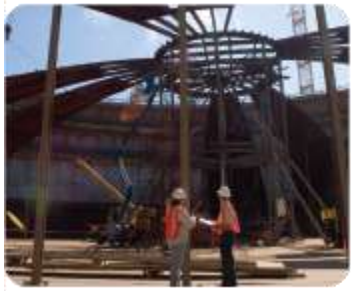




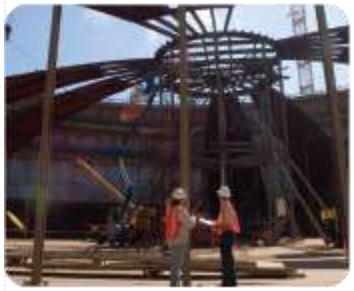
Construction of a New Type of Retaining Walls with Stabilizing Base using Precast Panels at Tolo Highway Widening

(10 October 2013)

Ir Benson Lam and Ir John Chan

Outline

- Project Background
- Scope of Geotechnical Works
- Cantilever Retaining Wall with Stabilizing Base
- Precast Panel and Hanging Platform
- Construction Sequences
- Construction Difficulties and Solutions
- Programme
- Monitoring on Retaining Wall Movement
- Photo Highlights
- Conclusion
- Q&A





Project Background

Project Background

- Tolo Highway at North-east New Territories of Hong Kong

Project Background

- To alleviate the traffic congestion problem
- To meet the anticipated traffic growth

Year	2008	2011	2016	2021
v/c ratio without the Stage 1 works	0.98	1.09	1.23	1.37
v/c ratio with the Stage 1 works	-	-	0.91	1.00

Year	2011	2018	2021
v/c ratio without the Stage 2 works	0.96	1.16	1.18
v/c ratio with the Stage 2 works	–	0.86	0.89

Project Background

- Stage 1 – Contract HY/2008/09
  - Widening of Tolo Highway between Island House Interchange and Ma Wo
- Stage 1 – Contract HY/2009/08
  - Widening of Tolo Highway / Fanling Highway between Ma Wo and Tai Hang
- Stage 2 – Contract HY/2012/06
  - Widening of Fanling Highway between Tai Hang and Wo Hop Shek Interchange

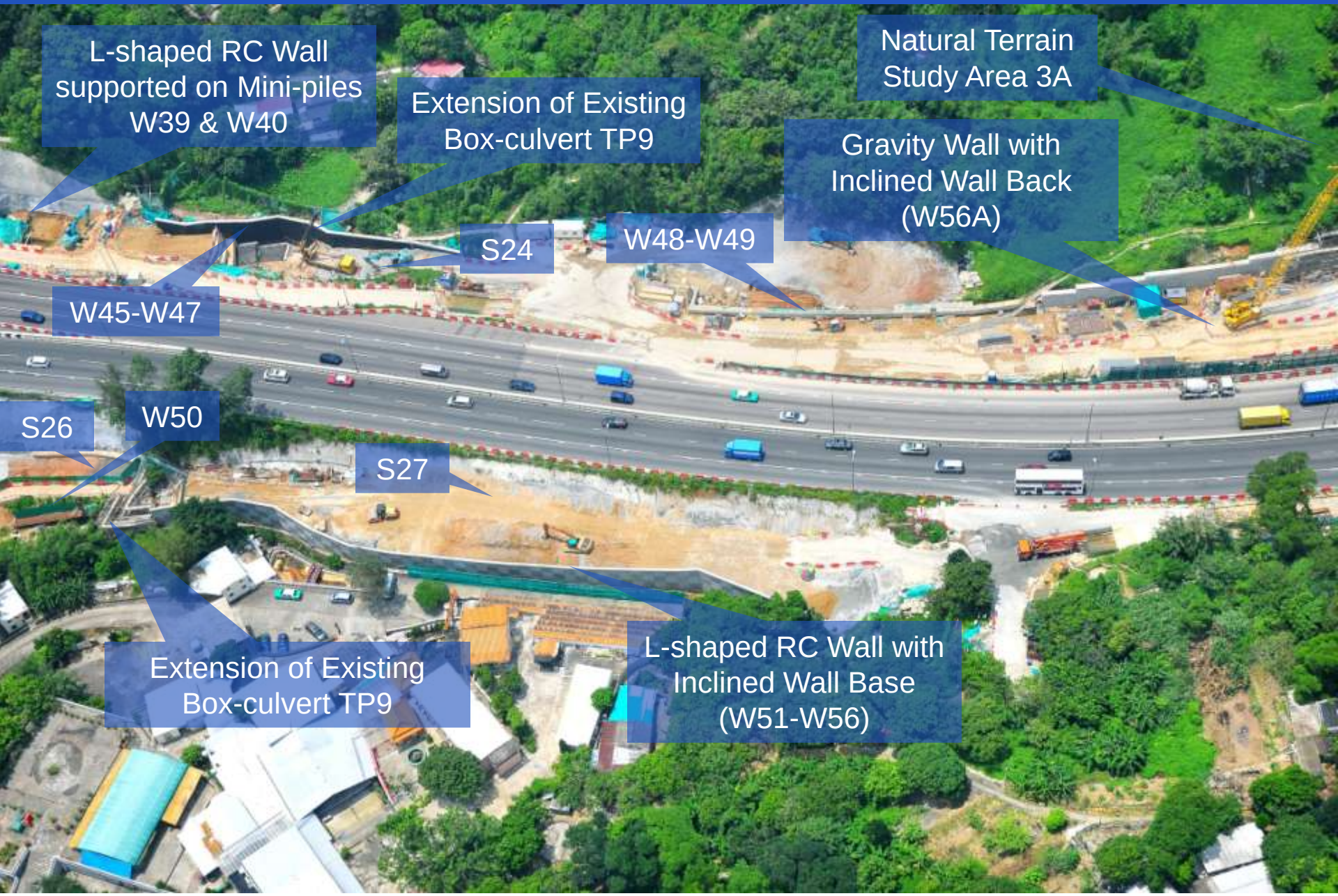
Project Background

Project Background

Contract	HY/2009/08
Client	Highways Department, HKSAR
Main Contractor	Gammon Construction Limited
Major Scope	• Widening of a **3.5** km section of Tolo Highway • Modification and reconstruction of highway and bridges • **Retaining walls and slopeworks** • Noise Barriers • Associated road and drainage, landscape and lighting works
Contract Sum	HK$2.38 billion
Contract Period	February 2010 to December 2013 (46 months)

Photomontage of Tolo Highway


Natural Terrain
Study Area 2A
Soldier Pile Wall with
Stabilizing Base (W38)
& Cut Slope S22
HY/2008/09
HY/2009/08
W35 & S21
Upgraded Existing Wall
W35A
Existing Box-culvert TP8


L-shaped RC Wall supported on Mini-piles W39 & W40
Extension of Existing Box-culvert TP9
Natural Terrain Study Area 3A
Gravity Wall with Inclined Wall Back (W56A)
S24
W48-W49
W45-W47
S26
W50
S27
Extension of Existing Box-culvert TP9
L-shaped RC Wall with Inclined Wall Base (W51-W56)


Natural Terrain
Study Area 3A
Soldier Pile Wall with Stabilizing
Base using Precast Panel
(W56B)
S29
S29
Goose Shaped Wall
(W56A)
S28


S29
Soldier Pile Wall with Stabilizing Base using Precast Panel (W56B)
S28


Goose Shaped Wall
(W56B)
Bridge 12A
Soldier Pile Wall with Stabilizing Base
(W57B)


Natural Terrain
Study Area 4
Rock Fill Slope &
Soil Cut Slope upgraded by
Soil Nailing Technique
(S31A)
Goose Shaped Wall
(W59)
Bridge 12A
Soldier Pile Wall with Stabilizing Base
(W57B & W57C)


Rock Slope (S31A)
Bridge 13A
Tai Po Tai Wo Road
Link Bridge
W58B
L-shaped RC Wall
supported on Mini-piles
W60 & W61A


Bridge 15A


Natural Terrain
Study Area 6-2
Existing Cut Slope 7NW-A/C35
upgraded by soil nailing technique
L-shaped RC Wall with
Inclined Wall Base
(W65A & W65B)
Rock Fill Slope in
front of W65B


Natural Terrain
Study Area 6-1
7NW-A/CR39 upgraded
by soil nailing technique
S40
Existing Cut Slope 7NW-A/C35
upgraded by soil nailing technique
S37
S38
L-shaped RC Wall with
Inclined Wall Base
(W66 & W67)


