,10m、15m;

3、土体分层沉降观测: 每个试验小区 1组分层沉降观测孔，共 3组；每组的磁力环埋设深度分别为: 5m 、10m 、15m ;

4、膜下真空度观测: 试验区共设6个真空观测点，真空监测深度见原位标注；试验区A和试验区B之间的真空监测孔位于排水板孔中间，试验区C区真空监测孔位于排水板孔内.

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

In-situ Trial Test



Observed Settlement vs Time During In-situ Trial Test

Due to time limitation, the in-situ trial test area keep running for 51 days. The main conclusions are:

1、Settlement in Test Zone-A is 0.810 m, average consolidation degree is 53.3%; Settlement in Test Zone-B is 1.037 m, average consolidation degree is 67.1%; Settlement in Test Zone-C is 0.664 m, average consolidation degree is 37.1%; Vacuum running well. Settlement keep growing and none clogging was found.

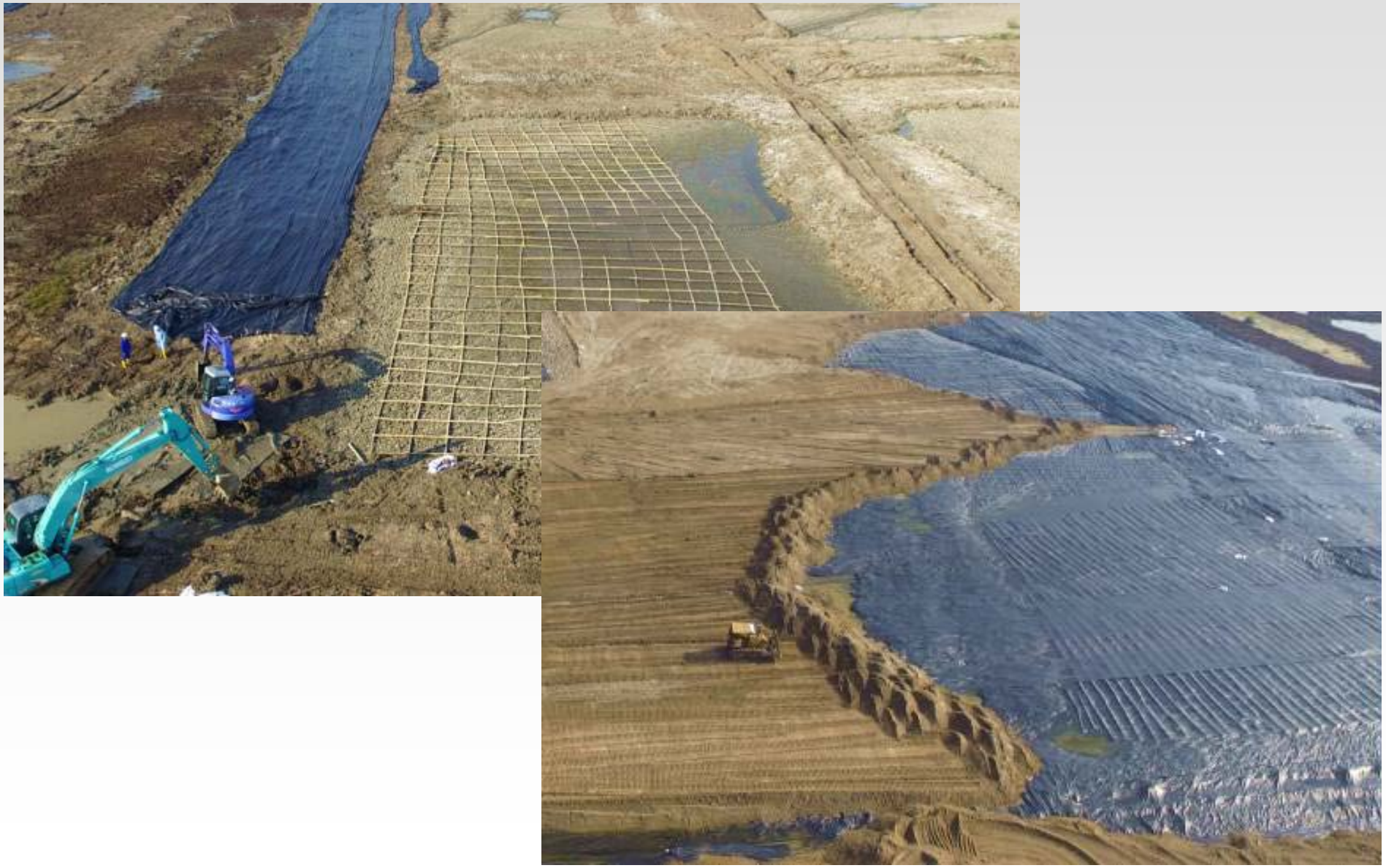
2、Spacing 1.2 m result obviously longer consolidation time which was not suitable for this case. Spacing 1.0 m is more proper.

