Use of deep soil mixing for excavation retention and groundwater control

Chris Lyons, Sergei Terzaghi

2015 AGS and IAH Symposium – Recent Developments and Experiences with Groundwater and Excavation
Friday 13th November 2015
Sydney

ARUP

Presentation format

- Project setting
- Proposed Solution - Deep soil mixing
- Retention design
- Construction
- DSM performance
- Conclusions

Project Setting

ARUP

2010/2011 Canterbury Earthquake Sequence

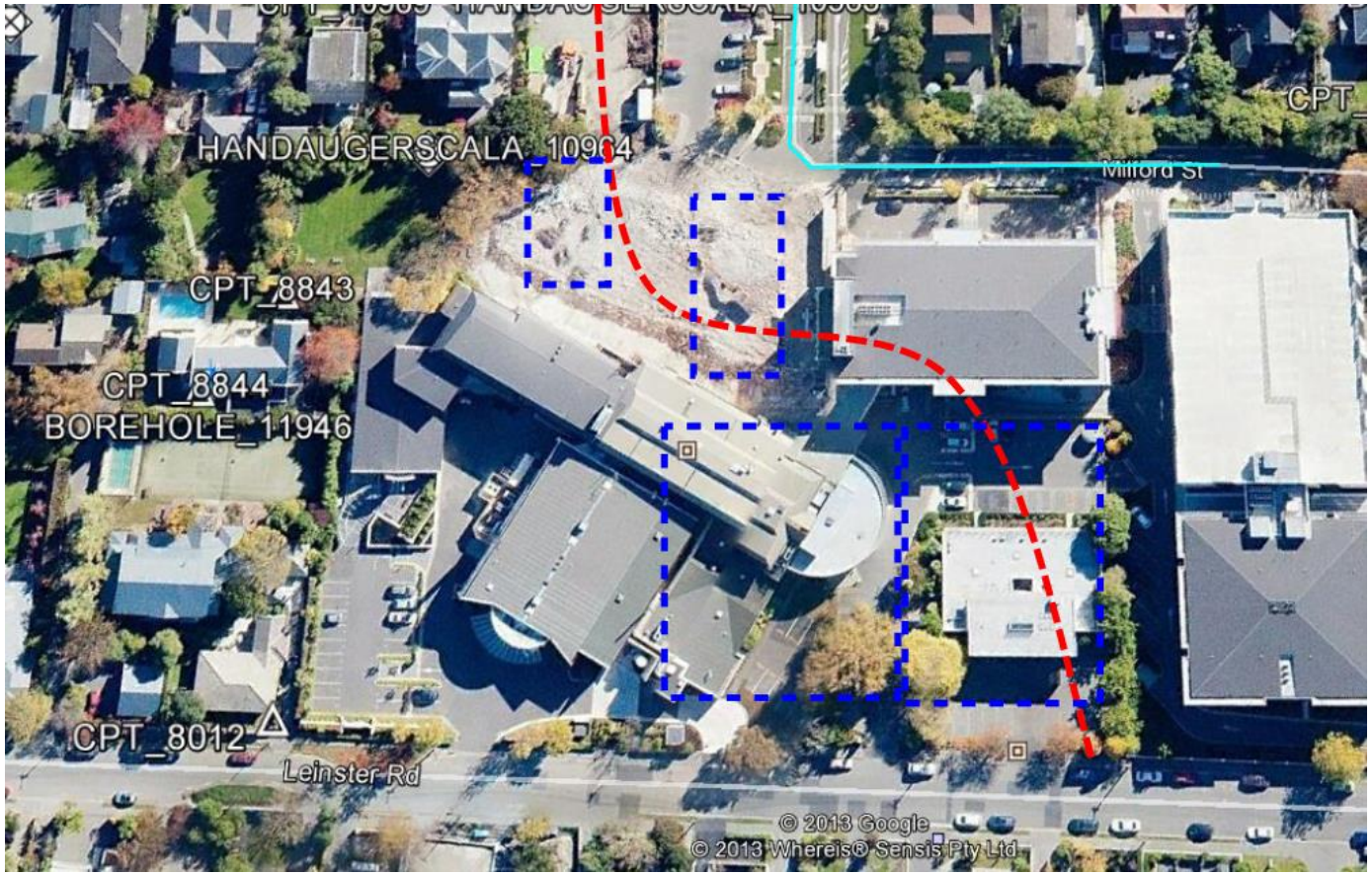
- Peak ground acceleration of +0.6g in the Christchurch CBD.
- Widespread damage to commercial structures.
- Large scale liquefaction.
- Severely compromised 15,000 residential structures.

© nzraw.co.nz

ARUP

St Georges Hospital

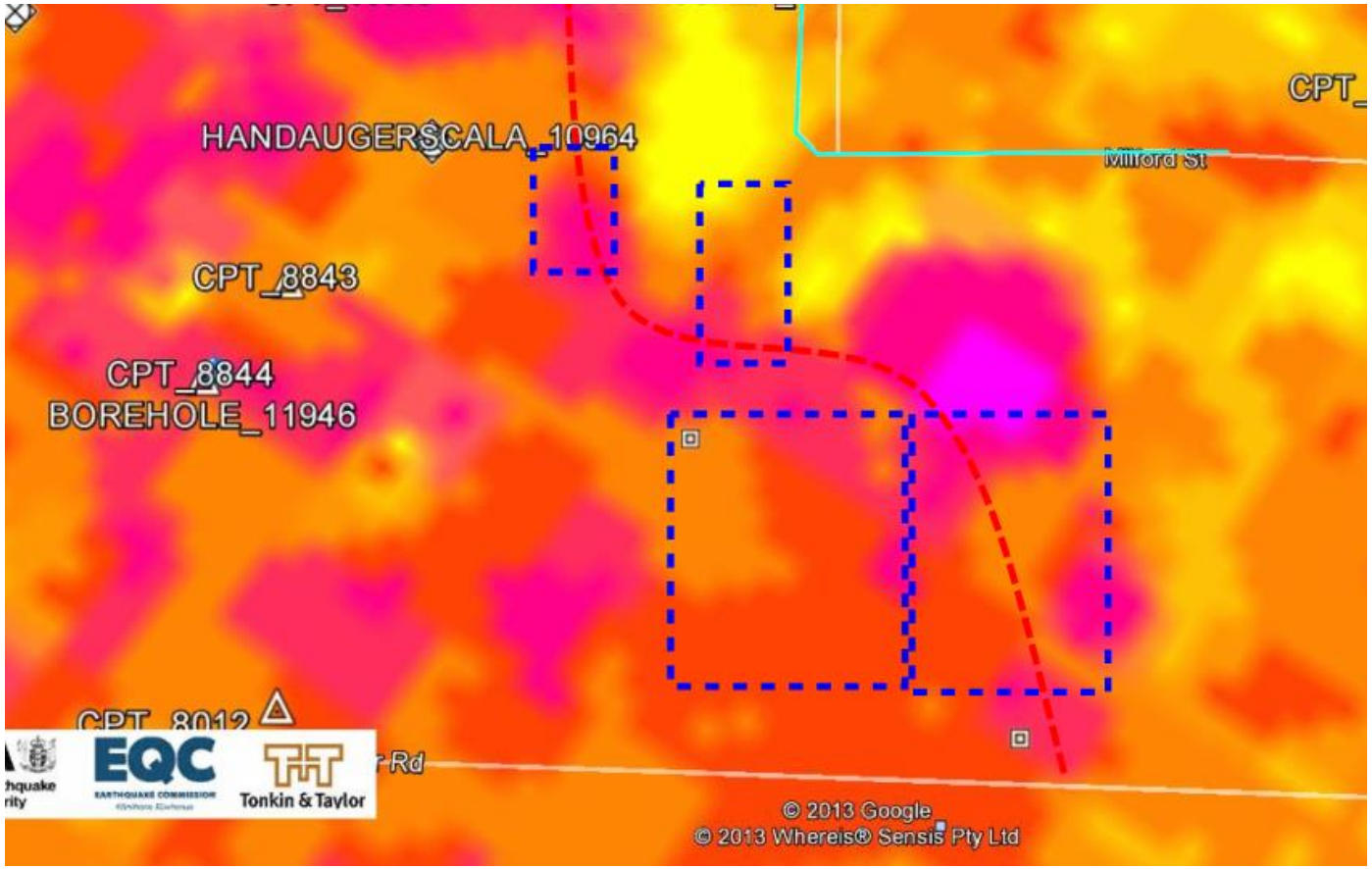
- Damage to existing heritage buildings.



