

Short PVDs method and horizontal drainage enhanced geotextile (HDeG) method for the improvement of soft clay fills

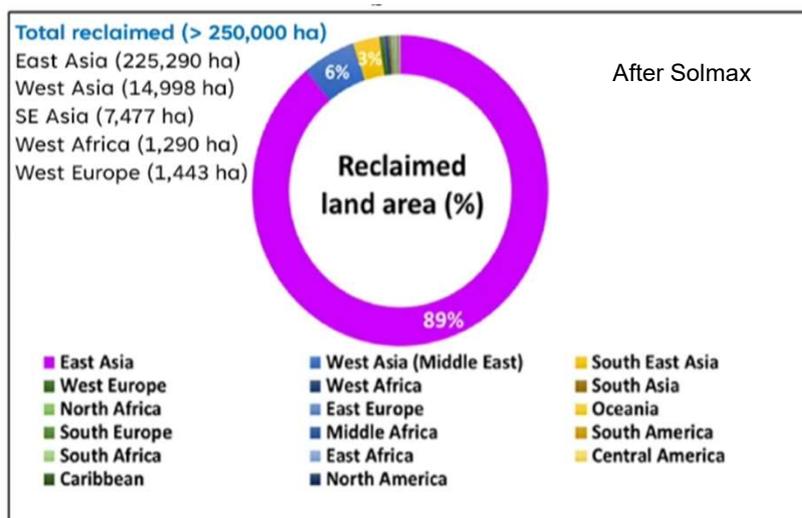
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*President's Chair Professor, Chair, School of Civil & Environmental Engineering
Director, Centre for Urban Solutions, Nanyang Technological University, Singapore



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Land Reclamation between 2000 and 2020

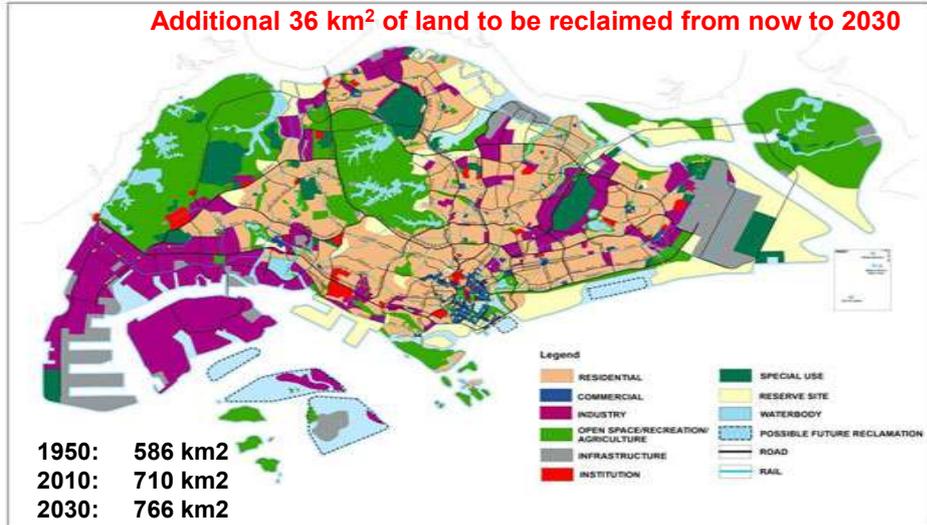


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Land reclamation in Singapore

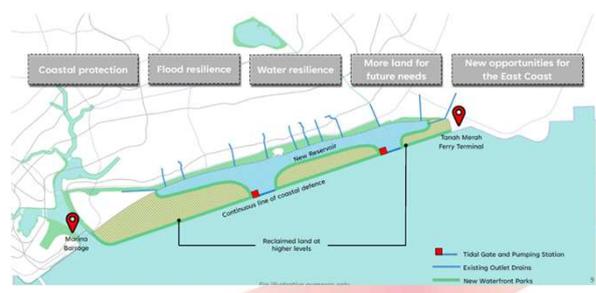
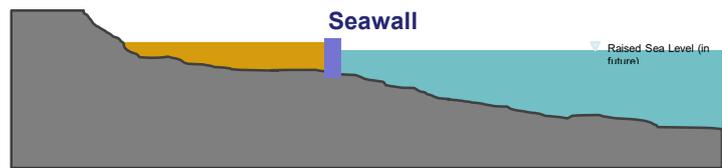