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Construction Steps

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

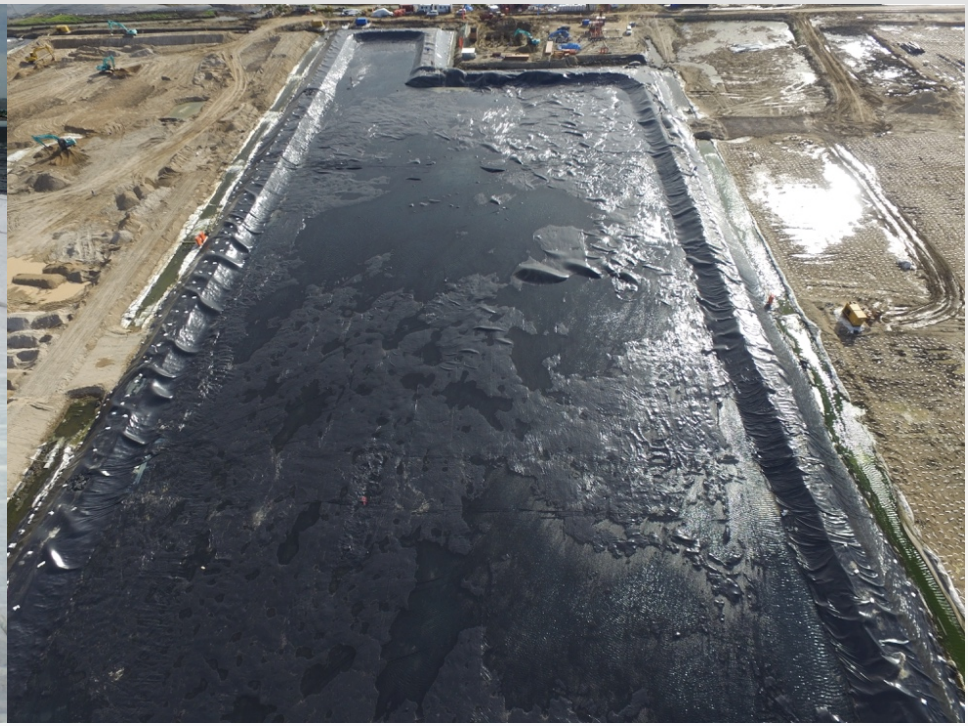
Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

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

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Jawa 7 Power Plant Project – VCM + Water Surcharge

Excavation up to 6.7 m without retaining wall

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Case 2
Sarulla Geothermal Power Plant Project

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

Challenge:

- Tuff, expansive soil.
- Rain every day.
- High backfill.
- Very loose / soft condition.