ARUP

St Georges Hospital

- Damage to existing heritage buildings.
- Widespread liquefaction.
- Vertical displacement up to 1.5m.

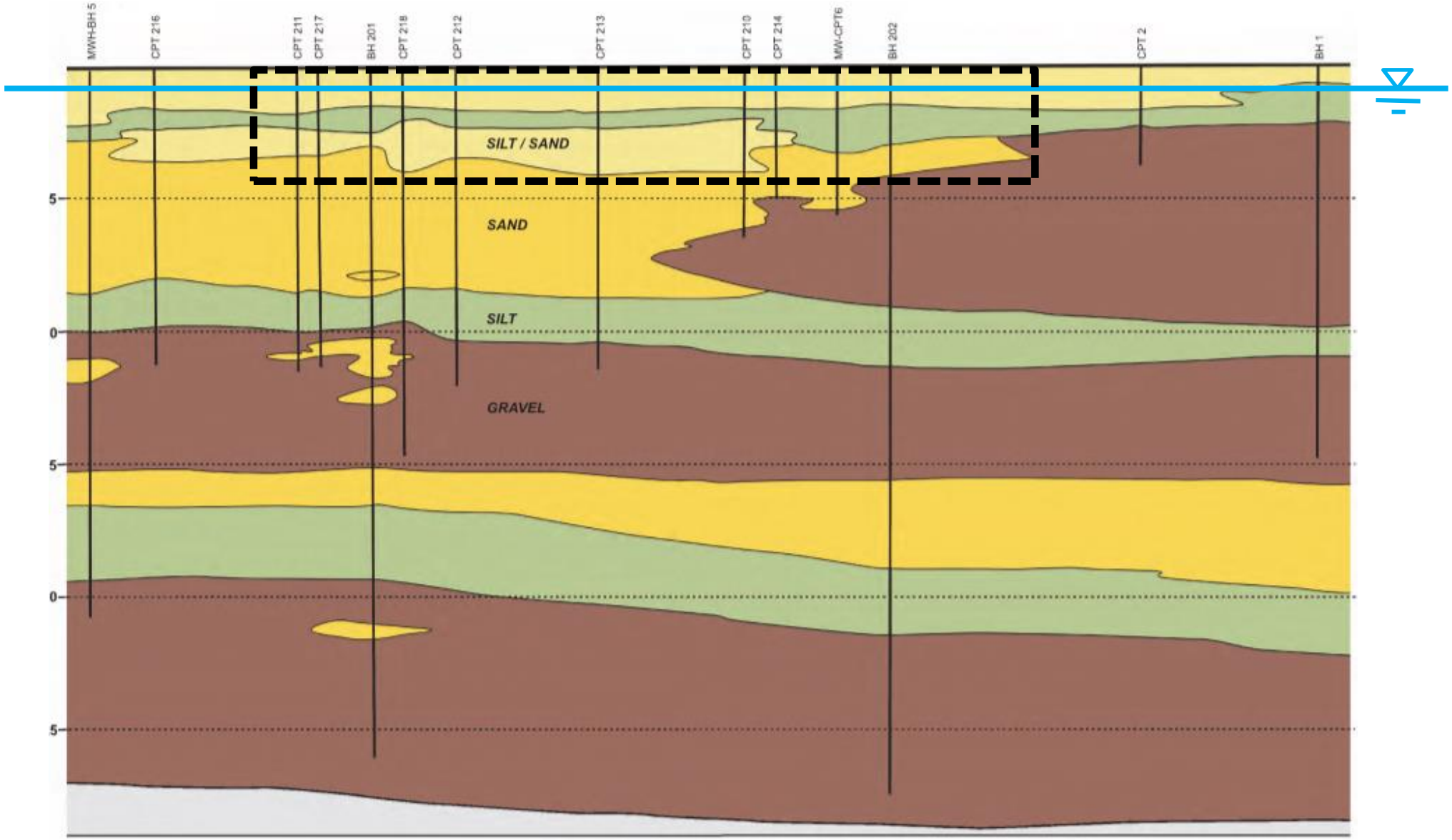


ARUP

Development objectives

- $120m (NZD) redevelopment works.
- Construction of 4 new buildings up to five stories + a single level basement.
- Importance Level 4 and 6 buildings.

ARUP



Geotechnical site model

ARUP

Project objectives

- Retain 4m deep excavations in poor ground conditions.
- Control groundwater inflow during construction.
- Provide a robust foundation solution to address seismic risk including liquefaction, settlement and bearing capacity.

Project tender

- Arup submitted a successful D&C submission for Deep Soil Mixing with Highway Geotechnics.
- First use of deep soil mixing in Christchurch.

Proposed Solution - Deep Soil Mixing

ARUP

Deep Soil Mixing (DSM)

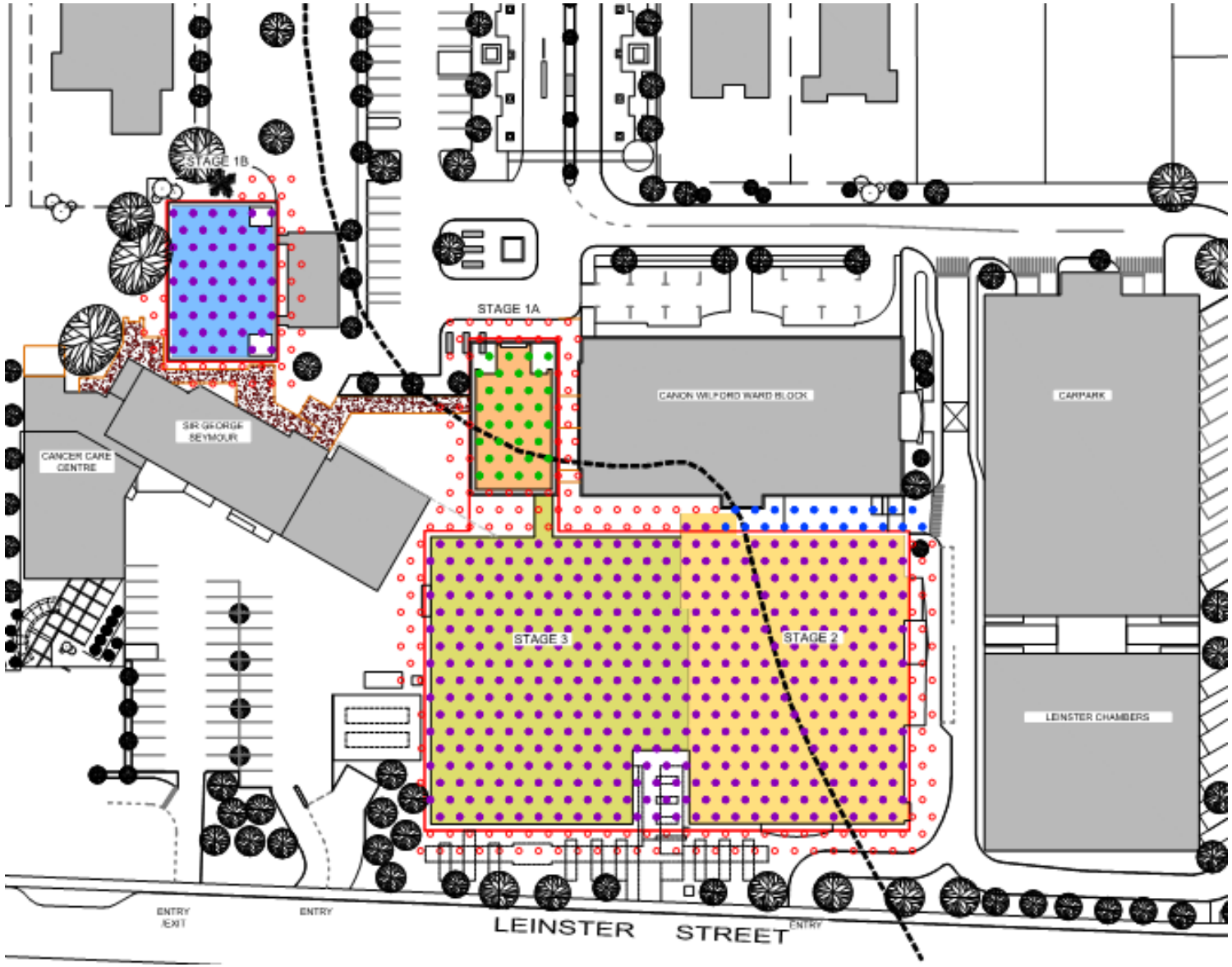
- Insitu ground improvement.
- Mechanics mixing with a cementitious binder.
- To 25m depth.
- Typically 600-1200mm dia.
- Uses include:
  Slope stabilisation, liquefaction, bearing, excavation retention, settlement control.