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Challenges of sea level rise

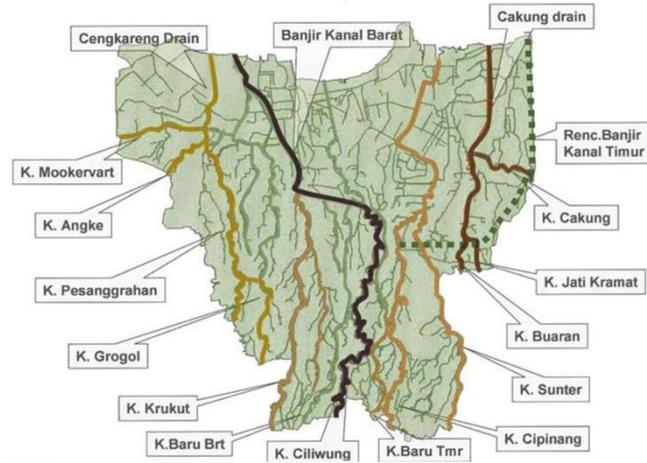


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Use dredged soil from the rivers for land reclamation



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Maintenance dredging materials for land reclamation of Port of Brisbane



Channel maintenance dredging materials consisting of river muds capped with sand was used. The thickness of the fill was up to 9 m. The seabed compressible clay was over 30 m.



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Outline

- **Two Methods for improvement of soft clay fills**
 - Short PVD + vacuum method
 - Horizontal Drainage enhanced Geotextile (HDeG) sheet method



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Types of dredged soils



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Difficulties in the use of slurry for land reclamation

- The top surface is too soft for workers and machines to go on top to carry out soft improvement work.
- How to form a working platform
 - ***The one with the lowest unit cost!***



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METHODS FOR FORMATION OF WORKING PLATFORM ON ULTRA SOFT GROUND



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Formation of a working platform

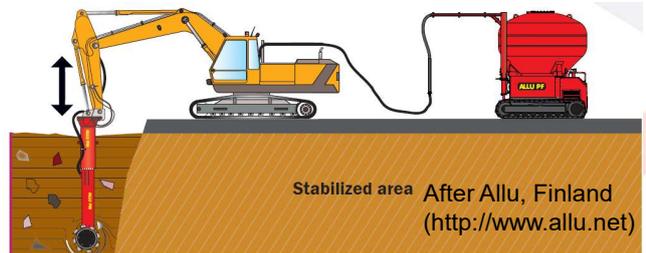


In-situ treatment of dredged materials for Port of Valencia, Spain. A working platform was formed on top of muddy deposit ($c_u=75$ kPa)



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Use a layer of sand

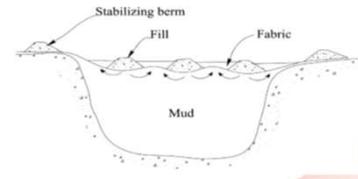
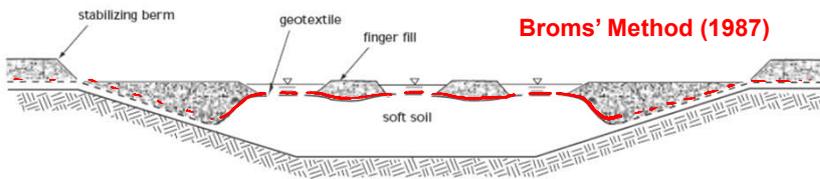
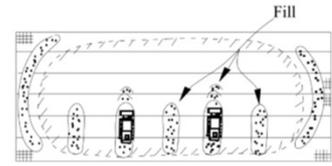
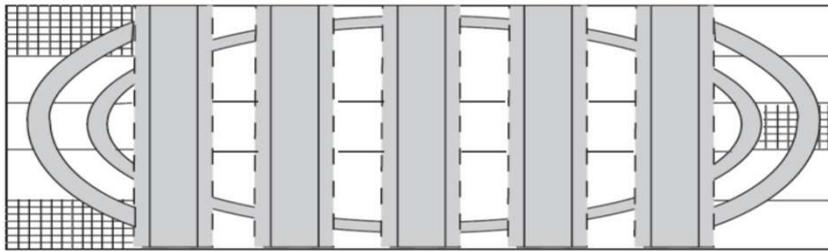


