Seawall Found on PVDs Treated Ground with Geo-synthetic Reinforcement

AGS(HK) One-day Seminar on "Ground Improvement"

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12 May 2018

Introduction

- Project Background
- Site Setting
- PVD Principles
- Considerations and Approach
- Design and Construction
- Geotextile Reinforcement / Deformation Assessment
- Instrumentation and Monitoring
- Lesson learnt and remarks

Project Background

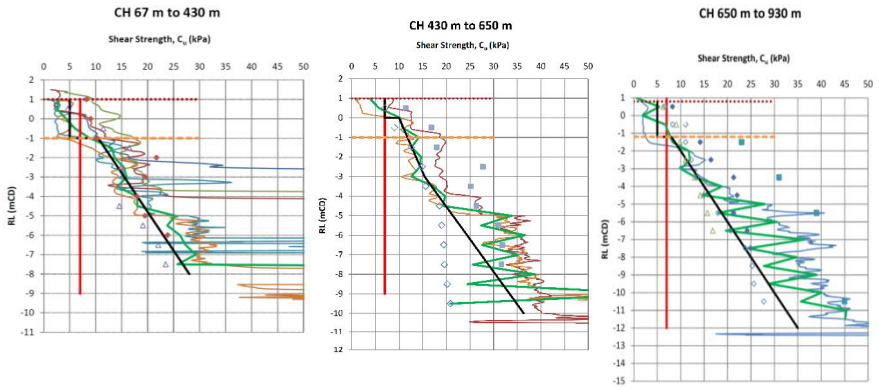
Project Background

- Port expansion Project in India
- EPC Contract, AECOM is Contractor's designer
- Reclamation and seawall for
  - container stack area,
  - access road
  - railway picking up area
- Piled quay structure in dredged basin further away connected by link bridge
  (design and constructed by others)

Site Conditions

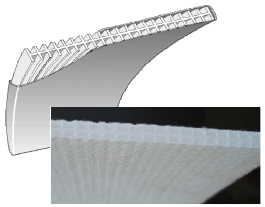
Site setting – Difficult Access to Tidal Mud Flat Area

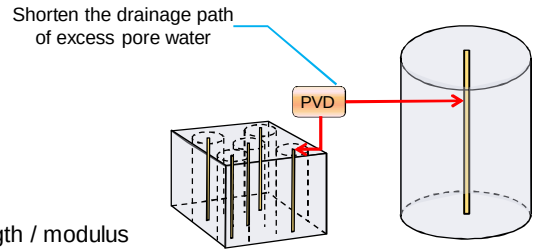
Site setting – Very soft clay



PVD Principles

PVD - What is a PVD (Prefabricated Vertical Drain)?





- Accelerate consolidation
- Increase the shear strength / modulus

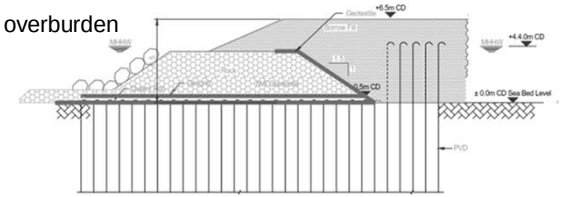
PVD is only the measure

Ground treatment - Increase in effective stress by surcharging/dewatering/vacuum

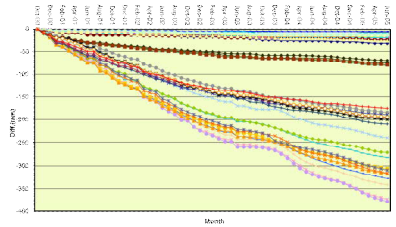
PVD - Installation

PVD principle - Why uncommon for seawall foundation in HK

- Lower strength without overburden

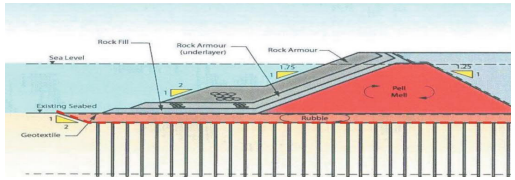


- Long consolidation time
- High uncertainty



PVD principle - Why uncommon for seawall foundation in HK

- Deep seabed level in HK and loading on soft clay foundation is high and mostly not feasible



- Very Flatten seawall slope occupied large foreshore area and environmental not preferred

Considerations and Approach

Considerations and Approach to the design – Tender Stage

- Basis of the use of PVD as seawall foundation?
- Limited choice of ground treatment due to
  - o Site conditions
  - o Available local technique / experience
  - o Availability of material (sand, gravel)
  - o Method preferred by Contractor Client
  - o Price to win the bid