Natural Terrain
Study Area 6-2
S40
S41
Reinforced
Fill Wall
Soldier Pile Wall with
Stabilizing Base
(W69)
Bridge 18A
Existing Bridge to
be demolished
S42
S39
W67
S43
W71

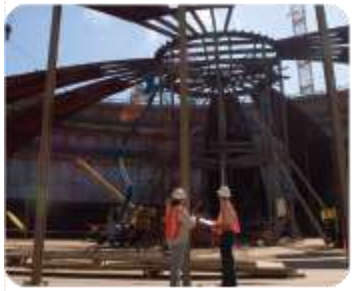

L-shaped RC Wall supported on Mini-piles (W72B)
L-shaped RC Wall with Inclined Wall Base (W73)
Counterfort Retaining Wall W72A
S41
W70
W68
Soldier Pile Wall with Stabilizing Base (W69)


L-shaped RC Wall supported on Mini-piles (W72B)
L-shaped RC Wall with Inclined Wall Base (W73)
Rock Fill Slope (S44A)
Re-compacted Existing Fill Slope (S44B)
Counterfort Retaining Wall W72A
Extension of WSD's Existing Accommodation Underpass
New Lam Kam Road Flyover


New Lam Kam Road
Flyover

General Constraints of the Contract

- Close proximity to the existing Tolo Highway
- The traffic flow of the existing expressway must be maintained.
- Vehicular access to the wall location is limited (only via the expressway)
- The solution must be cost effective.
- Tight Programme

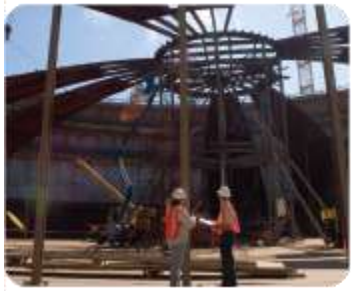




Scope of Geotechnical Works

Scope of Geotechnical Works

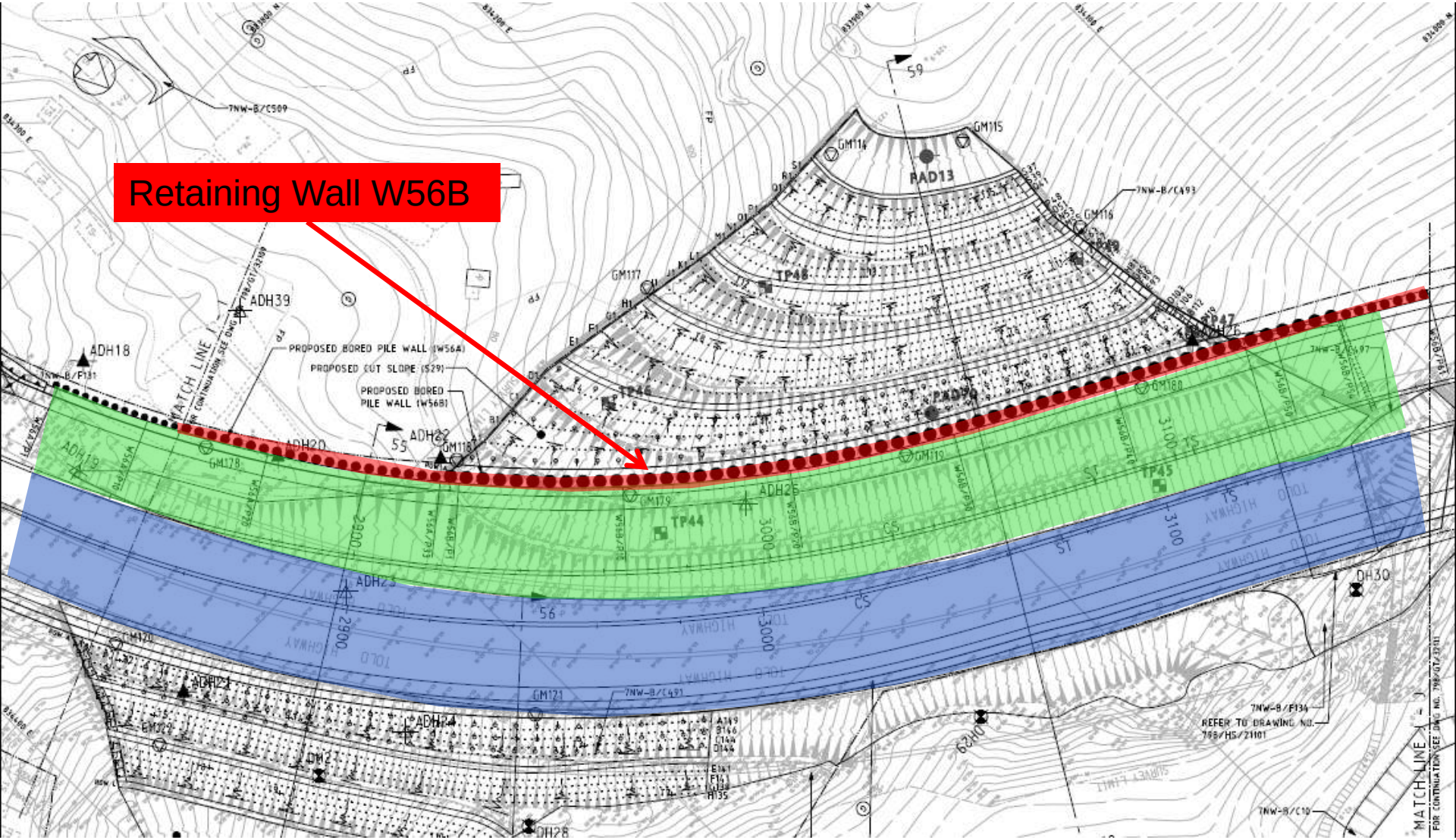
- Slope Works – Soil/Rock Cut Slopes, Compacted Fill Slopes, Rock Fill Slopes, Natural Terrain Hazard Mitigation, Soil Nails, Existing Loose Fill Slopes
- Foundations – At-grade Structures; Piling works including mini-piles and pre-bored-H piles
- Retaining Walls – L-shape RC Walls with/without counterfort, RC Retaining Walls with Sloping Wall Back, Upgrading of Existing Retaining Walls, **Cantilever Retaining Wall with Stabilizing Base using Precast Panel**, etc