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

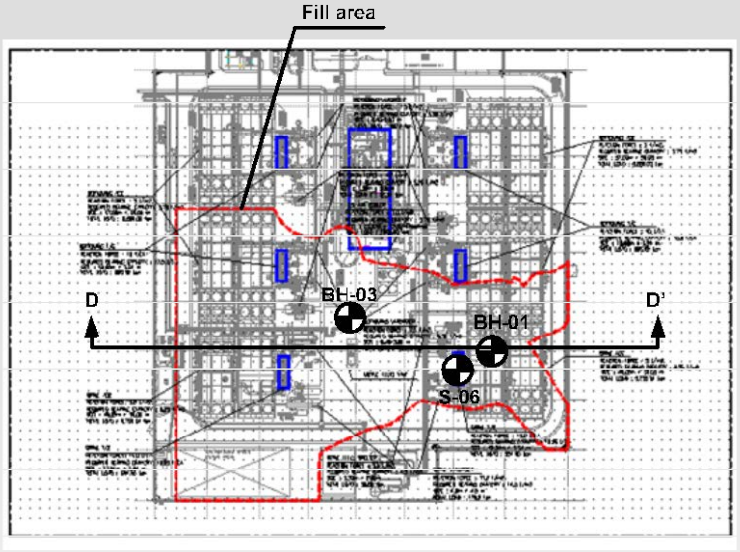
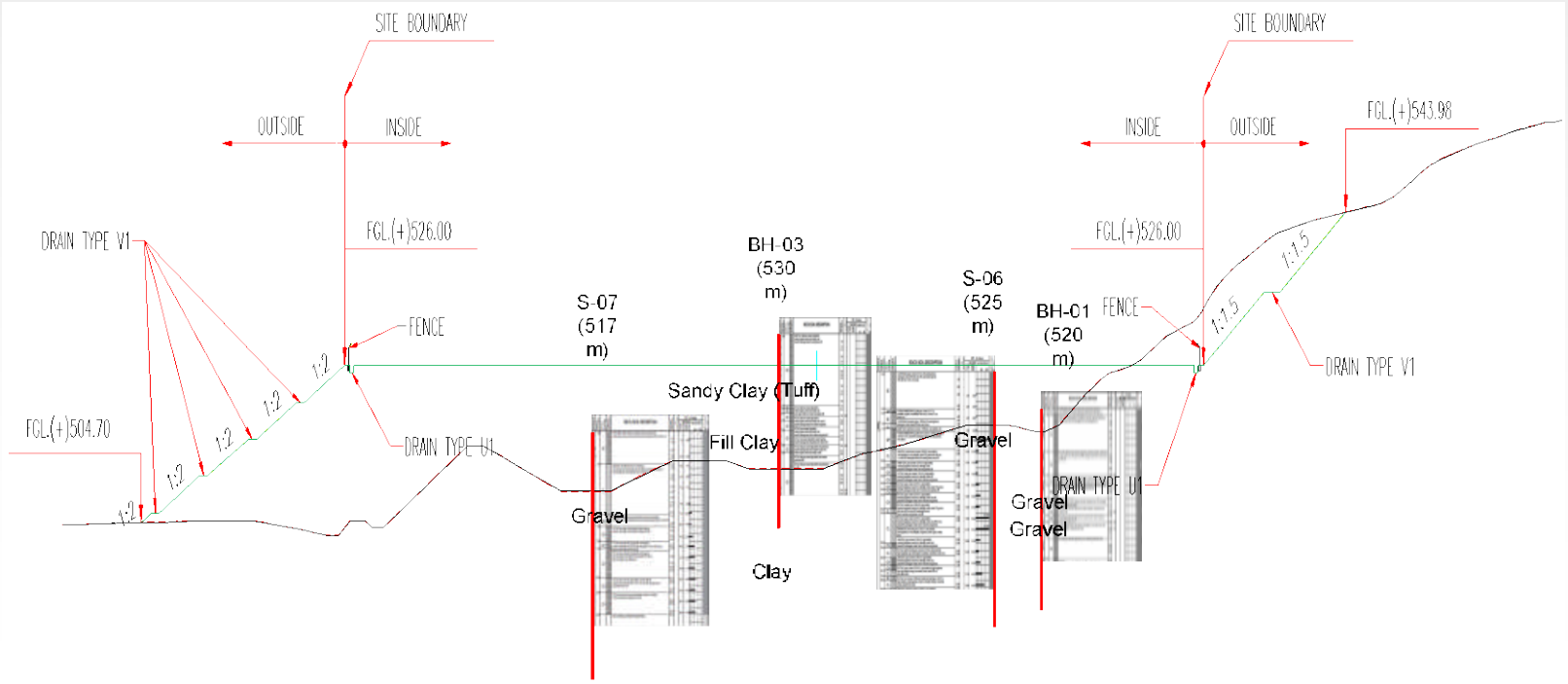


Figure 2. Layout of the Sil Area at Sarulla Power Plant



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

Table 4. DCM trial mixing laboratory result (Data from PT. Soilens)

Borhole	Depth of sample (m)	Cement Ratio (%)	Curing Time (days)	UCS, qu (kg/cm²)	Modulus, E (kg/cm²)	E/qu
BH-1	0.00 - 2.50	9	7	18.50	2000	108
			14	19.93	1875	94
			28	21.25	1875	88
		11	7	26.35	3600	137
			14	32.40	2000	62
			28	36.26	1875	52
		13	7	29.00	5000	172
			14	32.28	2750	85
			28	41.13	1800	44
		15	7	32.25	2500	78
			14	35.33	2000	57
			28	43.64	2400	55
		17	7	40.39	3000	74
			14	44.15	3000	68
			28	45.97	2000	44
	2.50 - 5.00	9	7	15.37	2000	130
			14	17.38	1375	79
			28	21.76	1500	69
		11	7	28.38	4250	150
			14	32.40	2500	77
			28	38.03	3000	79
		13	7	33.49	4000	119
			14	39.64	3000	76
			28	47.43	3000	63
		15	7	37.57	3500	93
			14	45.32	2750	61
			28	52.30	3000	57
		17	7	40.17	5500	137
			14	47.94	3250	68
			28	54.68	3500	64
	5.00 - 7.50	9	7	22.13	2000	90
			14	28.52	2250	79
			28	30.25	2750	91
		11	7	28.98	3000	104
			14	32.28	2500	77
			28	36.25	2500	69
		13	7	34.51	3500	101
			14	36.75	2250	61
			28	38.37	3000	78
		15	7	35.44	3000	85
			14	39.00	1875	48
			28	47.38	2500	53
		17	7	37.64	6000	159
			14	42.05	2250	54
			28	48.78	2500	51

