AGS Seminar on Soft Soil Engineering

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Engineering Design and Earthworks Aspect Related to Soft Soils at Busselton

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Soft Soils include…..

- Clays and Silts which are generally
  - Saturated with water
  - Possess low shear strength < 20kPa
  - Highly compressible
- These sometimes contain organic material

Compressible Clays in Busselton

Serial No.	Range of Depth (m)	Soil Decribtion Interpretented from EFCPT Tests @ Different Locations		
		CPT 6	CPT 5	CPT 4
1	0.0 - 0.5m	SAND WITH SIGNIFICANT		
2	0.5m - 1.0m			
3	1.0m - 1.5m		SAND WITH SIGNICANT SHELL	SAND WITH SIGNICANT SHELL
4	1.5m - 2.0m	Peat/Clay		
5	2.0m - 2.5m	SAND WITH SIGNICANT SHELL		
6	2.5m - 3.0m			
7	3.0m - 3.5m	SANDY & SILTY CLAY		
8	3.5m - 4.0m	SAND		
9	4.0m - 4.5m			
10	4.5m - 5.0m	DENSE OR CEMENTED SAND		
11	5.0m - 5.5m	REFUSAL	SAND	SANDY & SILTY CLAY
12	5.5m - 6.0m			
13	6.0m - 6.5m			
14	6.5m - 7.0m			
15	7.0m - 7.5m		SANDY & SILTY CLAY	
16	7.5m - 8.0m			
17	8.0m - 8.5m			
18	8.5m - 9.0m			
19	9.0m - 9.5m			
20	9.5m 10.0m			

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Developing on soft soil sites

- No guidance in AS 2870:2011, call these sites Class P
- Informed Client - Development Manager
- Informed Civil designer
- Geotechnical engineers with soft soil expertise
- Specialist ground engineering processes depending on the site conditions
- Specialist validation processes
- Informed authorities

Potential Engineering Issues

- Long Term Settlement
- Differential Settlement
- Low Bearing Capacity

Earthworks options when soft soil is encountered…..