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Broms method using geofabric



Broms' Method (1987)



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Field trial - Placement of geotextile/geogrid

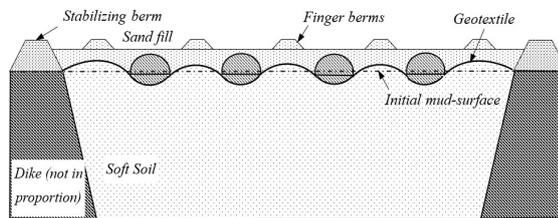
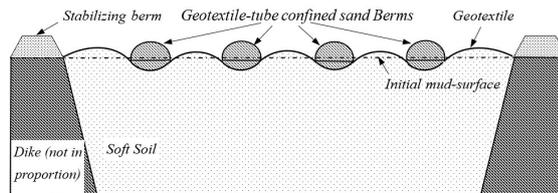
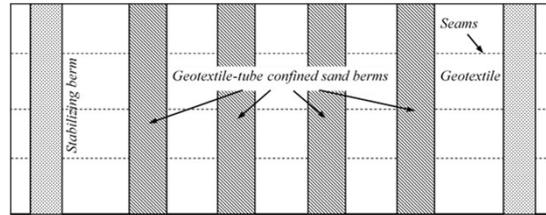


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Modified Broms' Method



Chen, Chu, Guo & Lam (2021) [Modified Broms' method for formation of working platform on very soft soil](#), Geotextiles and Geomembranes

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Land reclamation and soil improvement method for soft fills

Version 1 -V1

Fill materials:

- Grabbed lumpy soil for below -3 mCD
- Clay slurry or sand for above -3 mCD

Soil Improvement Method: Use two rounds of Vacuum preloading (VP):

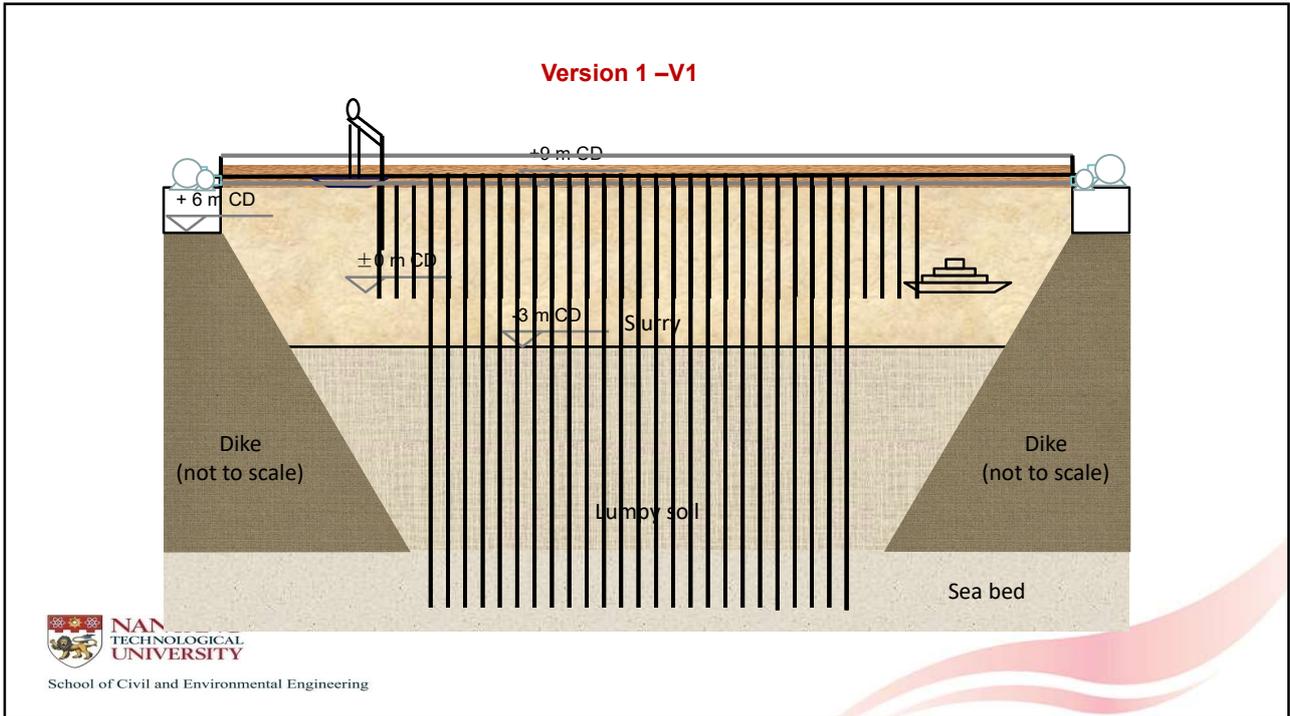
- R1: Use special VP to consolidate the top 4-5 m of slurry fill to form a working platform
- R2: Use conventional VP to improve the whole soft fill layers and the soft seabed soils