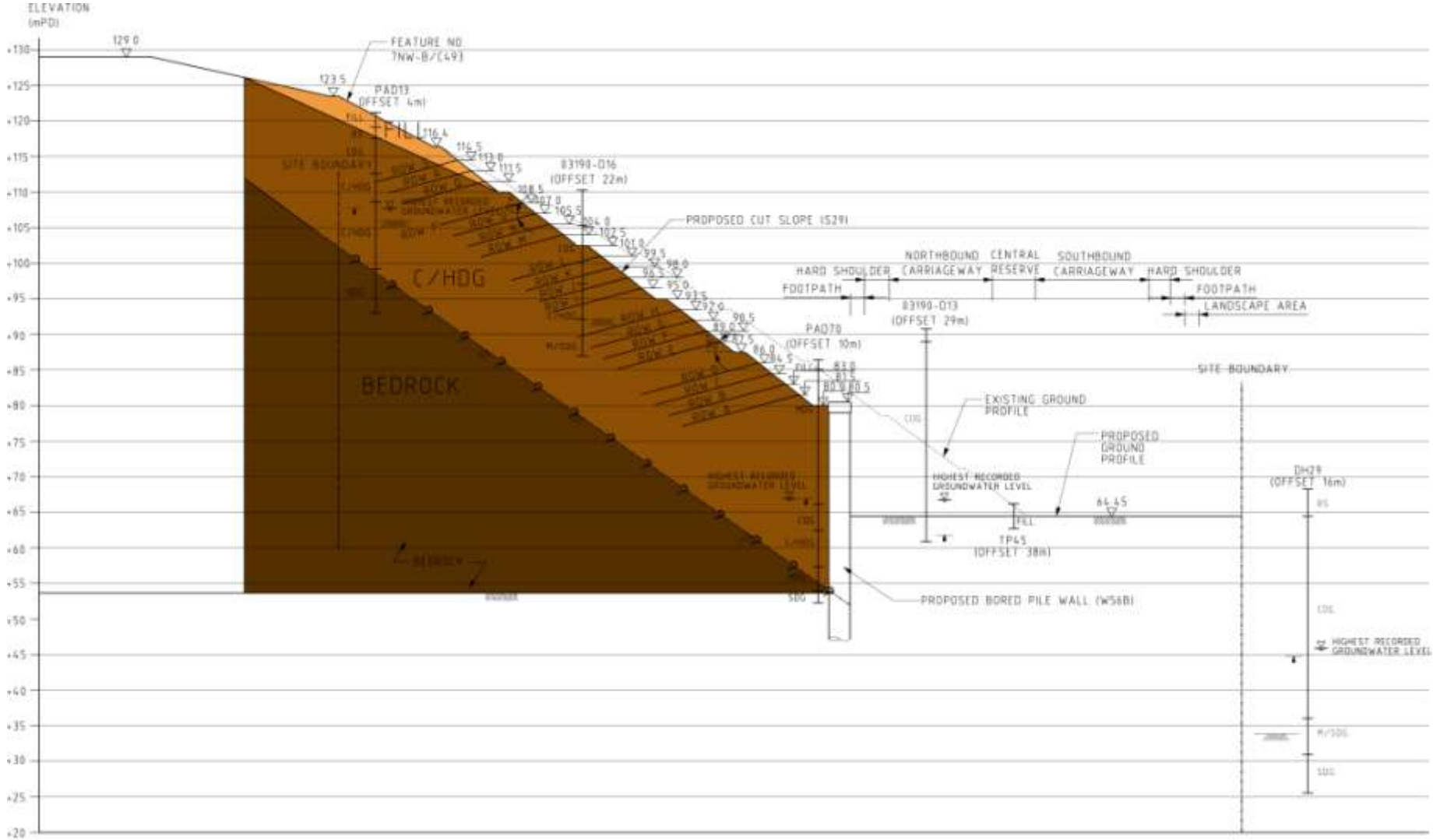


Cantilever Retaining Wall with Stabilizing Base using Precast Panel

Basic information

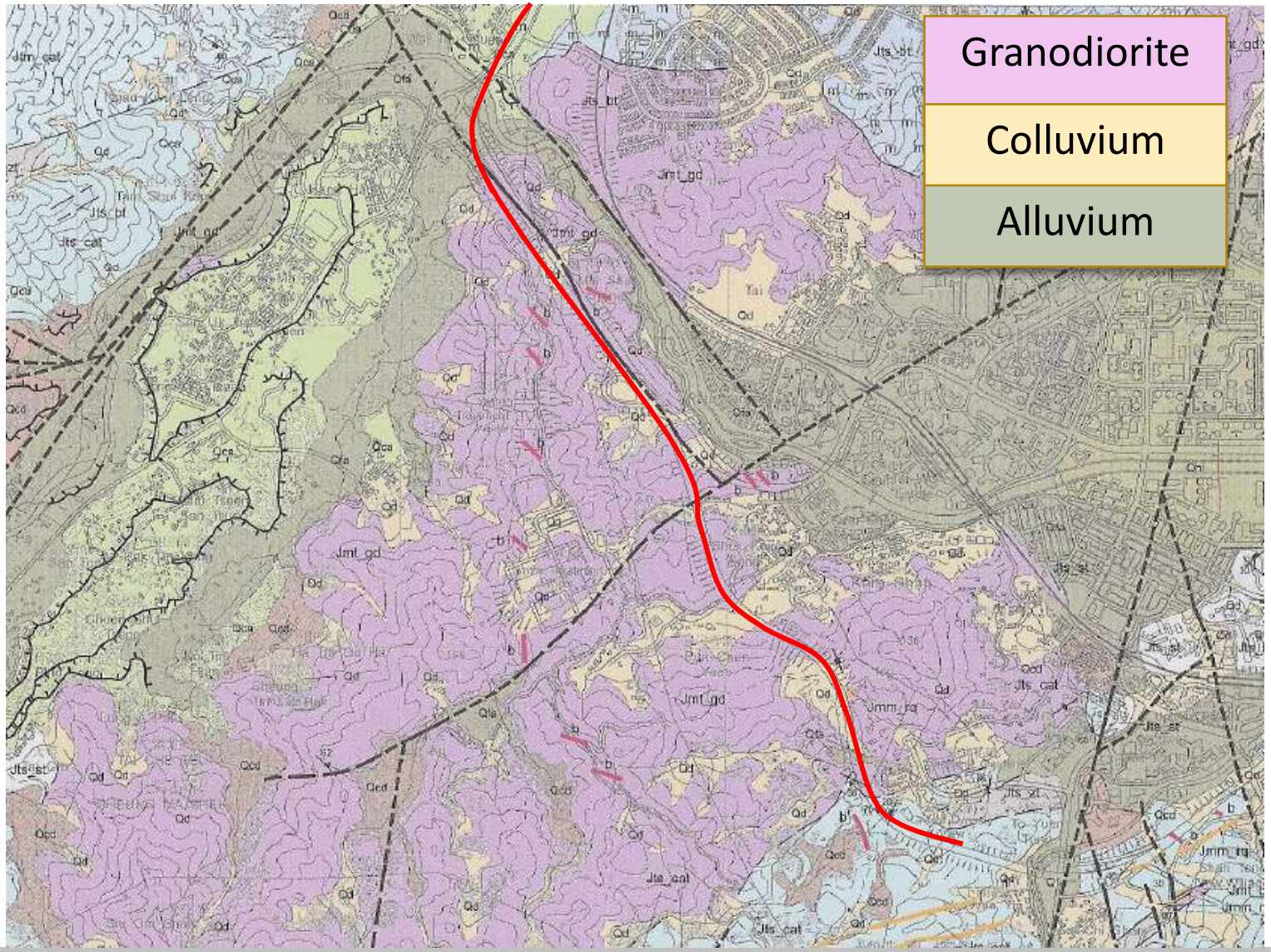


Basic information

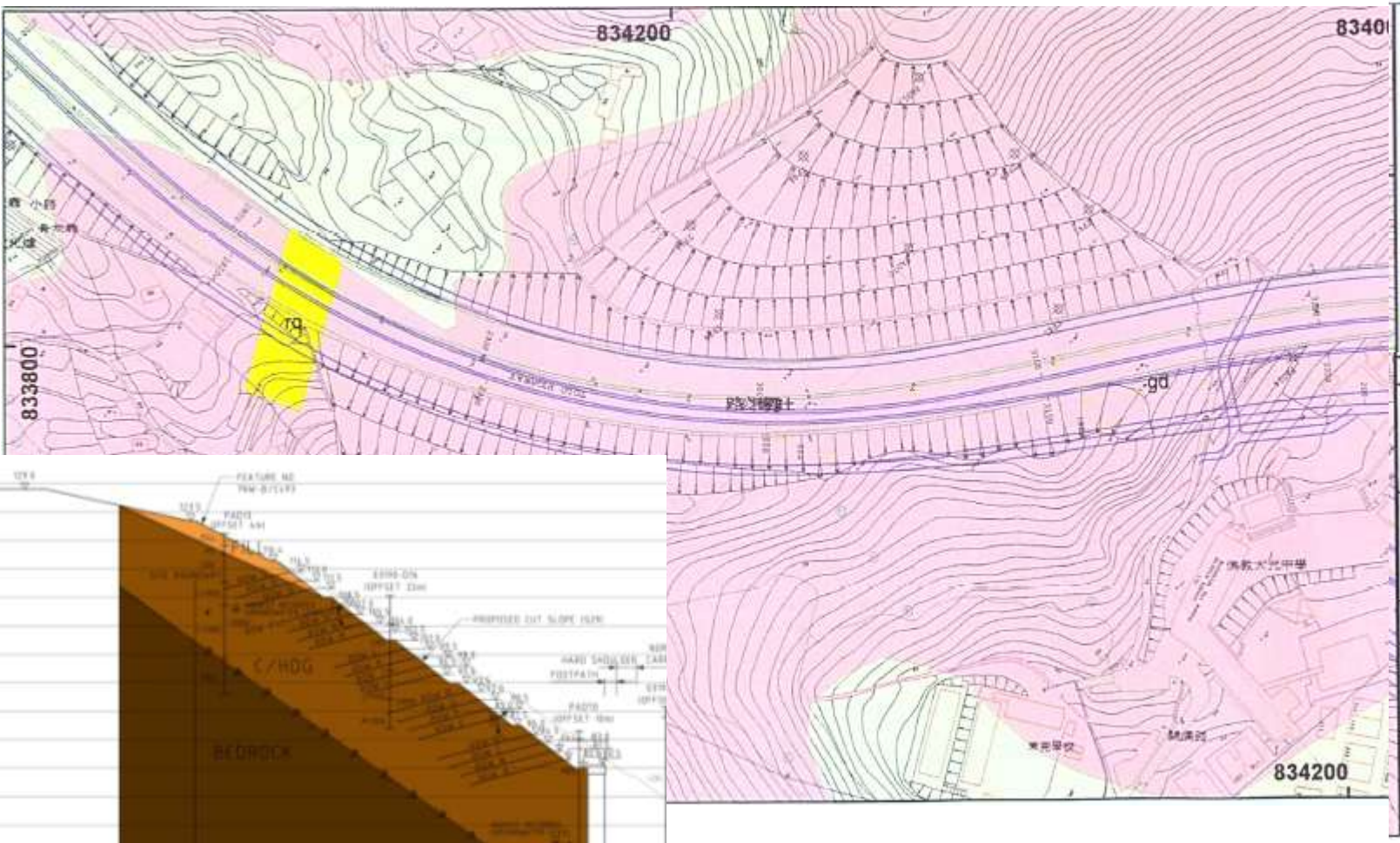


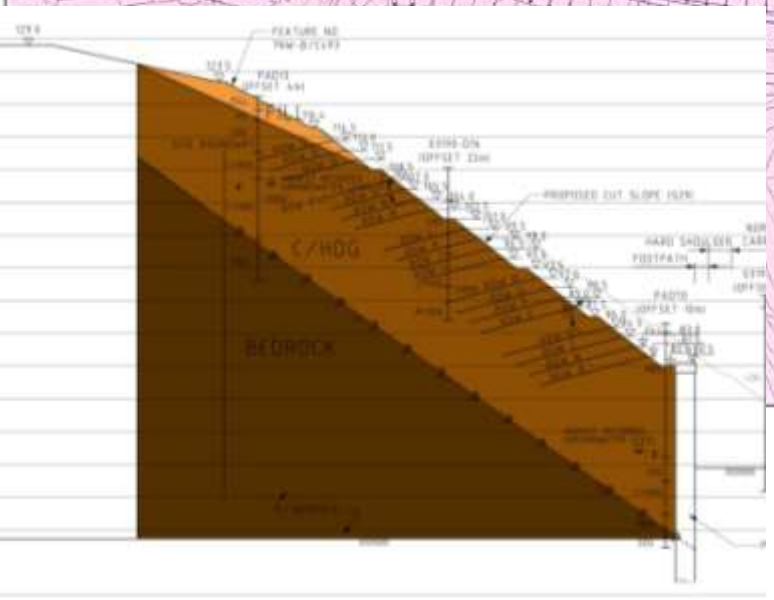
SECTION 59-59

Geology of the Site



Geological Model of W56B