Considerations and Approach to the design – Tender Stage

– Stone columns :
Not suitable for soft clay

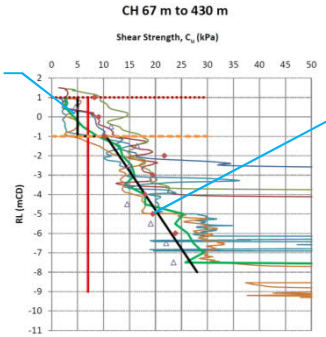
- Sand compaction piles:
Source for clean sand is restricted

Considerations and Approach to the design – Tender Stage

– Deep Cement mixing
Not available in local market and expensive

- Dynamic compaction / replacement:
Not suitable for soft clay and difficult for plant establishment

Technical Approach in Tendering Submission



Very soft clay at surface

High shear strength increment with depth

$Su / \sigma_v \sim 0.3$

How to effectively utilize the soil behaviour ?

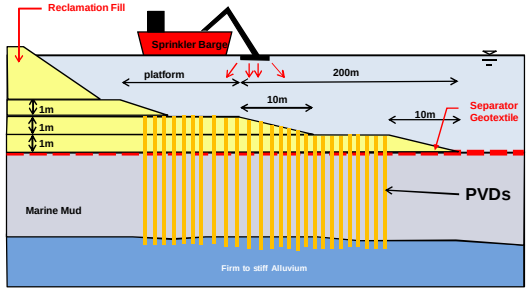
Technical Approach in Tendering Submission

Area of concerns	Measures
Low strength of Clay	Over-consolidation,
Surcharging stage stability	Stage loading allow strength gain
Short term stability	Overfilling platform before strength gain Control construction loading at edge area
Slope Toe area improvement	Extent PVD to overfilling platform
Permanent Edge stability	Geo-synthetic reinforcement
Mudwave	control by marine placing

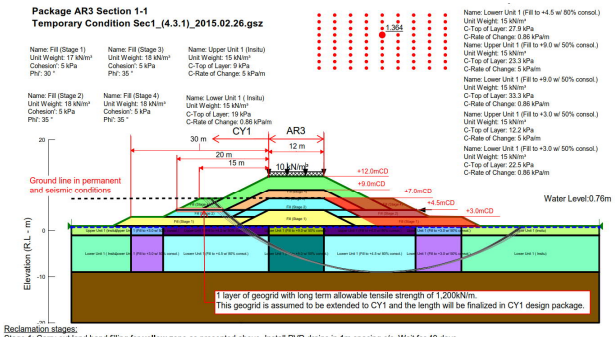
Technical Approach - Stability of Leading Edge

- Place initial fill layer (up to 2m to 3 m) carefully
  - o By sprinkling (Manual or computer controlled Sprinkler barges)
- Using geotextiles will help in stabilising the seabed
- Maintaining a gentle leading edge

Technical Approach - Stability of Leading Edge



Technical Approach – Stage preloading

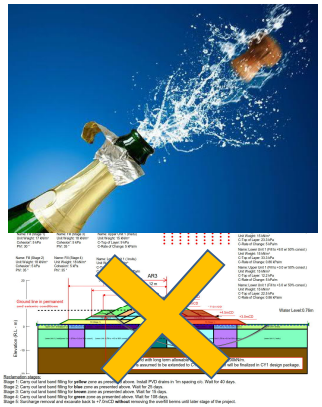


Reclamation stages:
Stage 1: Carry out land band filling for **yellow** zone as presented above. Install PVD drains in 1m spacing c/c. Wait for 40 days.
Stage 2: Carry out land band filling for **blue** zone as presented above. Wait for 25 days.
Stage 3: Carry out land band filling for **brown** zone as presented above. Wait for 15 days.
Stage 4: Carry out land band filling for **green** zone as presented above. Wait for 108 days.
Stage 5: Surcharge removal and excavate back to +7.0mCD **without** removing the overfill berms until later stage of the project.

Commencement of work

- Contractor client win the bid
- No construction jetty around
- Only murrum fill bring by truck
- Marine access is very limited if not impractical

- No marine fill placement
- Land placement is only choice
- Reassess all stability and construction sequence



Technical Approach during Construction Stage - What contractor need?