ARUP

DSM Benefits

- Single solution for retention, liquefaction mitigation and foundation improvement.
- Reduced noise and vibration compared to sheet piling.
- Cost effective.
- Lower embodied energy.
- Strong QA – provides client confidence.

ARUP



Proposed Solution: Deep Soil Mixing – DSM layout

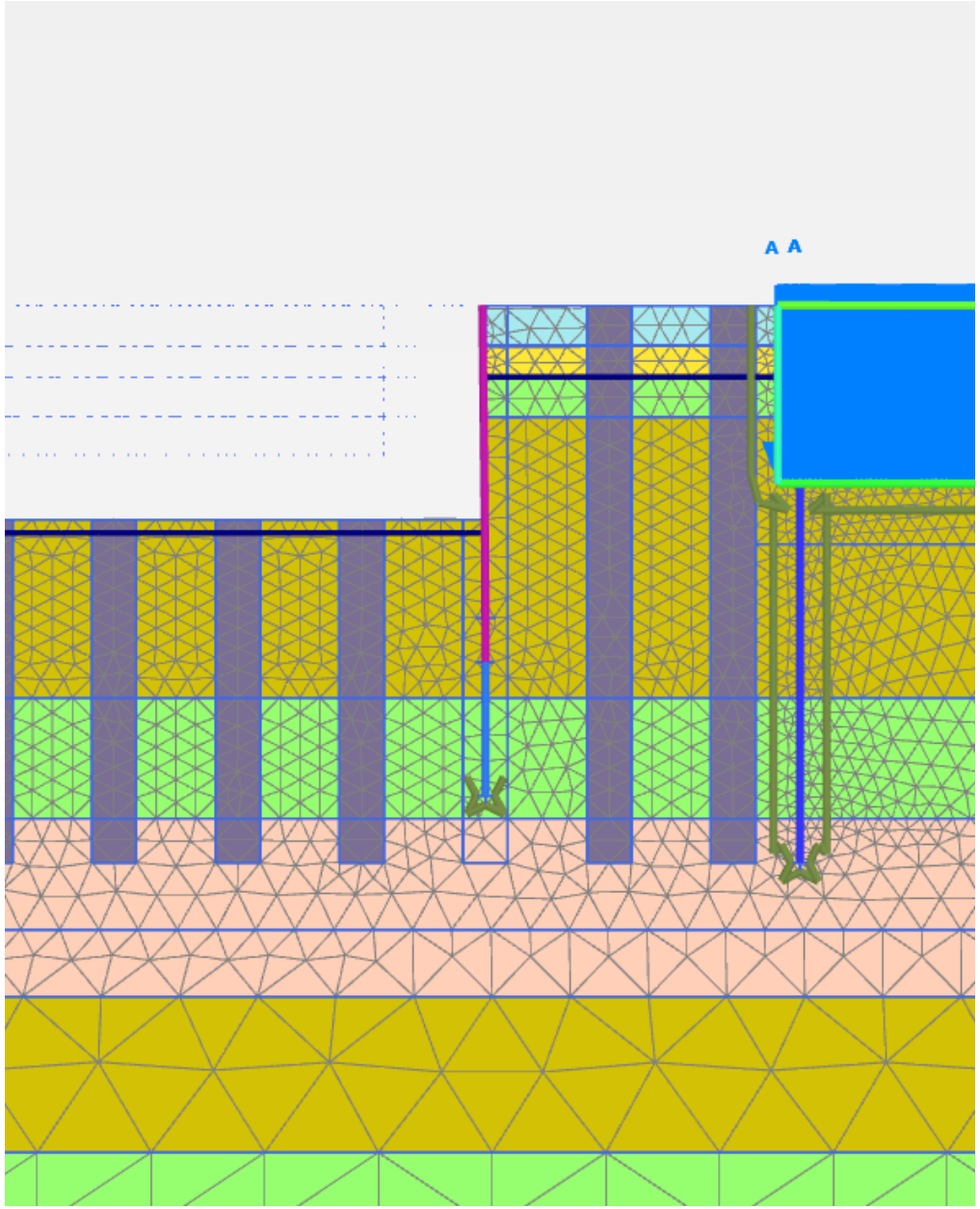
ARUP

Retention Design

ARUP

DSM retention design

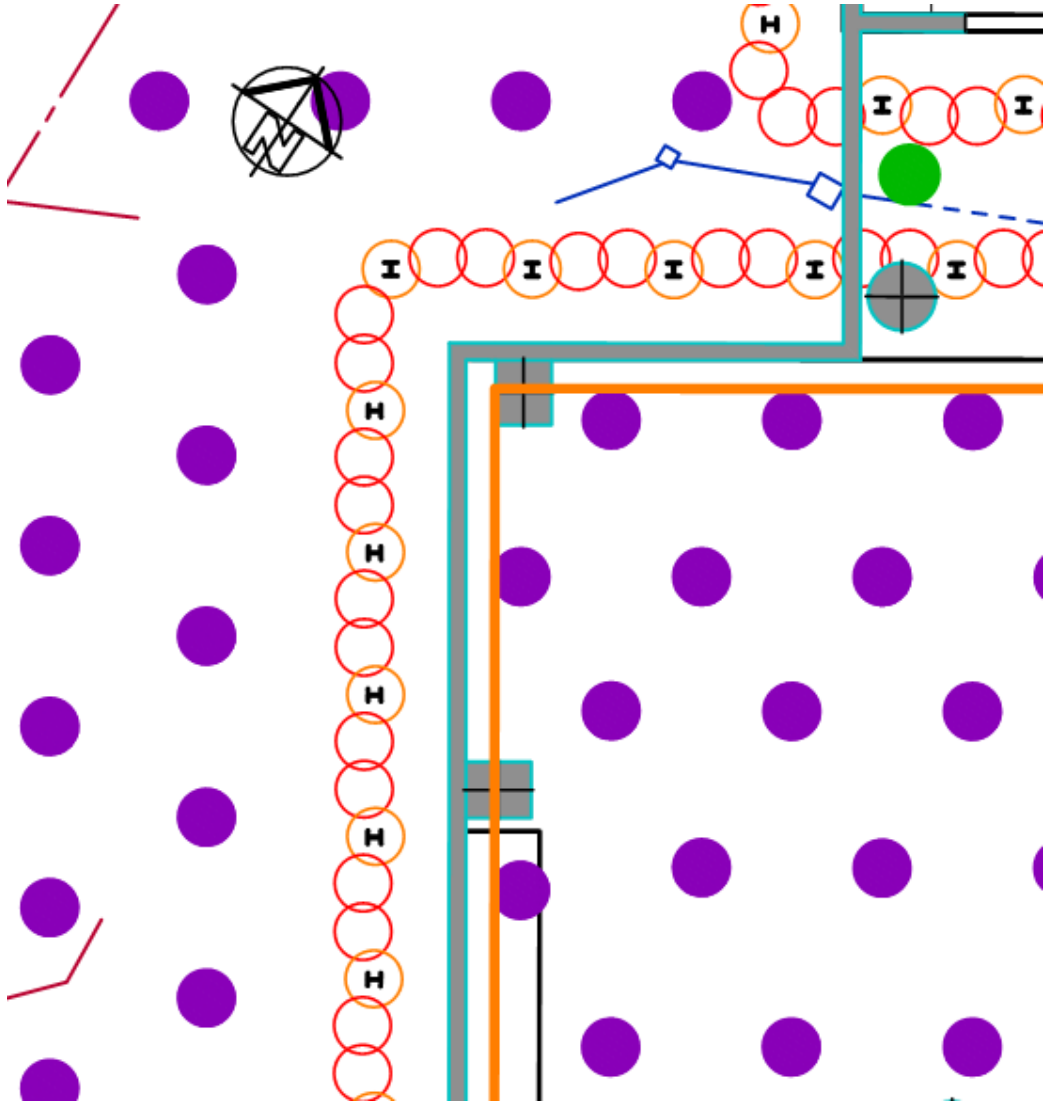
- 2D PLAXIS FEM using HS Small soil models based on CPT and sDTM testing.
- Properties of the grid DSM's were 'smeared'
- Small volume increase modelled as part of the DSM installation.
- Low tension cut off adopted in DSM's