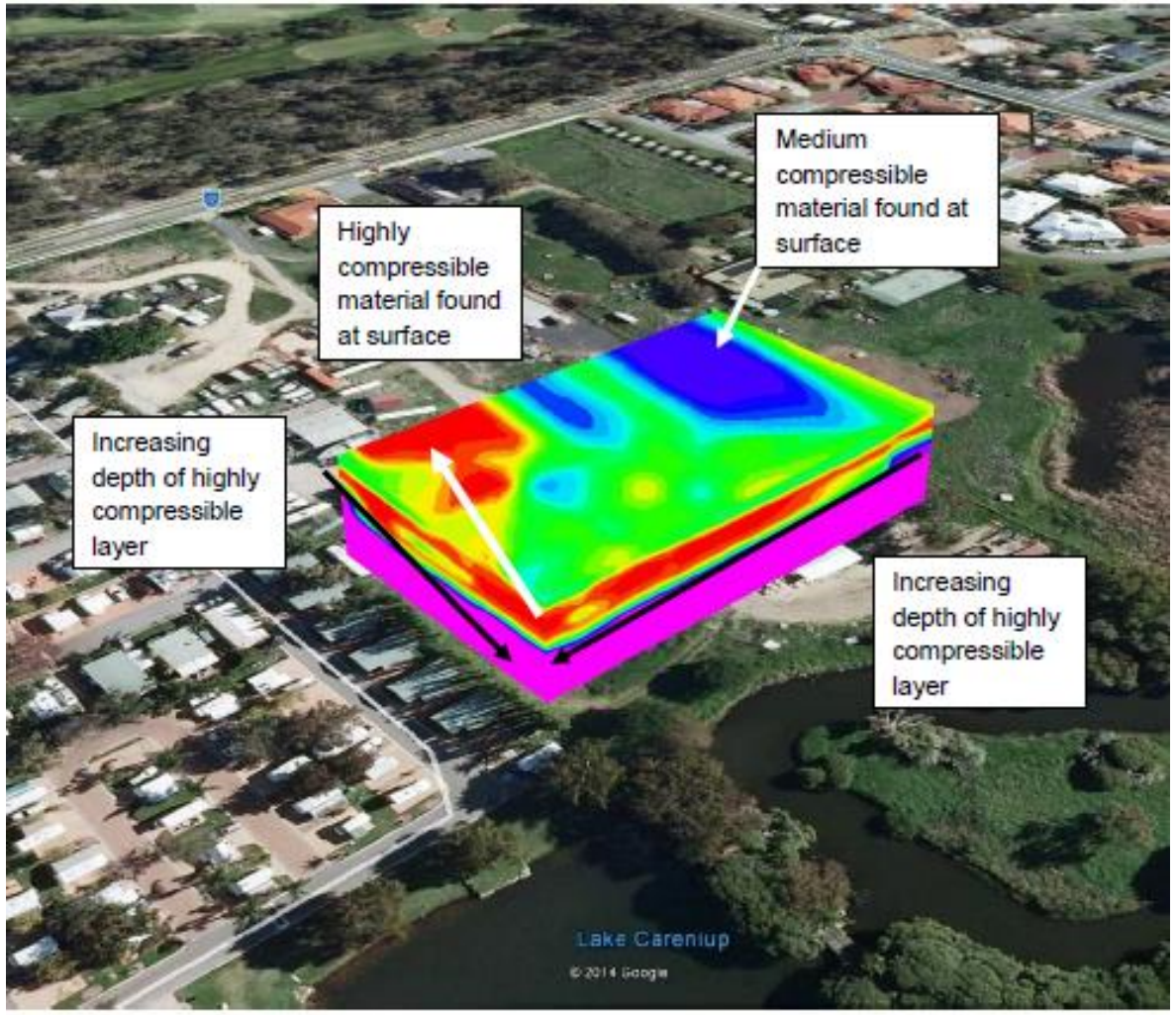
1. Remove these unsuitable materials

2. Work with these material

General Approach

- Investigation
- Identify engineering (particularly consolidation) properties of clay layers
- Identify settlement characteristics
- Identify potential solution(s)
- Develop methodology and specifications
- Develop instrumentation and monitoring scheme

Soft layers - Investigation



Common Earthworks Approaches

1. Consolidation Approaches
   - Surcharge
   - Surcharge with PVD
   - Stone / sand columns
2. Ground Strengthening
   - Stone columns
   - Soil Cement columns
   - Geosynthetic reinforcement
3. Piled Foundations; Raft Slabs
4. Excavate and Replacement

PVD + HIEDYC

Ground Improvement by CDYC

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Dynamic Compaction Methods

Deep Dynamic Compaction (DC)

Rapid Impact Compaction (RIC/CDYC)

High Energy Impact Rolling (HIEDYC)

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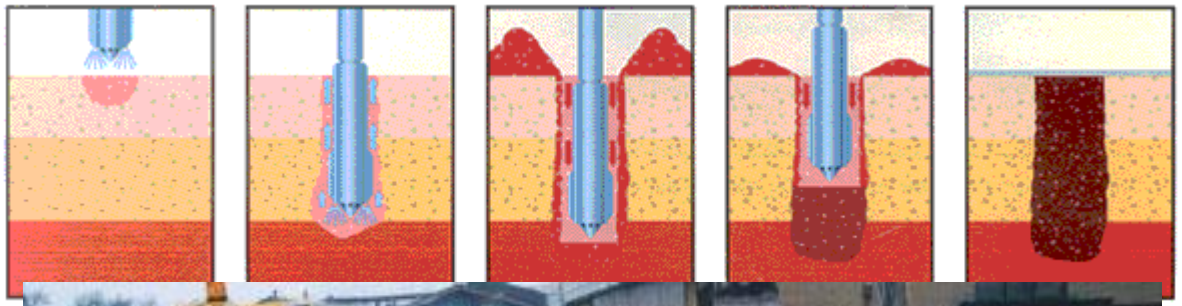
Stone Column