Borhole	Depth of sample (m)	Cement Ratio (%)	Curing Time (days)	UCS, qu (kg/cm²)	Modulus, E (kg/cm²)	E/qu
BH-3	0.00 - 3.00	9	7	24.33	2200	90
			14	29.68	2000	67
			28	30.32	1500	49
		11	7	33.94	2500	74
			14	34.15	1875	55
			28	38.99	2500	64
		13	7	40.67	3125	77
			14	42.18	2500	59
			28	43.15	3125	72
		15	7	44.19	2500	57
			14	47.29	2750	58
			28	52.33	3000	57
		17	7	45.08	3000	67
			14	48.78	2500	51
			28	53.99	3250	60
	3.00 - 6.00	9	7	20.83	3000	144
			14	22.47	2500	111
			28	26.51	2000	75
		11	7	28.70	2250	78
			14	32.97	2250	68
			28	35.00	3000	86
		13	7	31.29	1400	45
			14	35.73	1500	42
			28	46.25	2250	49
		15	7	33.07	4250	129
			14	40.98	2200	54
			28	46.58	3250	70
		17	7	39.02	2750	70
			14	46.57	2000	43
			28	47.38	2200	46
	6.00 - 9.00	9	7	20.69	2250	109
			14	27.60	2250	82
			28	31.63	3000	95
		11	7	24.69	3000	122
			14	30.63	2000	65
			28	33.09	2000	60
		13	7	33.00	2375	72
			14	36.68	2750	75
			28	40.91	2500	61
		15	7	35.07	2500	71
			14	38.97	2250	58
			28	44.29	2750	62
		17	7	37.74	2500	66
			14	42.52	2000	47
			28	53.15	2400	45

Cement Ratio 9% is acceptable.