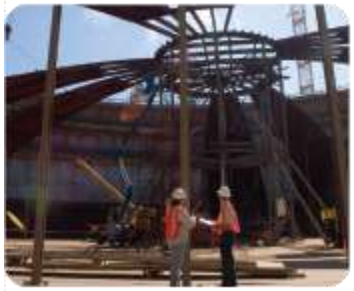




Initial Condition (for Part of the Wall)

Other Concerns

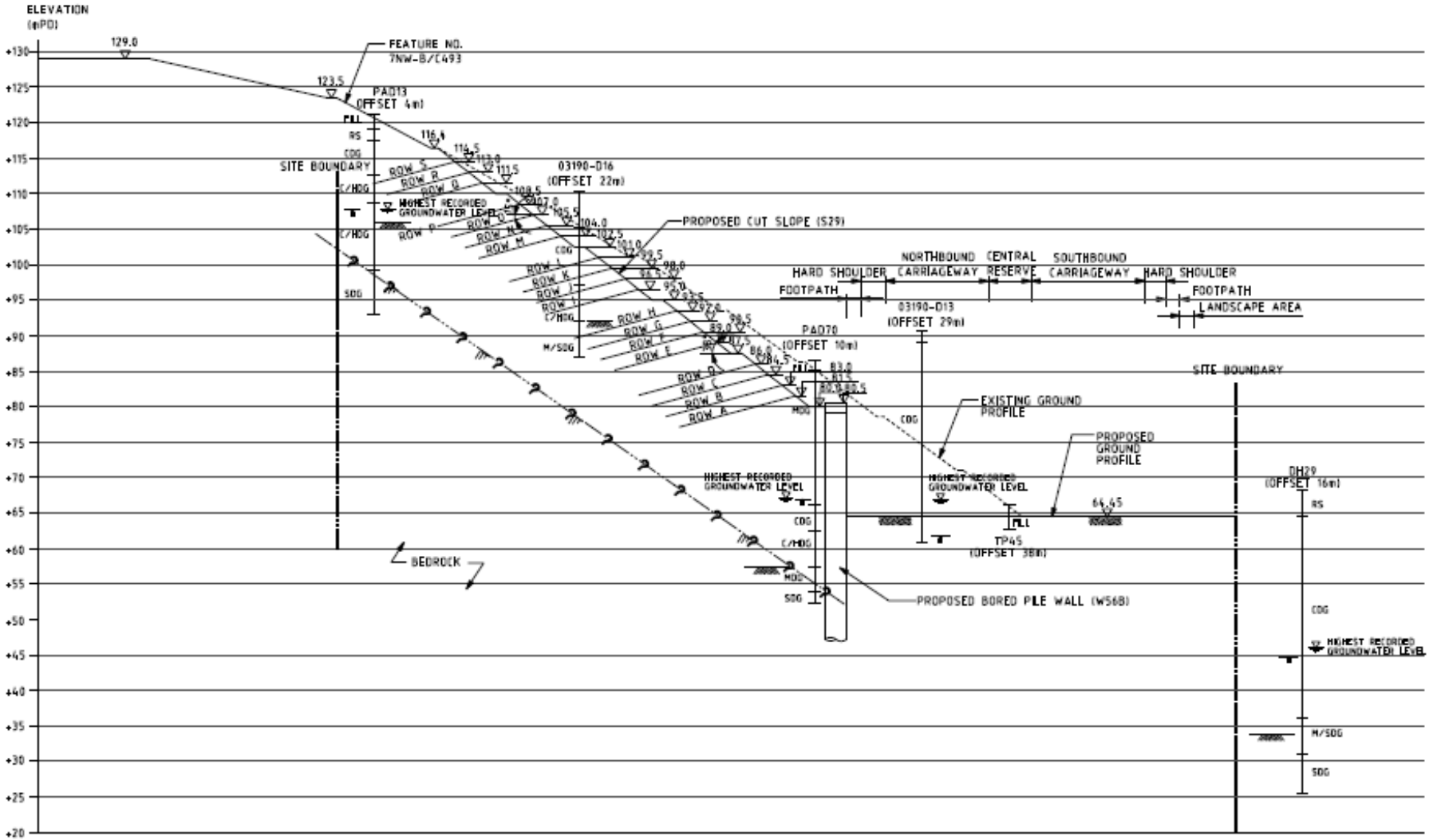
- Wall Alignment in Curvature
- Construction Sequence – Curing & Concrete Supply, etc
- Extensive Amount of Large Scale Formwork & Flasework required
- Working at Height