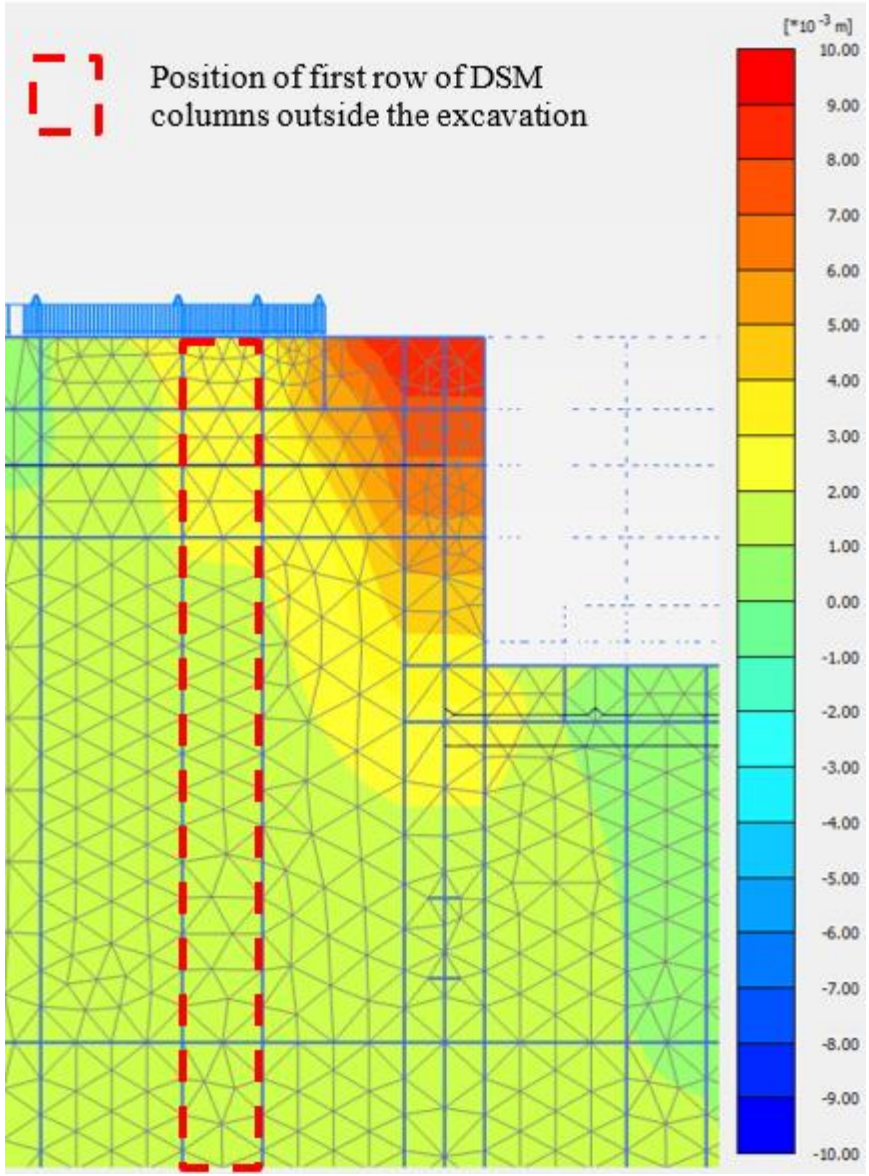
ARUP

DSM retention design

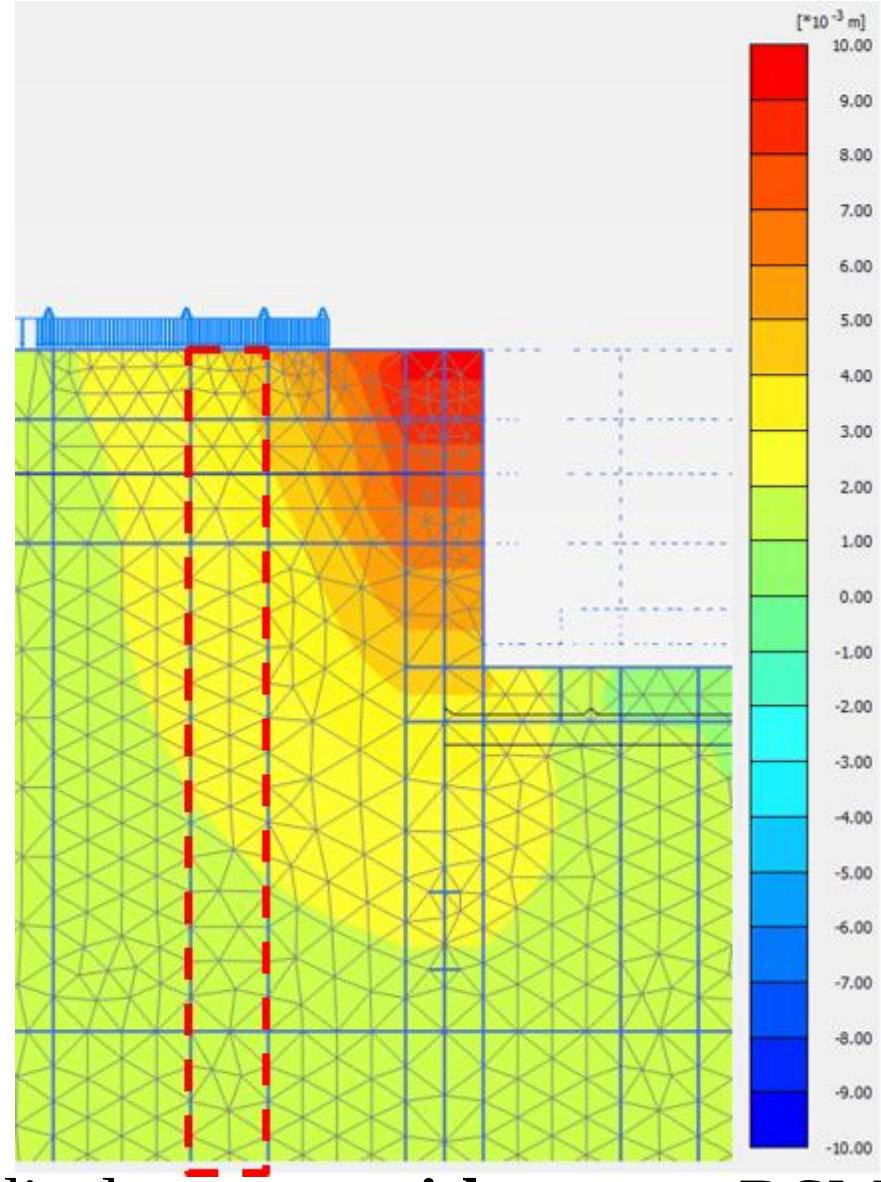
- Internal and external triangular grid of 1.0m DSM @ 3.2m crs.
- DSM secant pile wall with DSM @ 0.85m crs.
- 8m long 150UC23 sections in every 3rd column.
- Maximum target depth of 12m.
- 9m deep spanning piles for groundwater cut-off.



ARUP



Wall displacement **with** rear DSM



Wall displacement **without** rear DSM

ARUP

DSM retention reinforcing

- Questions regarding the ability of the DSM and a smooth UC to act as a composite member.

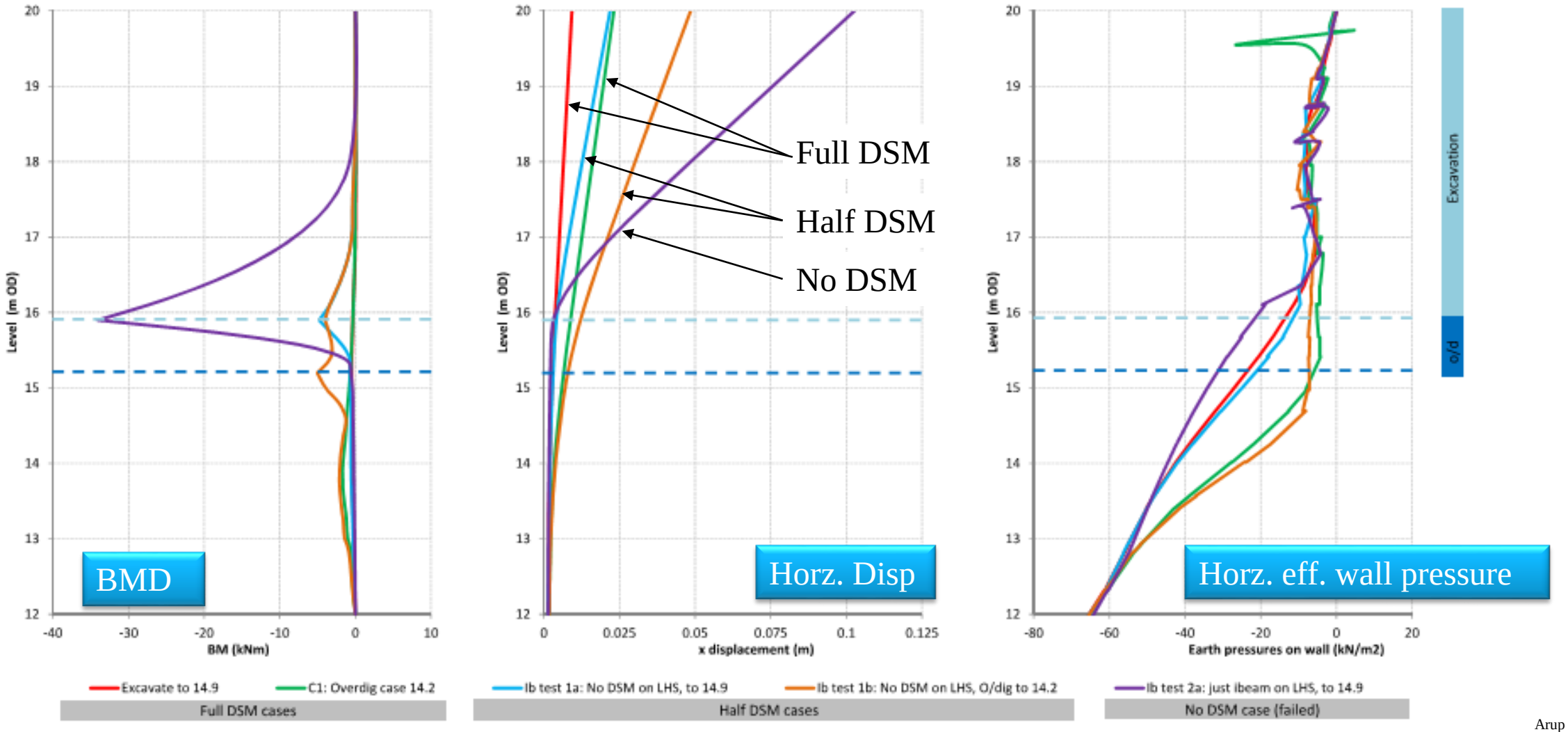
- Conventional design is to consider only the reinforcing members (Rutherford et al, 2007).

- 3 Cases were assessed during modelling with the UC reinforcing:
  - Full DSM;
  - Half (compressive) DSM; and
  - No DSM.