Sarulla Geothermal Power Plant Project

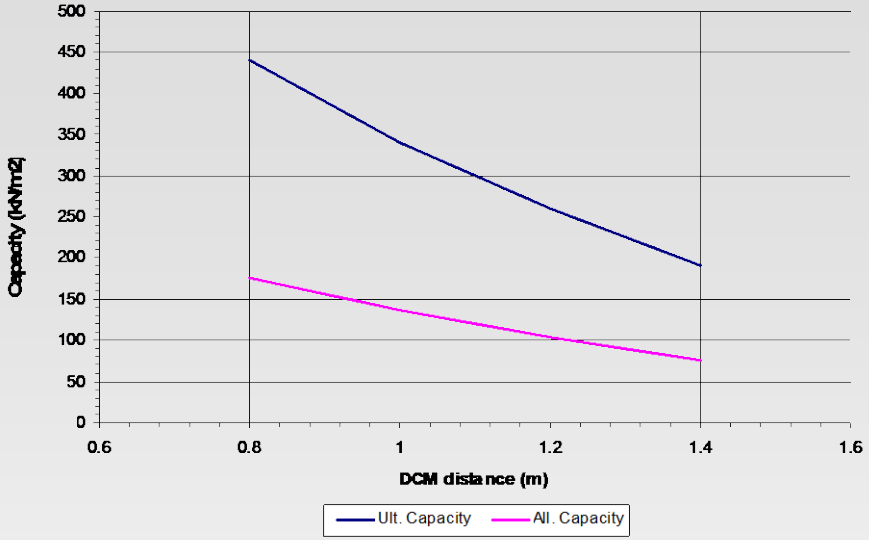


Figure 14. DCM distance vs Capacity

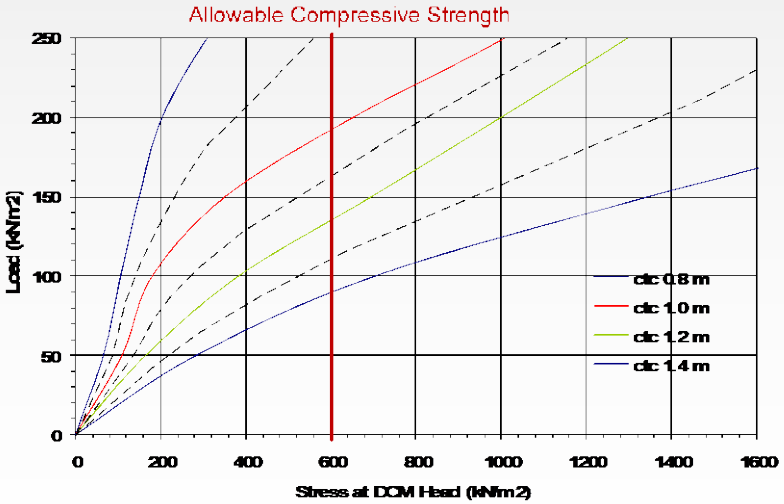


Figure 15. Stress at DCM head vs Load

Sarulla Geothermal Power Plant Project

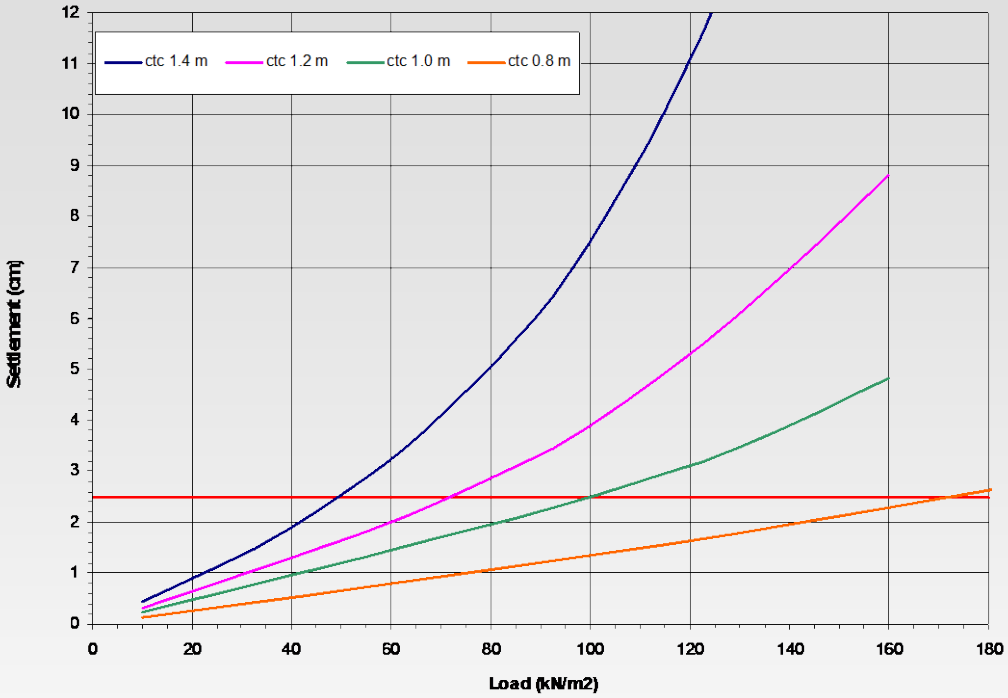


Figure 16. Load vs Settlement

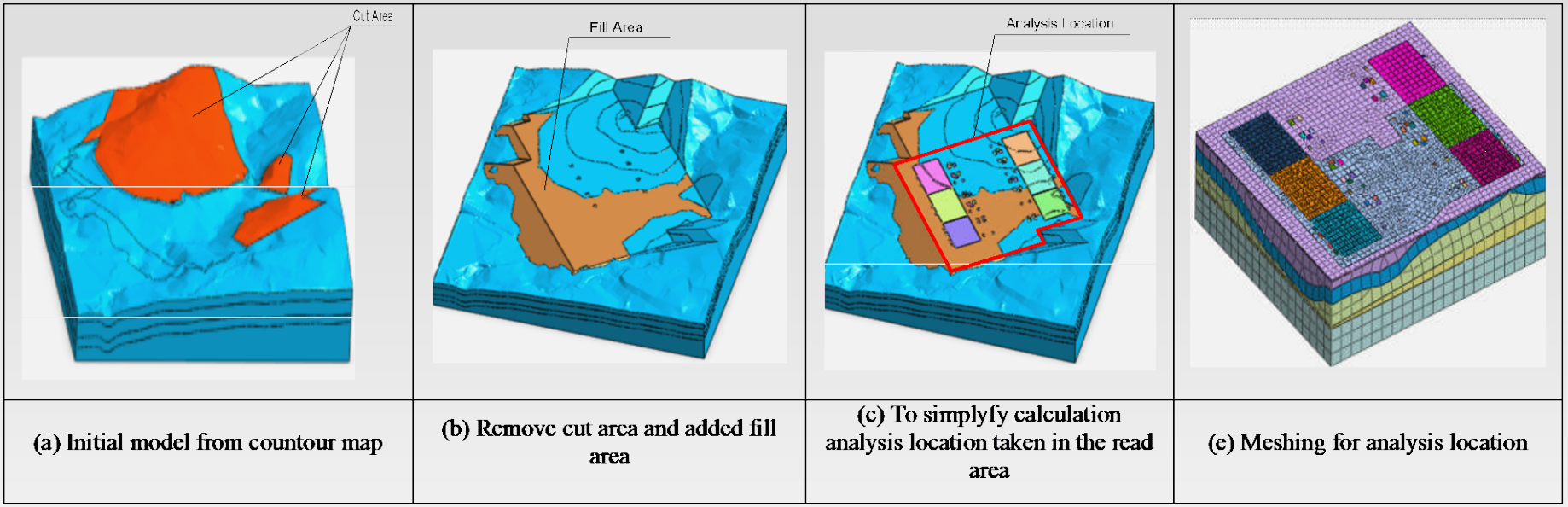
Table 7. Allowable load for 25 mm settlement