Conforming Design – Bored Pile Wall

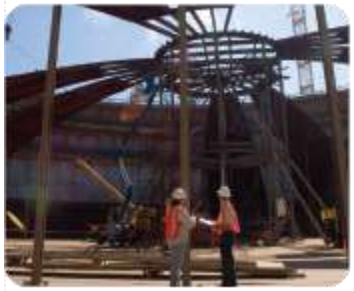
Design of Bored Pile Wall



SECTION 59-59

Construction of Bored Pile Wall

- Heavy equipments / piling platform is required

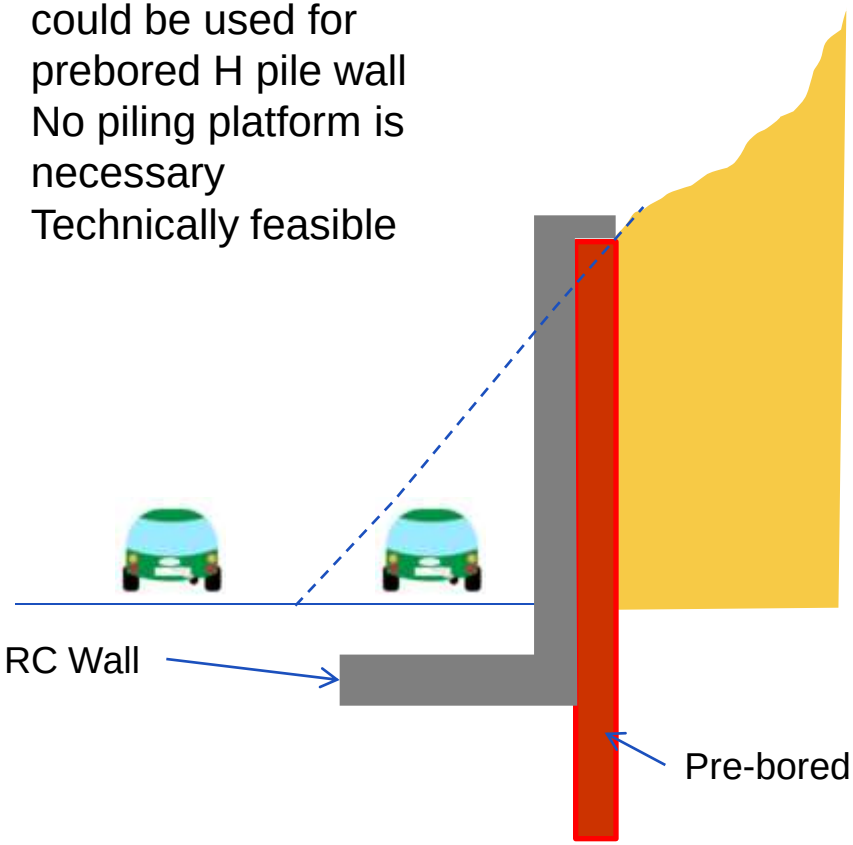


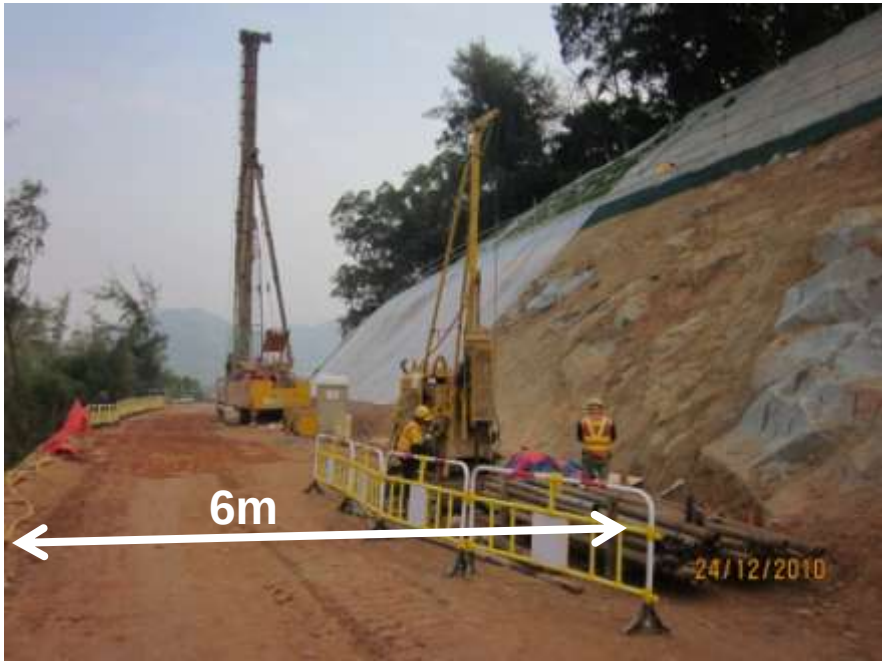


Alternative Design – Cantilever Wall with Stabilizing Base

Design Concept of the Cantilever Wall with Stabilizing Base

- Smaller equipments could be used for prebored H pile wall
- No piling platform is necessary
- Technically feasible

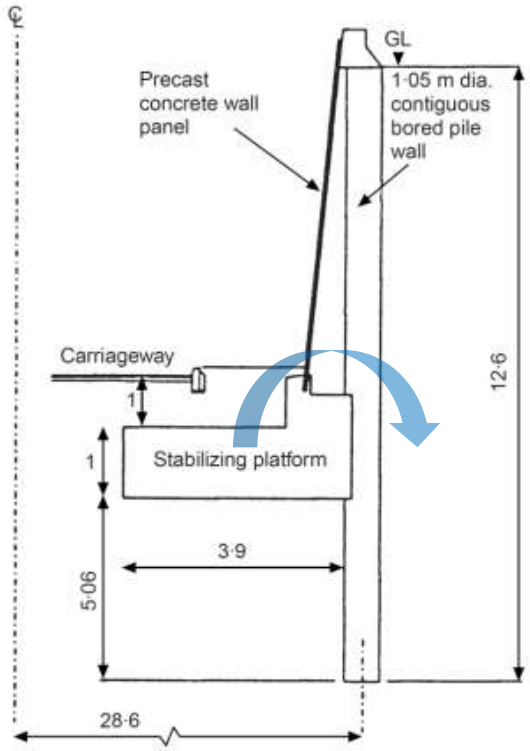


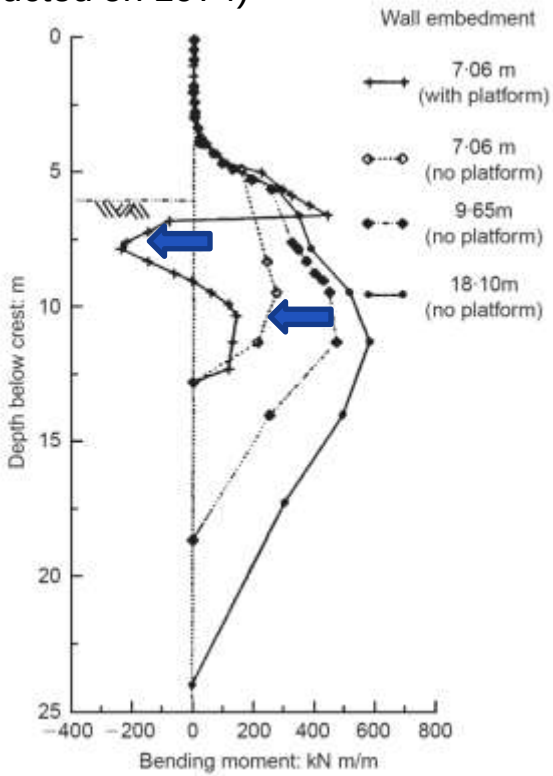


Alternative Design – Pre-bored H-pile wall with a stabilization base

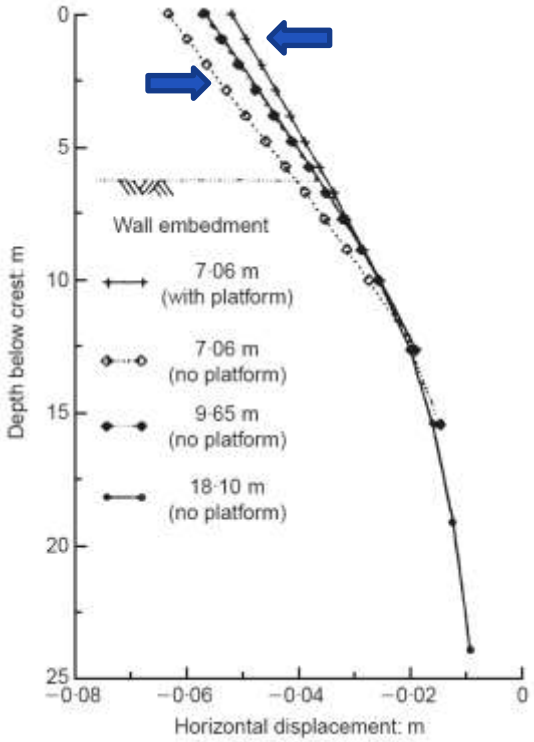
Literature Review (1)

- The influence of a stabilizing platform on the performance of an embedded retaining wall: a finit element study, Powrie and Chandler (1998)
  - Embedded bored pile retaining wall on the A406 North Circular Road at Waterworks Corner, South Woodford, London, UK (Constructed on 1974)