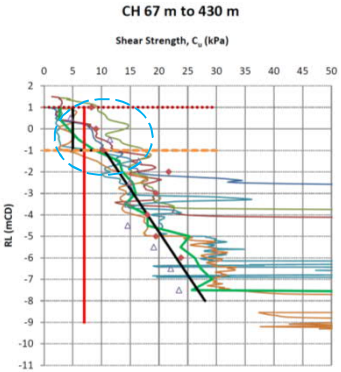
- Contractor need a stable land platform for
  - Install PVD and monitoring devices - Field testing
  - Placing drainage and geotextile filter - Surcharge in stages

Construction Stage – End Tipping

- End tipping and land filling is unavoidable
- How we can
  - Control it
  - maintain Stability

Construction Stage – End tipping

- Displace very weak soil away
  - Very weak at top 2-3m
  - stronger at about -1mCD
- Displacing the very soft mud away can <u>significantly improve the stability</u>
- How to
  - Ensure workmanship
  - Utilise mud in stabilisation
  - Removal



Construction Stage – End tipping and Mudwave

Construction Stage – Observational approach

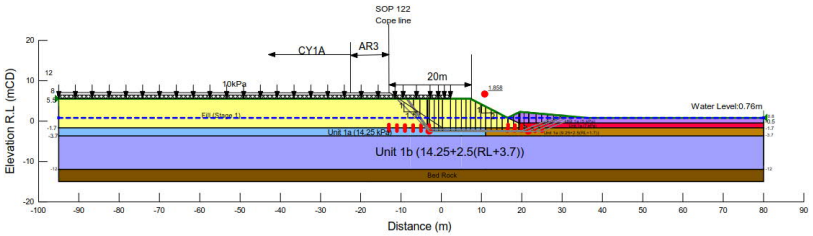
- Prepare the design
- Test with full scale intermediate embankment to:
  - verify consolidation strength gain
  - verify amount of settlement
  - verify amount of deformation
- Obtained back analysis parameters
- verify the design of subsequent phase seawall

Construction Stage – Seawall design and construction

- Create 10m wide access road by land filling
  - Post-fill placement borehole
  - verify displacement of mud and potential mud pocket
  - More filling front to speed up progress
- Fill between access road to form land platform

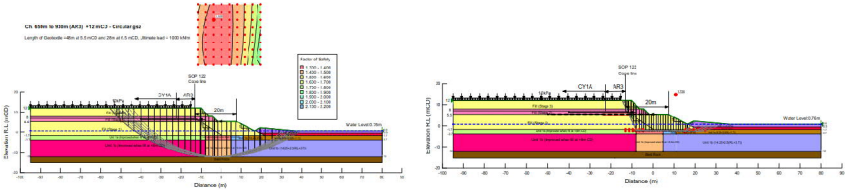
Construction Stage – Seawall design and construction

- Overfilling platform in front of permanent seawall
- Mud wave as toe weight
- Adequate platform width → Smaller deformation at permanent seawall area



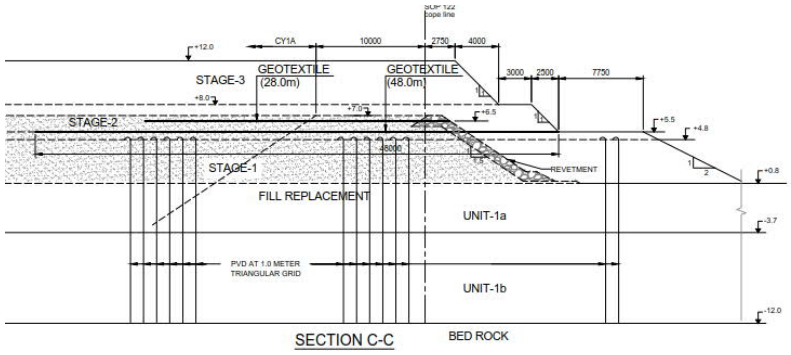
Construction Stage – Seawall design and construction

- Filling → Pause period → Verify Strength gain → Next filling stage → Pause Period … until surcharge top
- Overfilling a wider platform **Vs** longer waiting time



- Check
  - stability - geotextile anchor length - surcharge pressure and period

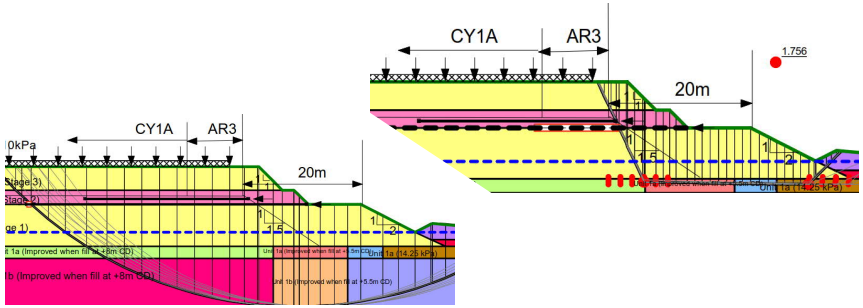
Construction Stage – Seawall design and construction