DCM Spacing (m)	Allowable Load For 25 mm Settlement (kN/m^2)
0.8	175
1.0	100
1.2	74
1.4	48

Figure 20. Load Zone for SIL area

Table 8. DCM Spacing Sarulla Power Plant - SIL area

Name	ID	Name	Foundation Size (m)	Max. Reaction (kPa)	Quantity (EA)	DCM Spacing With Raft (m)	Est. Stress at DCM Head (kN/m^2)	Load for each DCM (kN)
Zone 1	6	Brine Acc	49.02 x 39.00 x 0.40	28.3	1	1.3*	120	46
	7	Brine Elec. Shelter	3.30 x 2.60 x 0.40	34.7	1	1.3*	145	56
			4.60 x 2.30 x 0.40	34.7	1	1.3*	145	56
	8	Brine Vaporizer	4.00 x 4.00 x 0.70	87.8	2	1.1	250	96
			4.30 x 4.00 x 0.70	72.1	1	1.2	260	100
			4.70 x 3.20 x 0.70	78.8	1	1.1	200	77
	9	Brine Feed Pump	5.16 x 2.60 x 0.40	36.2	4	1.3*	116	45
Zone 2	6	Brine Acc	49.02 x 39.00 x 0.40	28.3	1	1.3*	120	46
	7	Brine Elec. Shelter	3.30 x 2.60 x 0.40	34.7	1	1.3*	145	56
			4.60 x 2.30 x 0.40	34.7	1	1.3*	145	56
	8	Brine Vaporizer	4.00 x 4.00 x 0.70	87.8	2	1.1	250	96
			4.30 x 4.00 x 0.70	72.1	1	1.2	260	100
			4.70 x 3.20 x 0.70	78.8	1	1.1	200	77
	9	Brine Feed Pump	5.16 x 2.60 x 0.40	36.2	4	1.3*	116	45
Zone 3	1	Bottoming ACC	57.00 x 39.00 x 0.40	22	1	1.3*	85	33
	2	Bottom. Cond.	4.40 x 4.40 x 1.20	76.1	2	1.1	194	75
	3	Bottom. Elec. Shelter	3.30 x 2.60 x 0.40	33.4	1	1.3*	92	35
			4.30 x 2.20 x 0.40	33.9	1	1.3*	92	35
	4	Bottoming Vaporizer	6.20 x 3.80 x 0.70	73	2	1.2	255	98
			6.40 x 4.30 x 0.70	79.1	2	1.1	198	76
	5	Bottom. Feed	2.80 x 2.60 x 0.60	97	2	1.0	178	69
	10	Cooling Water Air Cooler	3.70 x 3.70 x 0.40	63	2	1.3	270	104
			3.70 x 2.40 x 0.40	63	6	1.3	270	104
			2.40 x 2.40 x 0.40	63	4	1.3	270	104
Zone 4	1	Bottoming ACC	57.00 x 39.00 x 0.40	22	1	1.3*	85	33
	2	Bottom. Cond.	4.40 x 4.40 x 1.20	76.1	2	1.1	194	75
	3	Bottom. Elec. Shelter	3.30 x 2.60 x 0.40	33.4	1	1.3*	92	35
			4.30 x 2.20 x 0.40	33.9	1	1.3*	92	35
	4	Bottoming Vaporizer	6.20 x 3.80 x 0.70	73	2	1.2	255	98
			6.40 x 4.30 x 0.70	79.1	2	1.1	198	76
	5	Bottom. Feed	2.80 x 2.60 x 0.60	97	2	1.0	178	69
Zone 5	1	Bottoming ACC	57.00 x 39.00 x 0.40	22	1	1.3*	85	33
	5	Bottom. Feed	2.80 x 2.60 x 0.60	97	2	1.0	178	69



(a) Initial model from countour map	(b) Remove cut area and added fill area	(c) To simplyfy calculation analysis location taken in the read area	(e) Meshing for analysis location