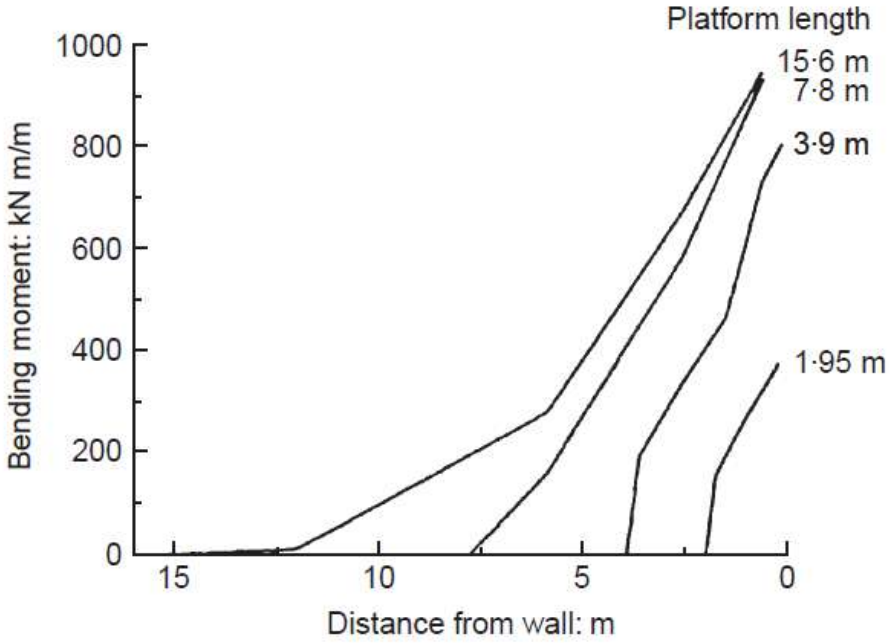
Bending Moment



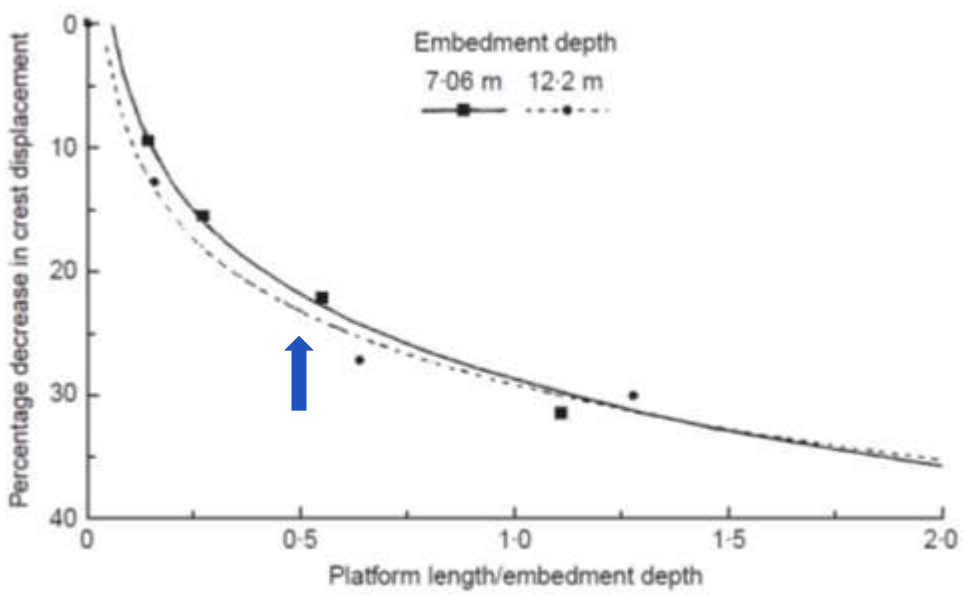
Wall Movement

Literature Review (1)

- The influence of a stabilizing platform on the performance of an embedded retaining wall: a finit element study, Powrie and Chandler (1998)
  - Embedded bored pile retaining wall on the A406 North Circular Road at Waterworks Corner, South Woodford, London, UK (Constructed on 1974)



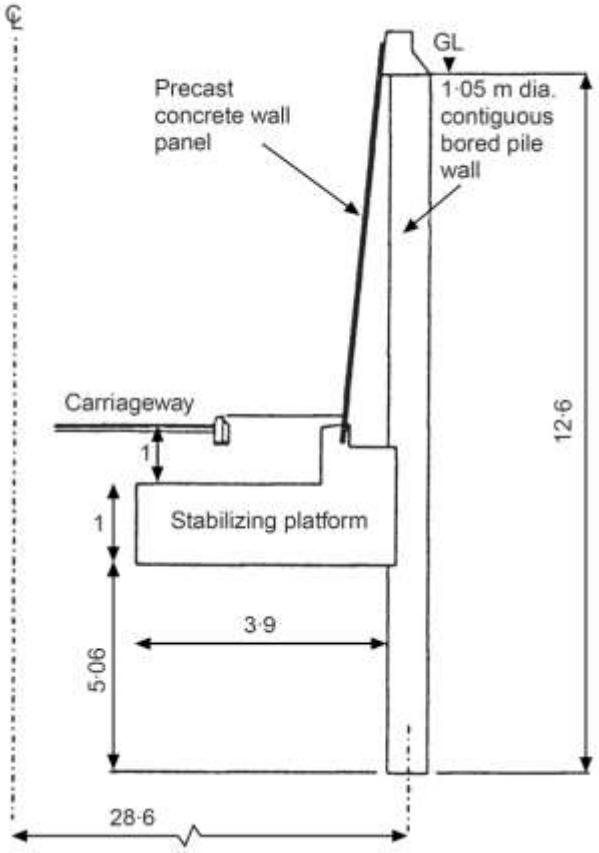
Bending moments in stabilizing platforms of different lengths



Percentage decrease in crest displacement against platform length / embedment depth ratio

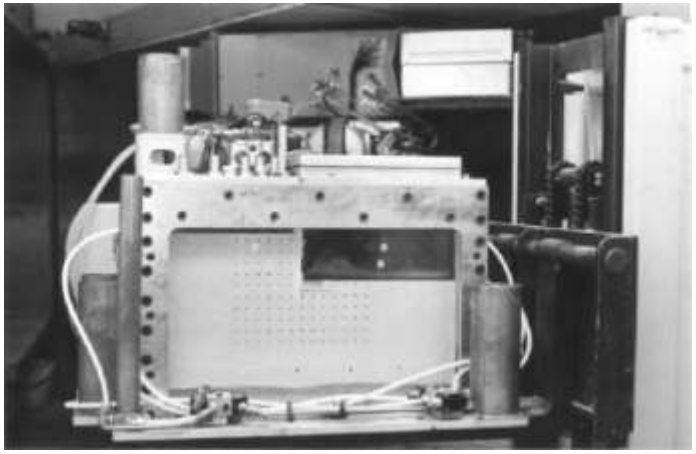
Literature Review (2)

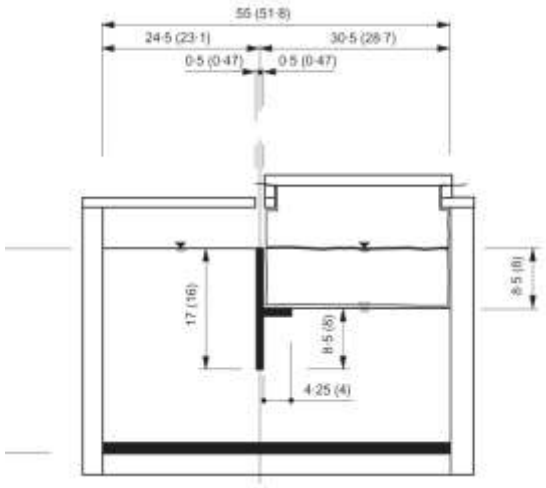
- Back-analysis of an embedded retaiing wall with a stabilizing base slab, Powrie, Chandler and Carder(1999)
  - Embedded bored pile retaining wall on the A406 North Circular Road at Waterworks Corner, South Woodford, London, UK (Constructed on 1974)
- No obvious mechanism of collapse on which to base a limit-equilibrium analysis
- The behaviour of the wall during construction depends on the sequence of excavation and propping, and may have a significant influence on the long-term performance of the structure
  - In over-consolidated clay