ARUP

ARUP

St George's Hospital I-beam test: Extracted results

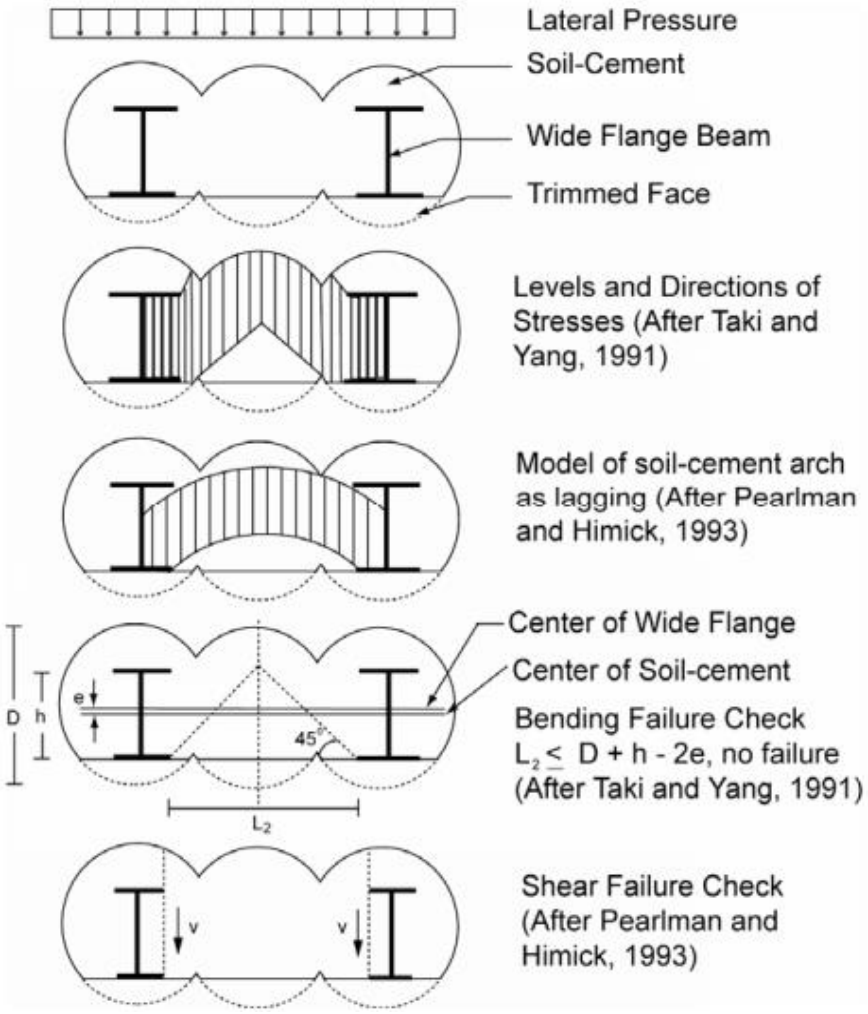


Arup 2014

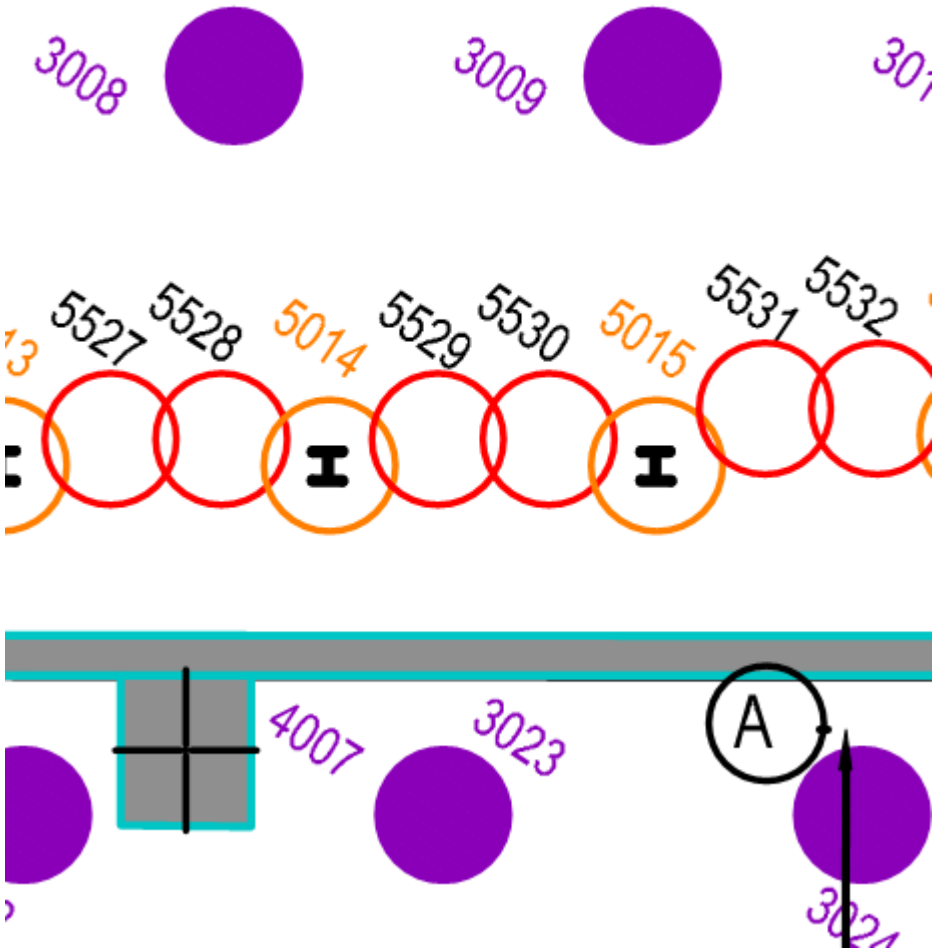
DSM Design – UC reinforcing sensitivity: 3 cases (with and without overdig)