Soil Mixing can Render Soft Sediments and Clays Stiff and Inactive

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Advantages

Method	Advantages
1. Consolidation Approaches	
• Surcharge only	An effective method where time and material supply is not a limitation
• Surcharge + PVD	An effective method where time is not a limitation
Strengthening Approaches	
• Stone Columns	An effective method for shallow soft soils
• Soil Cement Columns	An effective method for shallow soft soil
• Geosynthetic Reinforcement	An effective method for mitigation of bearing capacity & differential settlement issues
3. Piled Foundations	A structural solution to transfer loads to deeper bearing stratum
4. Excavate & Replacement	An effective method for shallow soil soils

Limitations

Method	Limitations
1. Consolidation Approaches	
• Surcharge only	Very lengthy surcharge period; requires large quantities of surcharge fill; possibility of bearing failures with placement of excessive surcharge fill
• Surcharge + PVD	Could be lengthy surcharge period between 4 – 12 months, requires significant quantities of surcharge fill generally of between 1m to 3m; difficulties associated with clogging of PVDs;
2. Strengthening Approaches	
• Stone Columns	Bulging of stone columns;
• Soil Cement Columns	Cost implications
• Geosynthetic Reinforcement	Generally only provide improvements in stability and bearing capacity. May reduce potential for differential settlement but does not address reduction in total compression.
3. Piled Foundations	Downdrag forces; reduction in pile capacity; potential structural damage to piles
4. Excavate & Replacement	Limited to shallow excavations <3m depth; problematic with ASS and contaminated soils

Dynamic Consolidation Concept

- Utilises dynamic compaction technology in combination with classical consolidation approaches
- Methods of Dynamic Compaction
  - Deep dynamic compaction (DC)
  - Rapid impact compaction (RIC/CDYC)
  - High impact energy dynamic compaction (HIEDYC)
- Consolidation methodology
  - Prefabricated vertical drains (PVD) with limited surcharge
  - Sand/stone columns with limited surcharge

Case Study

- Project: Busselton, Ford Road
- Original budget: Class P
- Challenges and constraints:
    - Low lying ground with soft clay to 8m depth
    - High water table
    - Class P site
    - High long term settlements expected with upto 2m of fill and house loads

Case Study cont.

Low lying ground, soft clays and sand lenses variable depths

Case Study Cont.

- Investigation and design phase
    - Geotechnical investigations,
    - Design of earthworks & ground improvement,
    - Quality control & validation,
    - Work with Developer to obtain approvals from City of Busselton for Class A

Upgrading to Class A Site Classification

Option 1: Accelerated settlement by PVD plus Surcharge and HIEDYC/CDYC compaction

Introduction of prefabricated vertical drains (PVD) and/or sand displacement columns, into the ground together with application of surcharge and dynamic compaction with HIEDYC/CDYC. This technique will accelerate the consolidation of the peaty and clayey layers, increase the density of the sandy layers and generally increase the stiffness and bearing capacity of the improved ground. The recommended surcharge height is 1m and is to be kept in place with settlement monitoring for 12 weeks.

Upgrading to Class A Site Classification

<u>Option 2: Deep soil mix columns</u>

In-situ mixing of the soil with cement/lime will result in a greatly improved soil modulus which leads to higher bearing capacities and lower compressibility. This is a soil strengthening technique and involves the introduction of varying amounts of cement/lime to create soil-cement mixed columns.