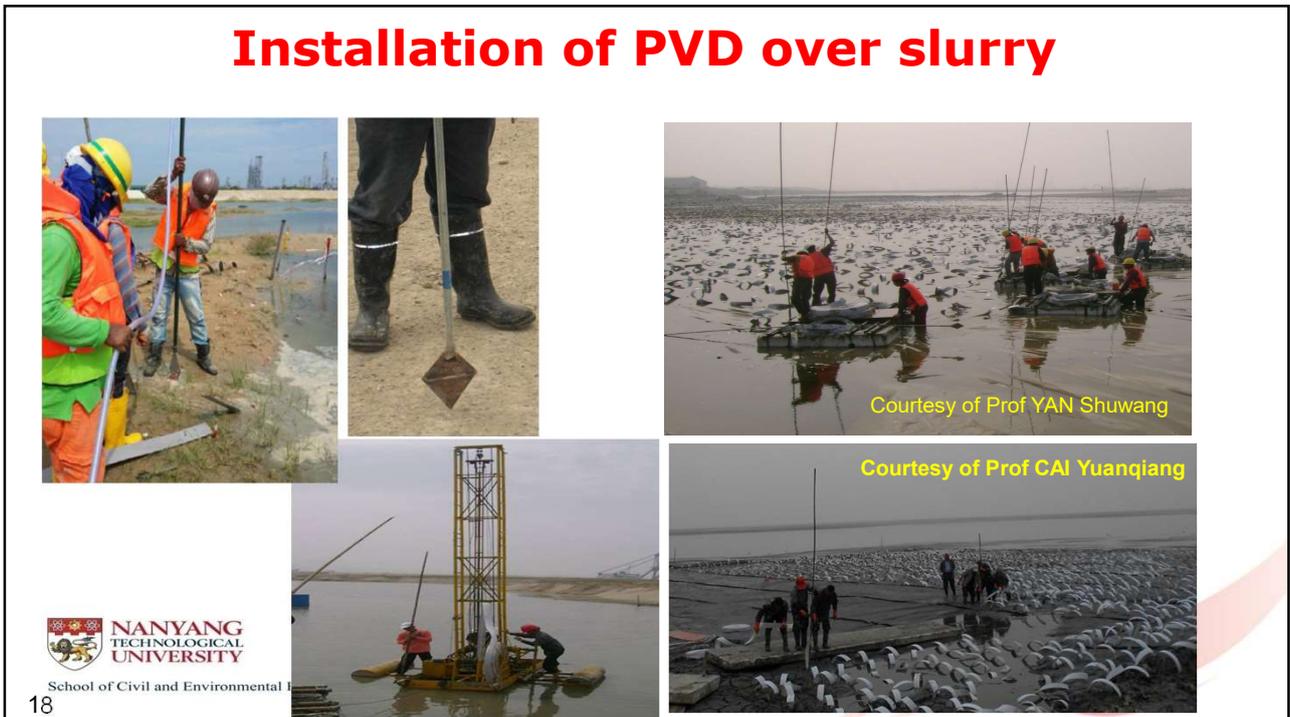
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Case studies from Singapore by Santarli Construction



Ang, Seet & Chu (2017). Slurry Clay as Infill Material for Land Reclamation in Singapore, Conference on Soil Improvement and Case Studies.