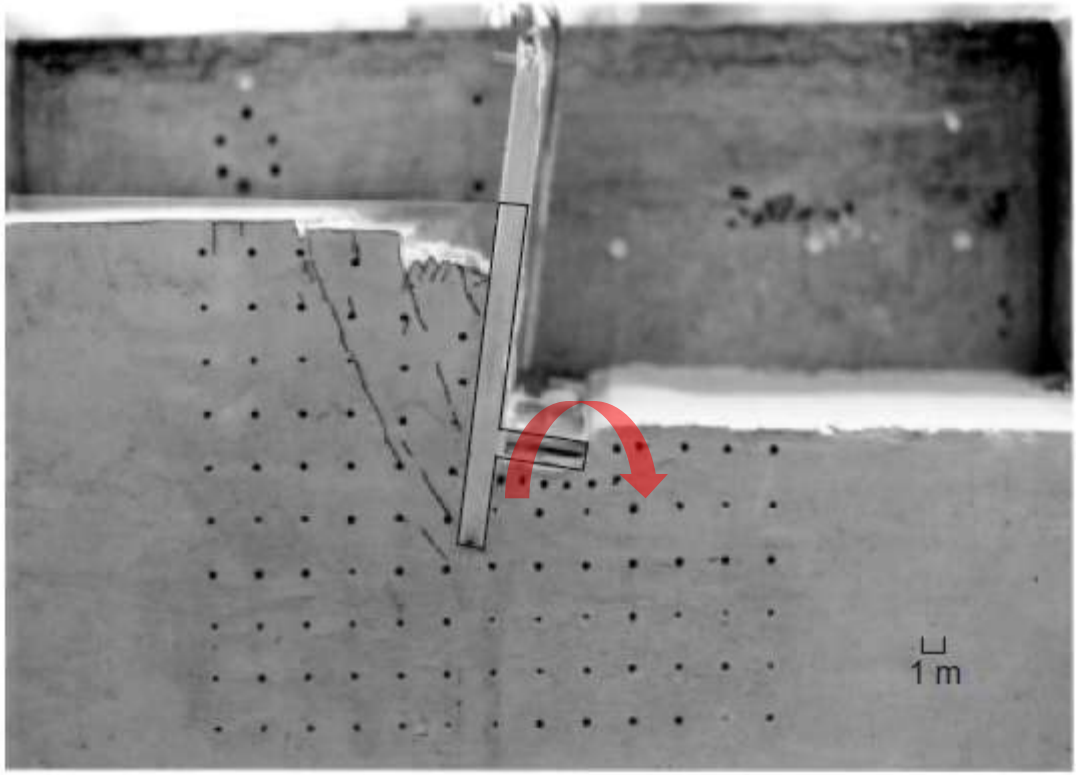


Literature Review (3)

- Centrifuge modelling of embedded retaining walls with stabilizing bases, Powrie and Daly(2007)







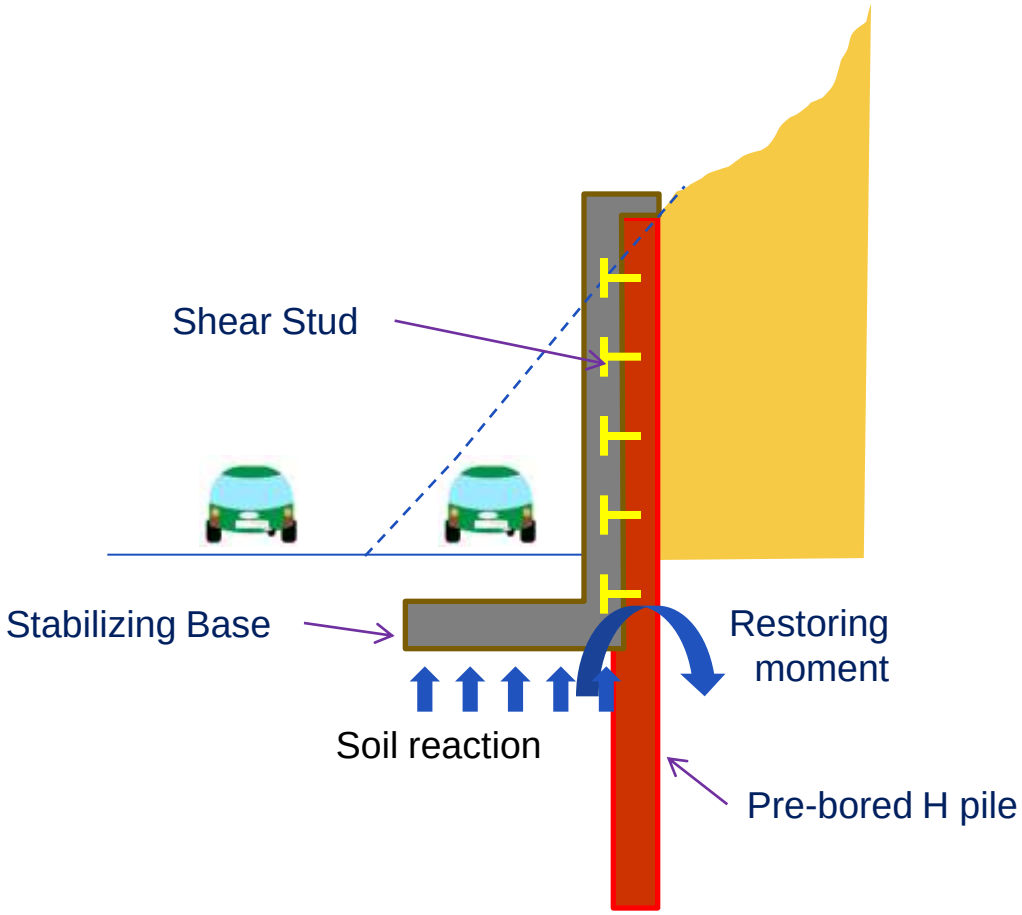
Post-flight view of test no. K4, showing slip surface

Design Consideration based on Literature Review

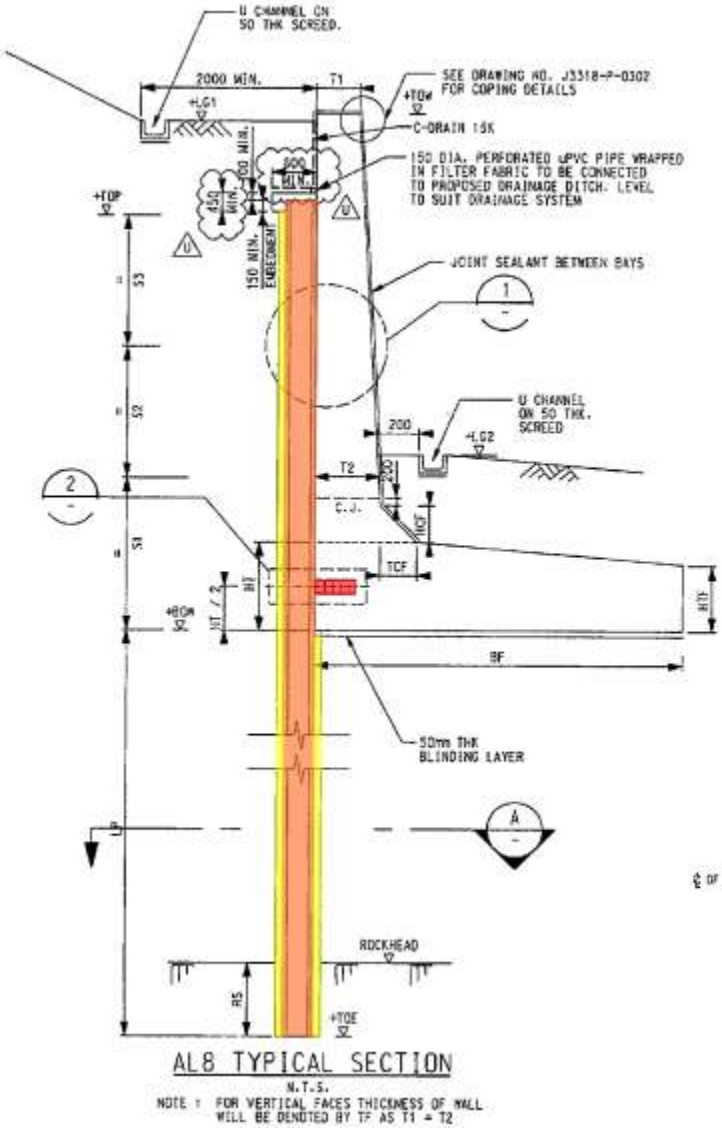
- Ground / Groundwater Condition
- Wall Geometry
- Bending Stiffness of the Cantilever Wall and Stabilizing Base
- Construction Sequence