Upgrading to Class A Site Classification

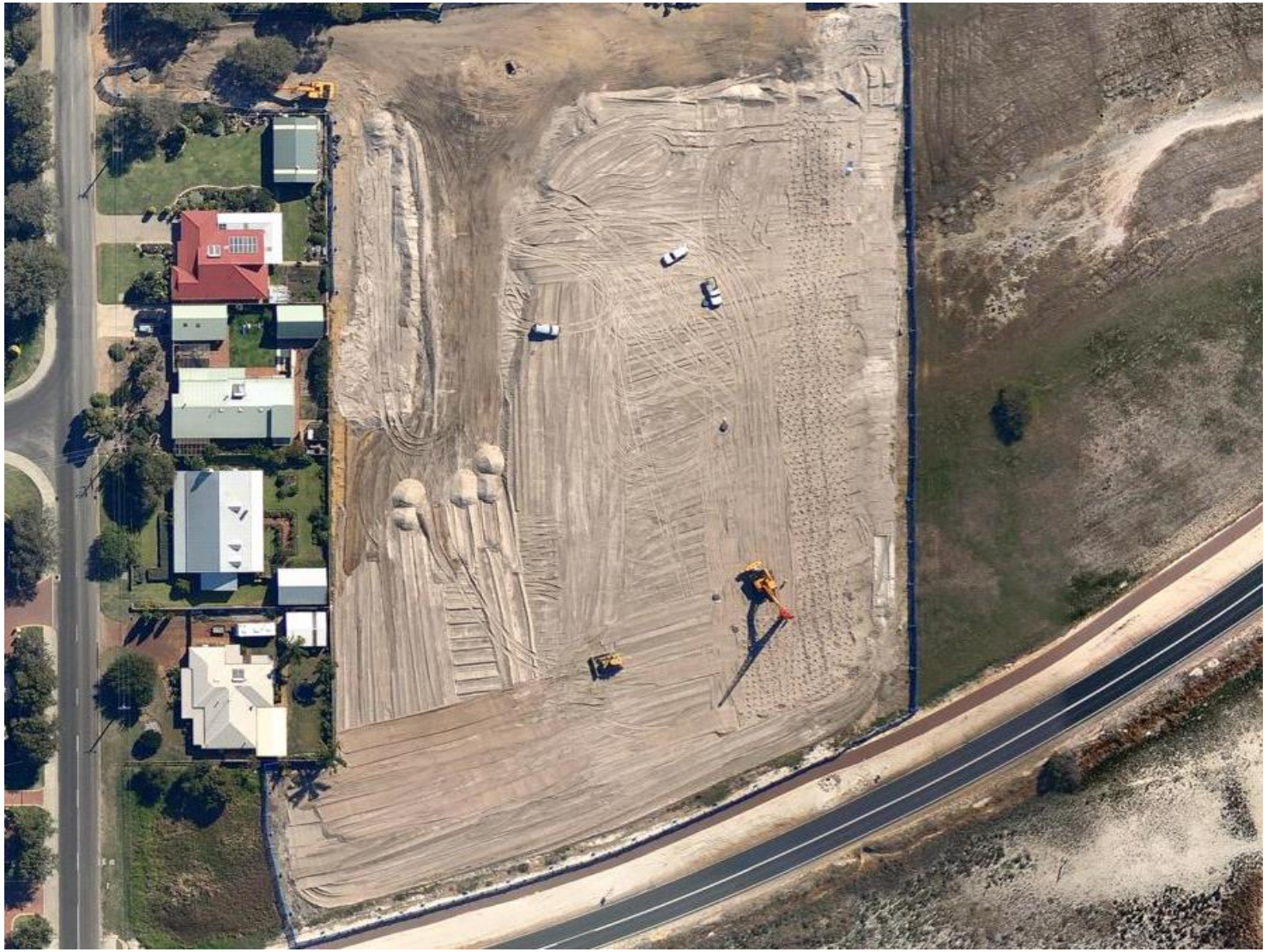
Option 3 Remove and replace all unsuitable/soft materials

Here all the compressible layers can be excavated and replaced with sand with appropriate compaction. The excavated materials may need treatment prior to disposal if these are acid sulphate soils.

Case Study Cont.

- Construction Phase
    - PVD installation
    - Bulk earthworks
    - HIEDYC over PVD
    - Earthworks by Deep Lift Compaction using HIEDYC
    - Settlement plates & settlement monitoring
    - Quality control & validation
    - Earthworks, Site Classification Sign-Off as Class A

PVD installation in progress



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PVD installation

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Placement of Fill & HIEDYC dynamic compaction

Instrumentation and Validation

- Settlement Plates – Asaoka Plots and/or Inverse Hyperbolic Plots
- Piezometers – dissipation of excess pore water pressure
- Boreholes to collect soil samples for consolidation testing

Thank you for your attention……