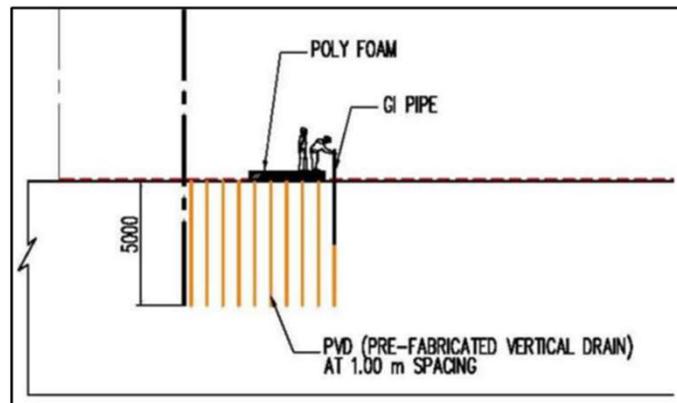
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Parameter	Units	Range	Average
Moisture Content, w	%	82 to 133	98.5
Unit Weight, γ	KN/m ³	11.7 to 16.3	14.6
Liquid Limit, w_L	%	69 to 90	78.25
Plastic Limit, w_P	%	29 to 47	34.5
Void Ratio, e	-	2.23 to 3.52	2.58

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Installation of Short PVDs



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Vacuum with membrane, but without sand blanket



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Cover the PVDs with membrane for vacuum

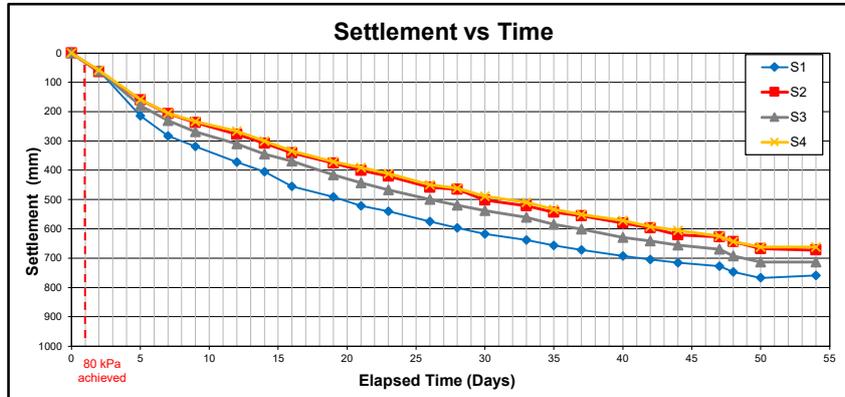


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Monitoring Data – Settlement

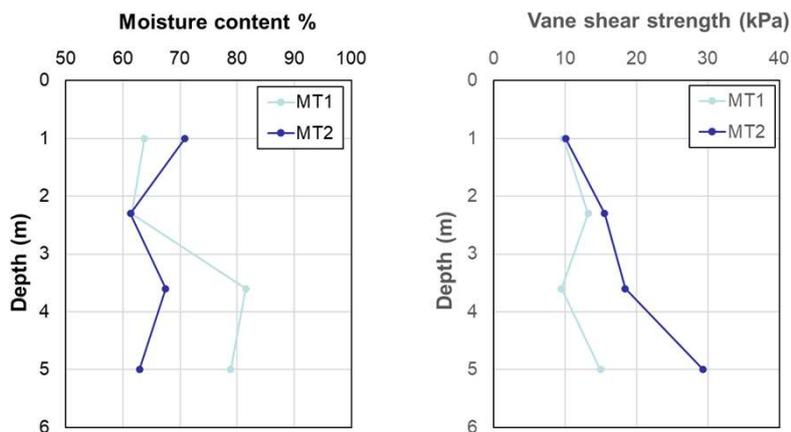


Degree of consolidation = 85% (Asaoka Method)



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Monitoring Data – Vane Shear Strength



- ✓ The average undrained shear strength is within 10 to 15kPa
- ✓ The bearing capacity may be estimated to be in the range of 51 to 77kPa using $5.14c_u$