ARUP

DSM Intermediate support design



Concepts of improved ground as lagging



Adopted solution of offset piles

ARUP

DSM Construction

ARUP

DSM Construction – Installation of trial columns

Arup 2014

DSM Construction – Installation

ARUP

DSM Construction – Inspection of trial column excavation

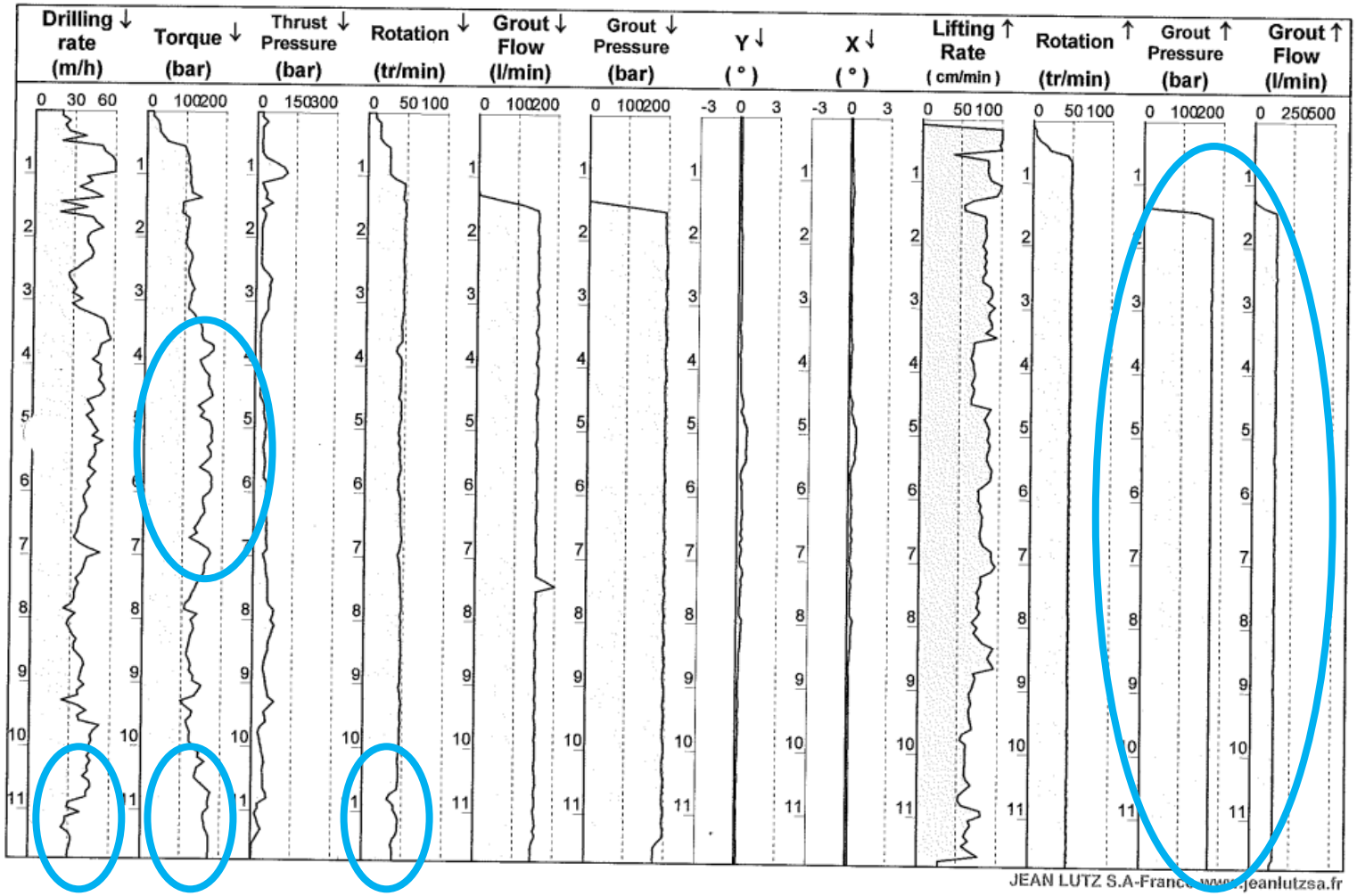
ARUP

DSM Construction – Installation

ST GEORGES ST2 (Contract 60016/2)
JETGROUTING

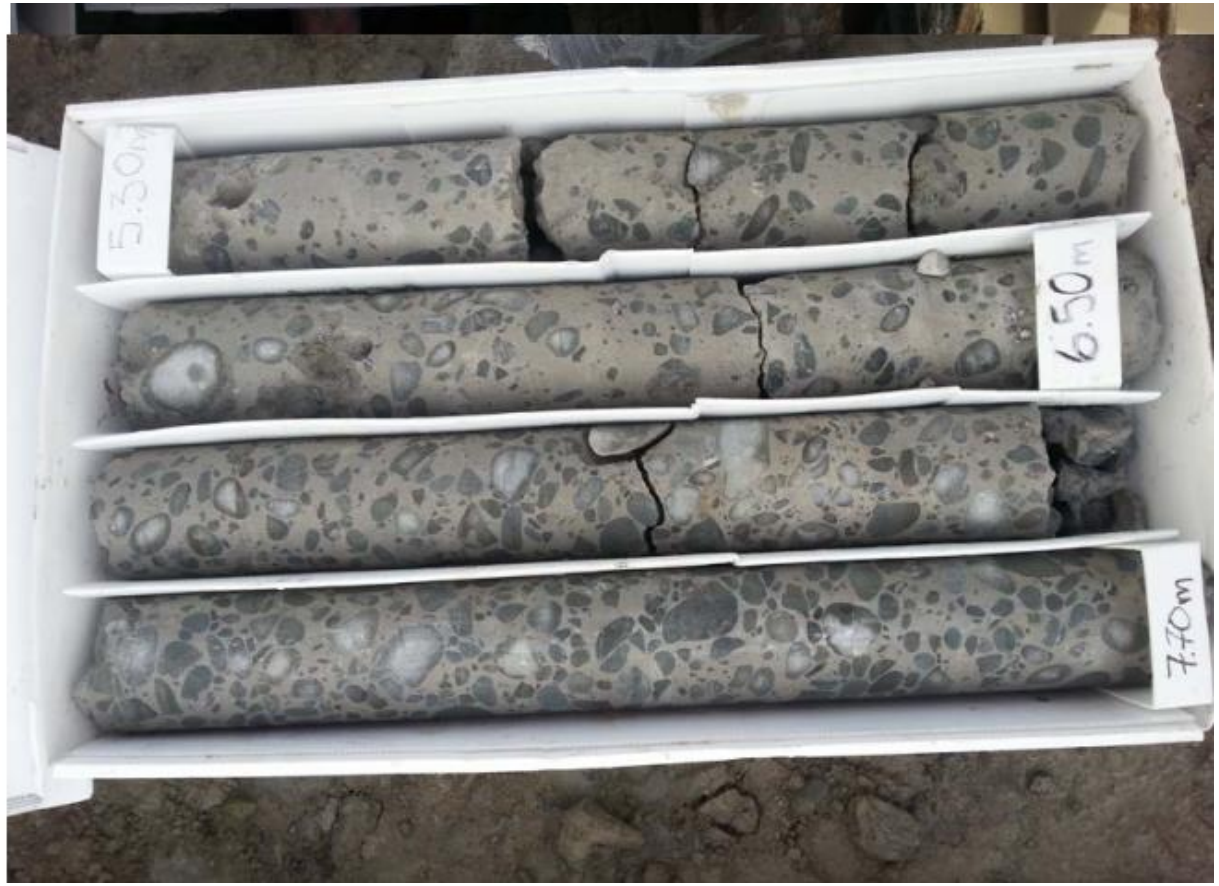
Date : **11/06/2014**	Drilling duration : **00:19:41**	Drilling volume : **2.517 m3**	Drill Depth : **0.00-11.76 m**