Geotextile Reinforcement / Deformation Assessment

Construction Stage – Geotextile Reinforcement

- Provide lateral support during filling
- Sufficient long to provide anchorage until global slip is stable



Construction Stage – Geotextile Specification

- Woven type geotextile with 3 ultimate strength (950, 750, 550kN) for different area

PRODUCT PROPERTIES		TEST METHOD	UNIT	TFI-31000
MATERIAL		100% High Tenacity Polyester Filament Yarn With Molecular Weight ≥25000 and CEG ≤30		
MECHANICAL PROPERTIES				
Ultimate Tensile Strength	(MD/CD)	EN ISO 10319	kN/m	≥ 1000/50
Strain at Ultimate Tensile Strength	(MD/CD)	EN ISO 10319	%	10 ± 2
Tensile Strength at 5% strain	(MD)	EN ISO 10319	kN/m	415
Tensile Strength at 10% strain	(MD)	EN ISO 10319	kN/m	1000
Tensile Modulus at 5% strain	(MD)	EN ISO 10319	kN/m	8100
Tensile Modulus at 10% strain	(MD)	EN ISO 10319	kN/m	10000
Long Term Design Strength (LTDS) Partial Reduction Factor for Creep RFcr at 20 °C = 1.40 (60 years) Partial Reduction factor for Installation Damage RFid = 1.10 (in Clay, Silt or Sand) Partial Reduction factor for Durability RFd = 1.00 (Geotextile to be covered in 1 day & for Ph = 4 to 8) fs = Factor for extrapolation of data = 1.0	(MD)		kN/m	≥ 635
Puncture Strength		EN ISO 12236	N	>1500
Trapezoidal Tear Strength		ASTM D 4533	N	>300
UV resistance at 500 h retained strength		ASTM D 4355	%	50

- Long term reduction factor is about 1.5 with design strength >625 kN/m

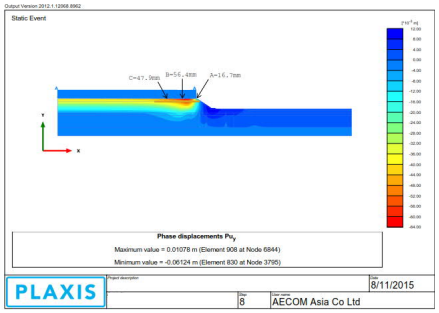
Construction Stage – Seawall Deformation

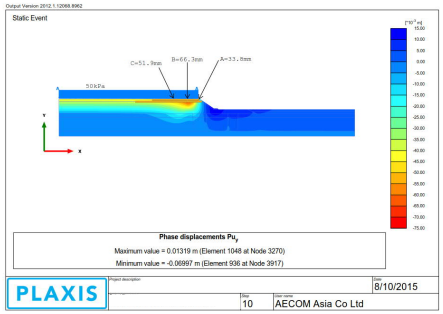
- Assess the amount of deformation of permanent conditions
  - Consideration of the high plasticity soil, lower deformation modulus assumed Su =100cu

Section	Check Point Location	Vertical Displacement (mm)	Horizontal Displacement (mm)
CH67-430	Point A	9.4	10.1
	Point B	33.4	15.2
	Point C	26.7	10.2
CH430-650	Point A	16.7	19.1
	Point B	56.4	27.5
	Point C	47.9	19.9
CH650-930	Point A	33.8	25.1
	Point B	66.3	34.9
	Point C	51.9	27.0

  - Movement under live load after permanent seawall formed

Construction Stage – Seawall Deformation





Construction Stage – Seawall Deformation

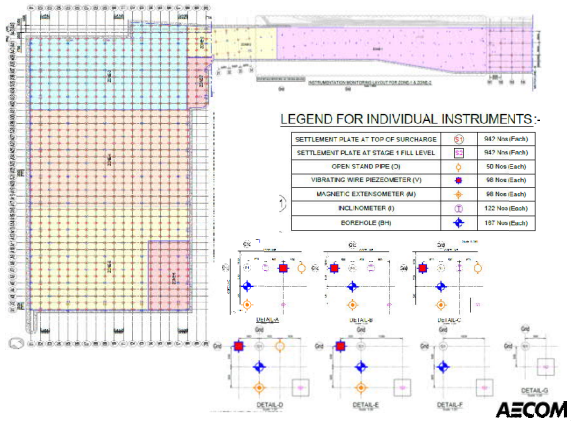
- More vertical than lateral deformation, possibly due to
  - Analysis does not include construction stage soil stress (Simplify to avoid couple model with a lot of uncertainty)
  - Tensile reinforcement at 0% strain at the initial stage of the model Deformation and stressing geotextile to develop the tensile strength
- Actual situation, reinforcement placed earlier and some lock-in stress during the earlier stage