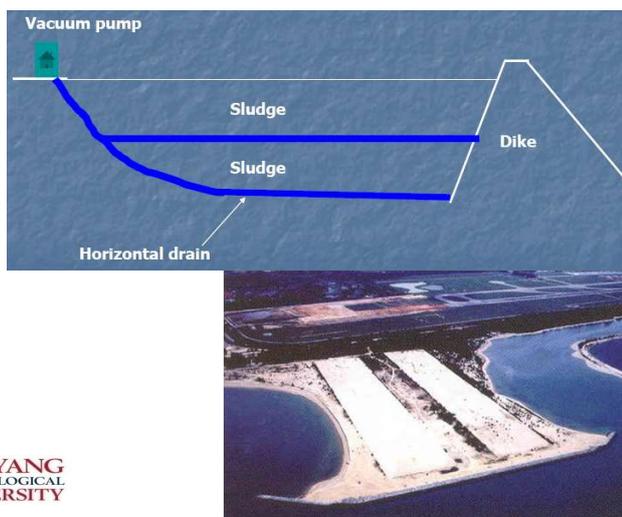
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Difficulties in using PVDs

- Need a working platform which is difficult and time consuming to build;
- Soil improvement can only be carried out **after** all the fill materials have been placed and the working platform has been formed;
- **Difficult to design due to large uncertainties** Due to large compressibility, more fill materials need to be placed and more reconsolidation... Difficult to estimate the final level. Time consuming;
- **Maximum preloading is 80 kPa**



Use of horizontal drains

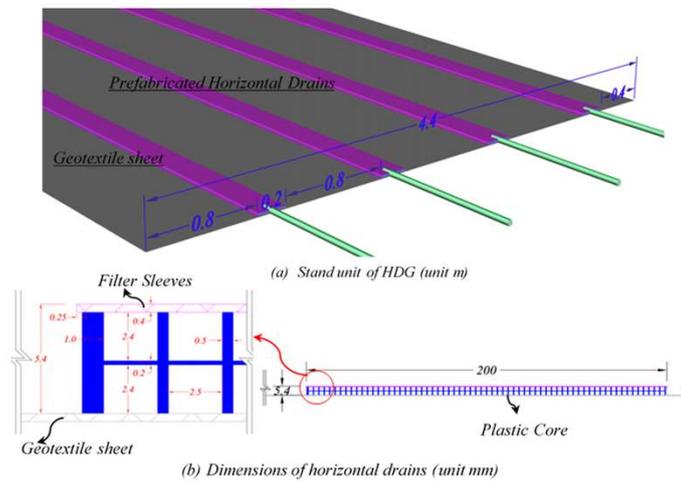


**Horizontal
drain +
vacuum
method:**

**To save time &
construction
cost**



Horizontal Drainage enhanced Geotextile sheet (HDeG)



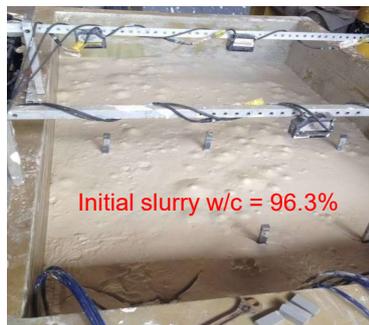
Patented by Chu and Guo (2015)

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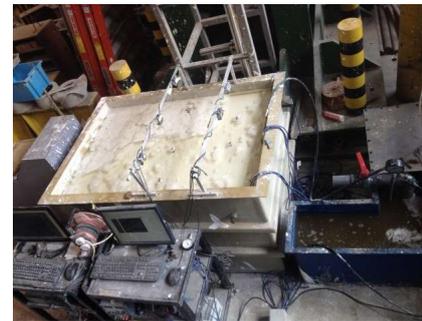
Model tests for HDeG



(a) Position of the HDeG



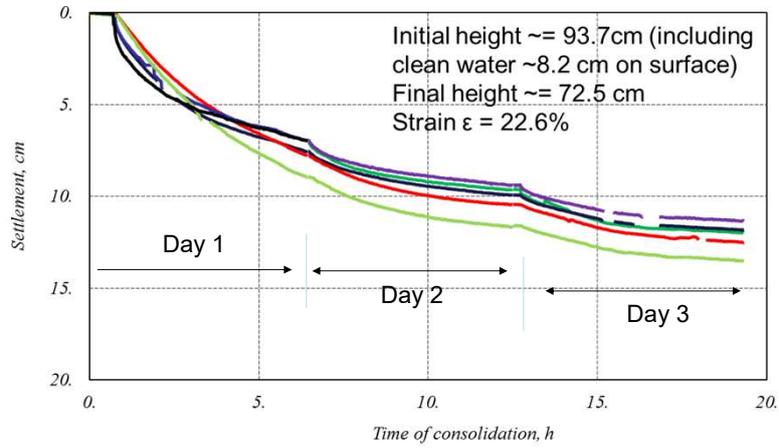
(b) Fully filled by sludge with instrumentation