Begin : **14 h 48**	JET duration : **00:15:43**	Grout volume : **1.96 m3**	JET Length : **11.60 m**
End : **15 h 23**		Volume by meter : **169 l/m**	

1/110 **Column 16** EXJTC 5.24/TG2TTJ312EN

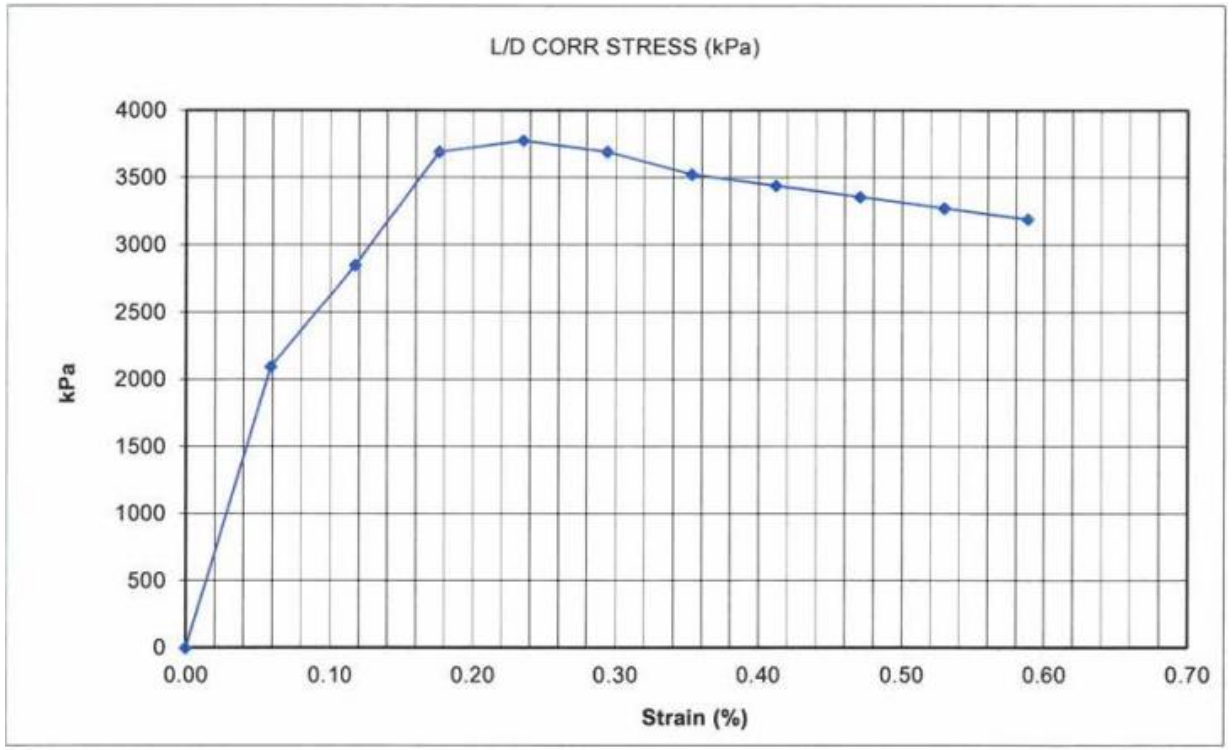


DSM Construction – Drill logs

ARUP



DSM core samples



DSM UCS strength testing

ARUP

DSM wall performance

ARUP

Dry conditions with minor dampness in lower part of columns

Arup 2014

Cracking behind DSM columns

- Approx 10mm wide.
- Single continuous crack.
- Supports the provision of reinforcement.
- No cracking on the DSM face or effect on water retention.
- Access restriction behind this wall, so no rear DSM's.