Figure 21. 3D modeling step for full scale model

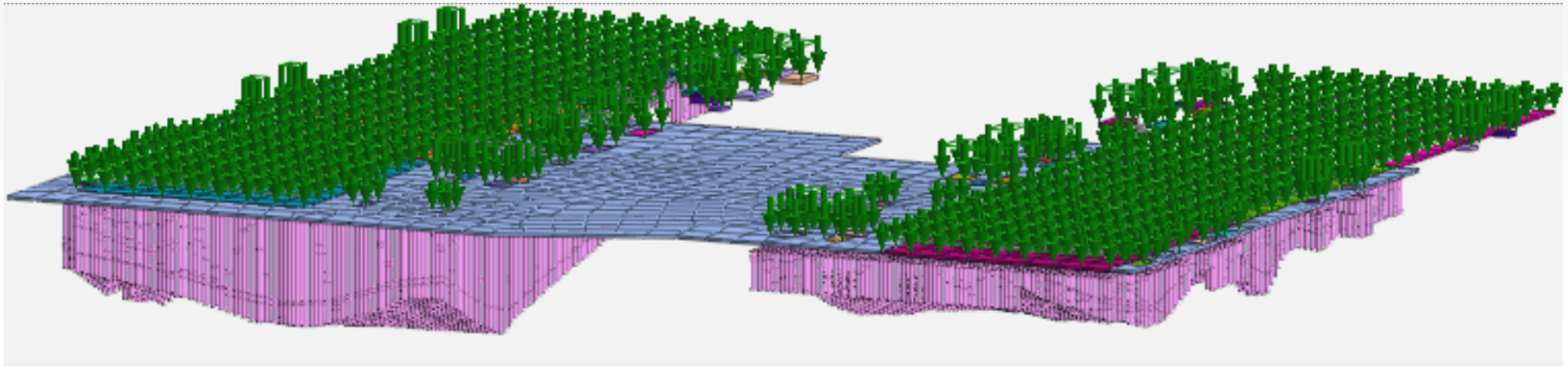


Figure 22. Raft, Cushion, DCM, & Load model

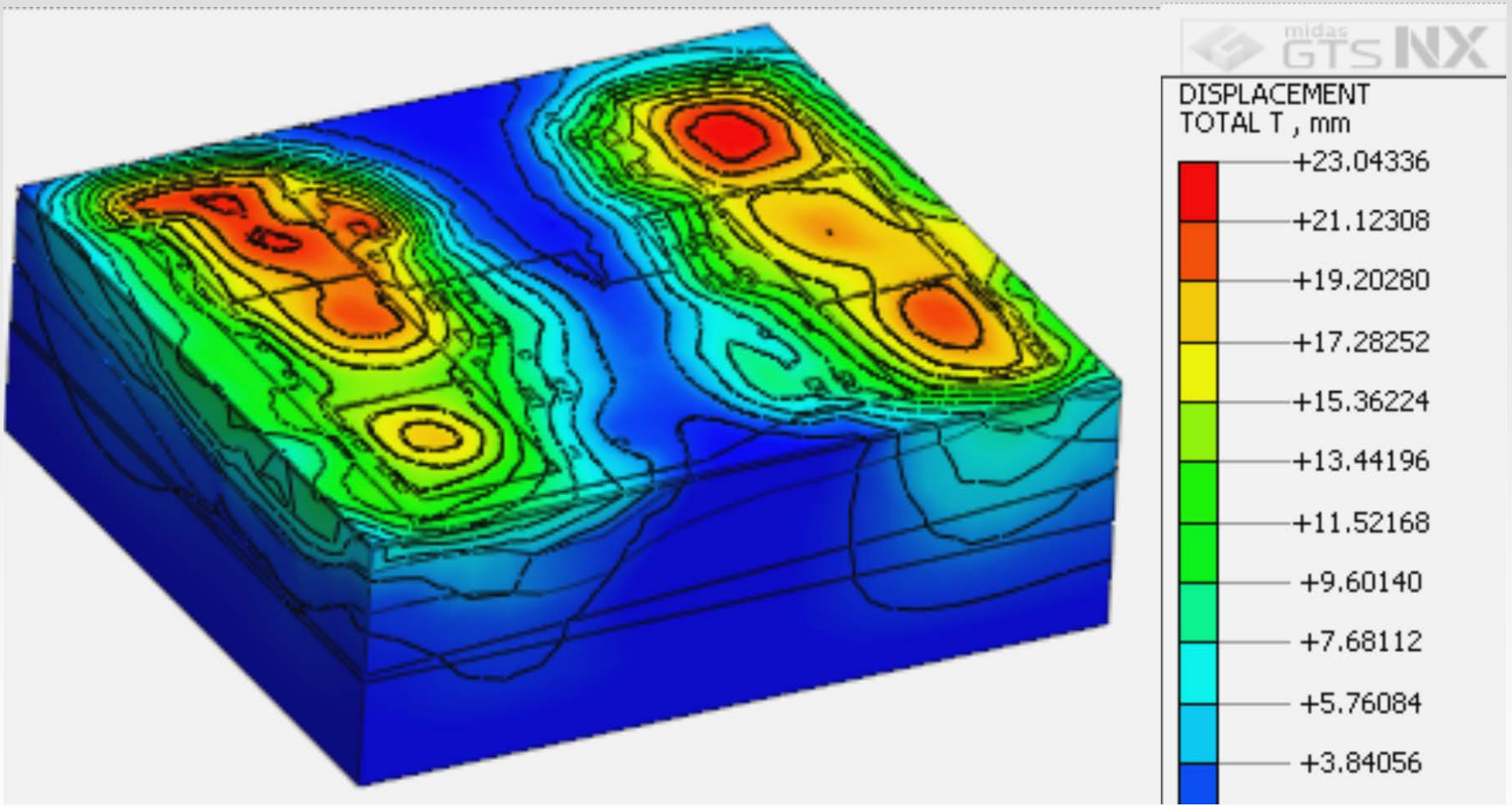
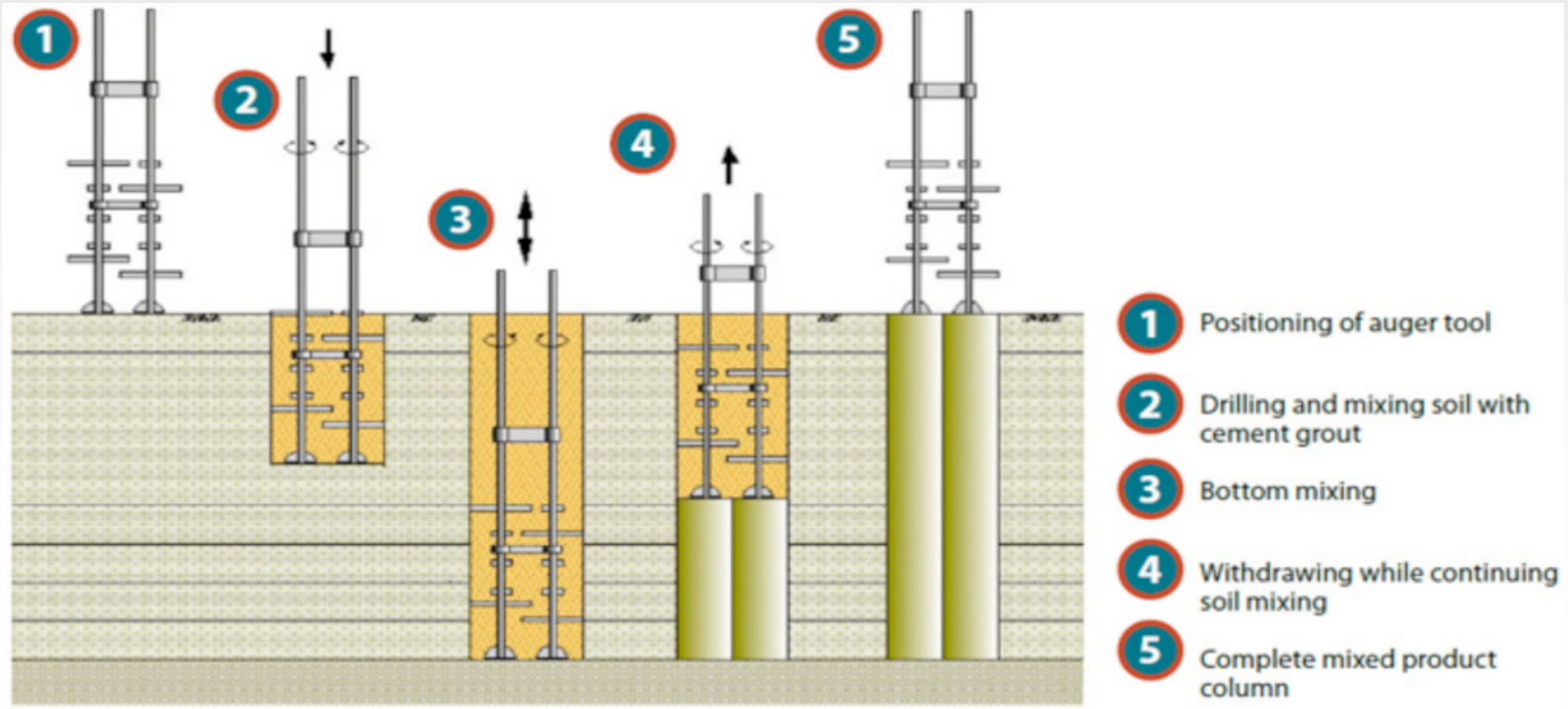


Figure 24. Analysis result for full scale model

Sarulla Geothermal Power Plant Project

Deep cement mixing (DCM) is a geotechnical technique where a binder material, typically cement, is injected into the ground for ground stabilization and land reclamation. In ground stabilization applications it is typically used to obtain a better load bearing capability of the existing soil, e.g. in order to bear buildings and other structures. In land reclamation applications it is typically used when cheaper techniques such as dredging or draining cannot be applied because of environmental concerns due to contaminated soil that these two techniques would release.



GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

GEOTEKINDO
GROUND IMPROVEMENT SPECIALIST

Sarulla Geothermal Power Plant Project

Site Condition after DCM Soil Improvement

Thank you for your attention.

Geoharbour Group

PT. Geotekindo