(c) Model test set up with vacuum pressure

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Model testing results

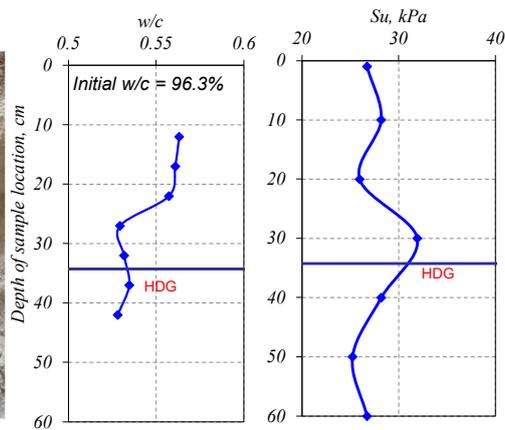


Surface settlement versus time curves



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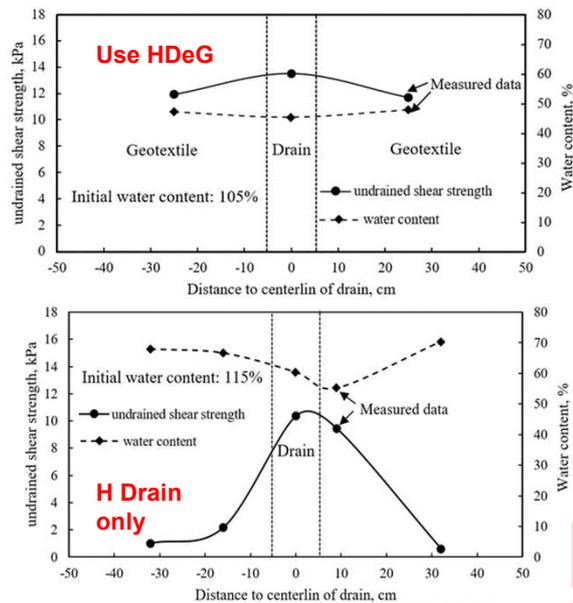
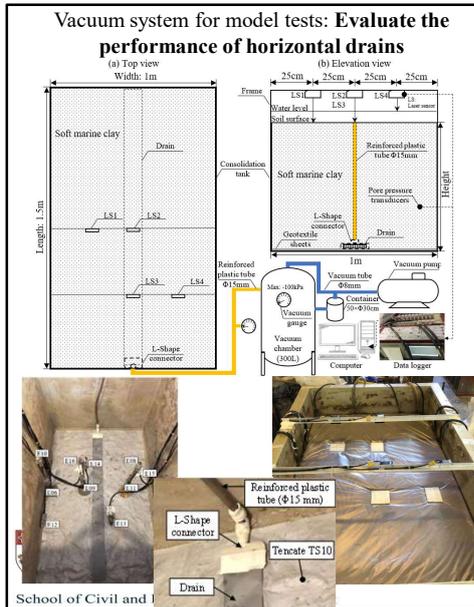
Model testing results



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More Model Tests using HDeG (Chen, 2021)

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Advantages of HDeG

- Vacuum pressures can be applied layer by layer while the fill materials are placed;
- Fills on top of the horizontal drains become surcharge;
- No sand fill (or sand blanket) is required;
- **Save time:** Soil improvement is completed soon after the last layer of fill has been placed;
- **More reliable design:** Settlements and the amount of fills used can be calculated more reliably;
- Treatment is more uniform
- **Disadvantages:** Need to install HDeG over water

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Summary

- Two methods for consolidation of clay slurry fill were presented:
 - Short PVD + vacuum preloading
 - HDeG + vacuum preloading
- The short PVD + vacuum method has been proven to be effective. However, like other methods using PDs, this method is time consuming.
- The HDeG method is proposed for land reclamation using clay slurry. It saves time, allows application of larger surcharge and the treatment is more uniform.



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Acknowledgements

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Thank you!



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