Construction Stage – Seismic conditions

- Deformation Assessment under seismic conditions is required, soil degradation according to Eurocode 8, E' reduce to 20%
- No seismic design parameters obtained from field SI work
- Use empirical approach to estimate the shear wave velocity Vs using
  - SPT-N method for Mumbai Clay **Vs = 72 (N)^0.40**
    Mhaske and Choudhury, 2011, Geospatial contour mapping of shear wave velocity for Mumbai city,Natural Hazards, 59(1), 317-327
  - Vs from Su for San Francisco Bay Mud **Vs = 23 S_u $^{0.475}$**
    Wair and DeJong, 2012, Guidelines for Estimation of Shear Wave Velocity Profiles, PEER
- Deformation is well within the requirement and smaller than static case
- Results shown in this presentation is not the most critical section

Construction Stage – Instrumentation and monitoring plan

- Instrumentation along the seawall to monitor
  - Lateral deformation
  - Settlement
  - Excess pore pressure dissipation

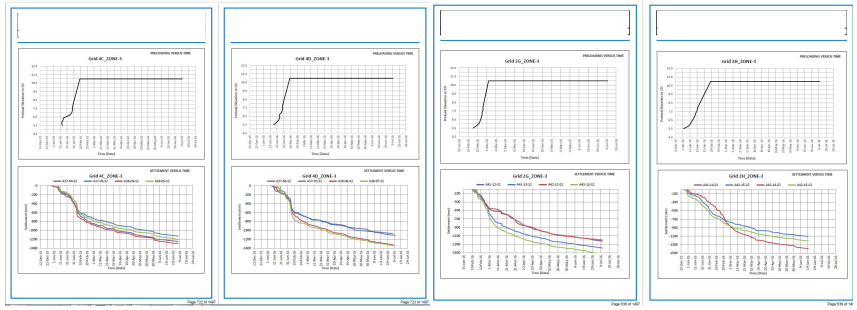


Construction Stage – Monitoring

- Movement controlled laterally within about 100mm along the road and 300mm within the stack area of high surcharge load and deeper seabed

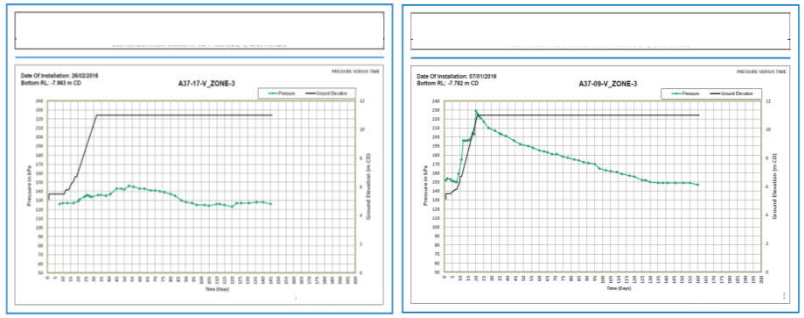
Construction Stage – Monitoring

- Relatively small Settlement ~0.8 to 1.5m for 6 to 12m thick mud



Construction Stage – Monitoring

- Excess pore pressure, always stagnation pressure



Lesson Learnt and Remarks

Lesson Learnt and Remark

- PVD as seawall foundation is a feasible solution but with quite a lot of constraints
  - Need very Shallow seabed / mud flat
  - Allow overfilling
  - Amount of strength gain is very important
  - Very soft can be easily displaced and need provision to remove/treated
- Geotextile reinforcement can limit the deformation and need to consider
  - stressing and strain level during construction
  - Subsequent-construction works protection

Lesson Learnt and Remark

- Understand what you are going to built
  - Work closely with the contractor on the actual method of construction
    - Fully non-dredge → Partial mud wave heaving → Large displacement of mud
  - Observational approach is very practical to overcome uncertainty in the soft ground treatment design

The reclamation work completed and the port was open in 2018


Thank You