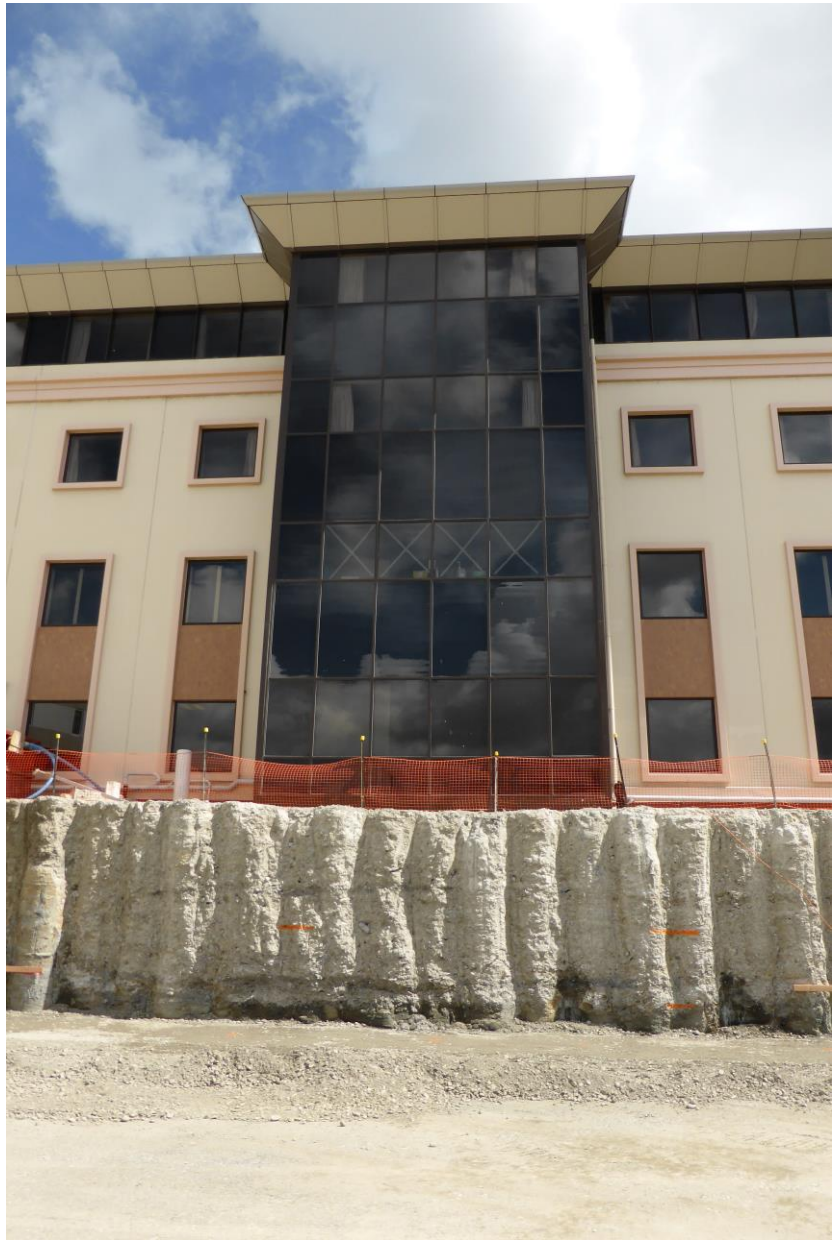
ARUP

Conclusions

ARUP

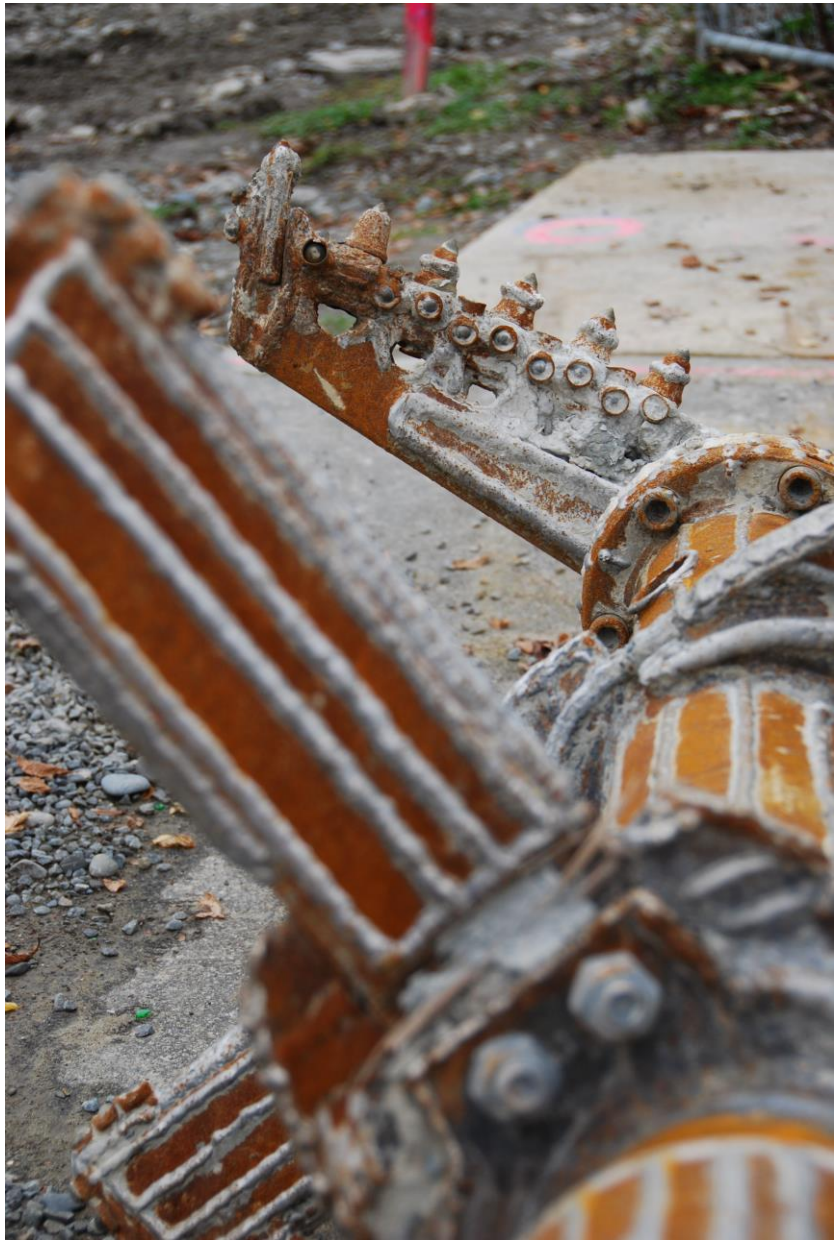
Conclusions

- The use of deep soil mixing resulted in cost and construction efficiencies due to it's adaptable nature.
- Low noise and vibration resulted in minimal impact on hospital operations.
- DSM's preformed well as groundwater/retention solution.
- Opportunities to refine the interaction between DSM's and steel reinforcing inclusions



ARUP

Questions?



ARUP