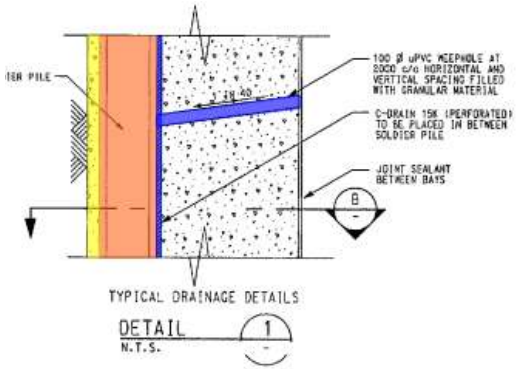
Design Concept of the Cantilever Wall with Stabilizing Base

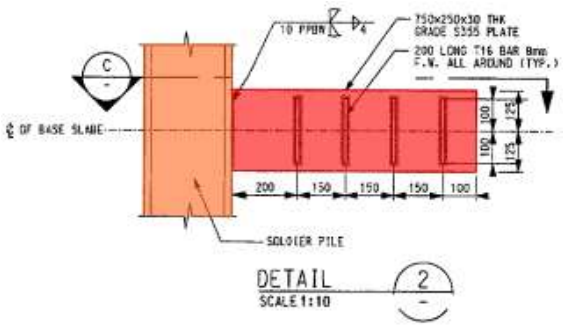
- Soil reaction from the stabilizing base provides a restoring moment to enhance the overturning stability of the cantilever wall
- Passive soil resistance on the cantilever wall contributes to increasing the sliding stability of the wall
- Composite section at wall stem increases stiffness
- Shear studs are needed to be provided between the R.C. wall and the pre-bored H pile wall to resist the interface shear force

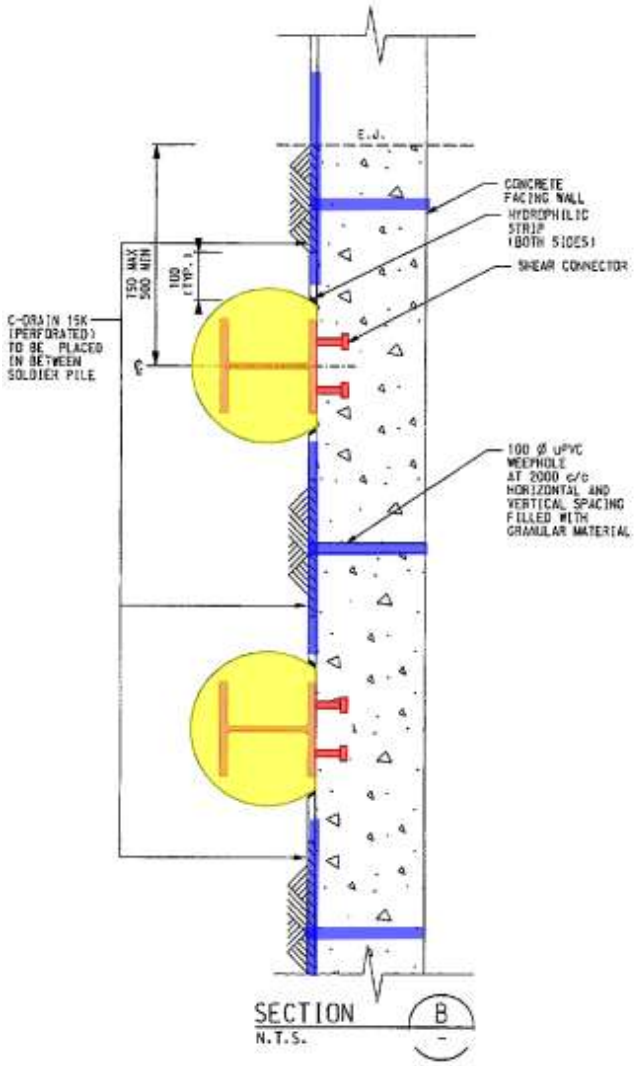


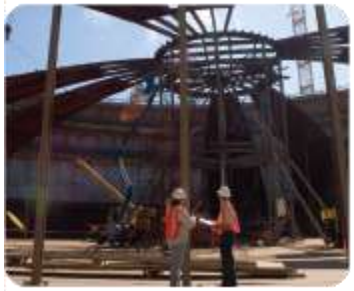
Design of the Cantilever Wall with Stabilizing Base













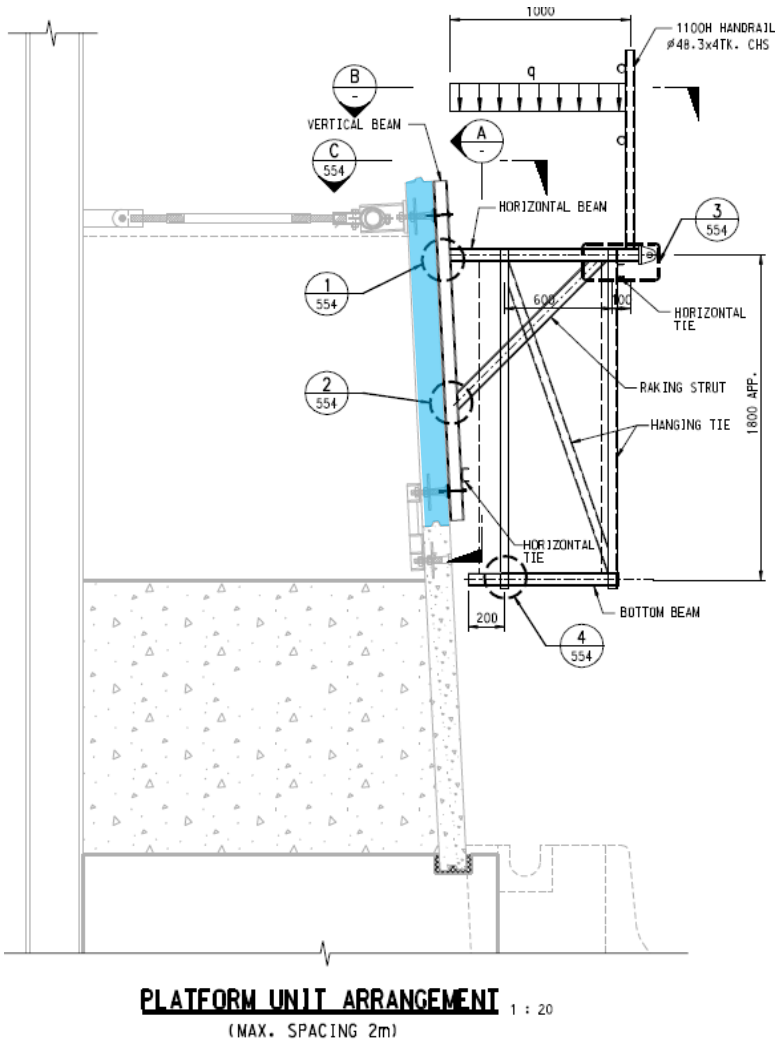
Further Revision– Precast Panel and Hanging Platform

Other Concerns

- Wall Alignment in Curvature
- Construction Sequence – Curing & Concrete Supply
- Extensive Amount of Large Scale Formwork & Flasework required
- Working at Height
- Excessive boulders, slow progress in rock excavation and thus seriously insufficient time for wall stem construction

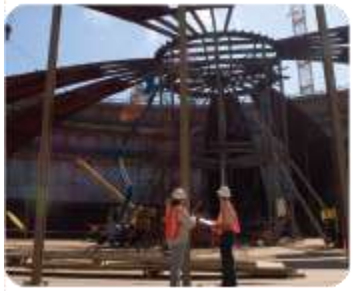
Design Concept of the Precast Panel

- Use non-structural precast panel as permanent formwork of the RC wall
  - Additional Reinforcement
  - No temporary formwork
  - No temporary falsework in front of the RC wall
- Use hanging platform
  - Fixed on the precast panel
  - No working platform sitting on ground level in front of the RC wall



Advantages of using Precast Panel and Hanging Platform

- Near perfect concrete surface at retaining wall face
- Smaller concreting volume & Better temperature resistance
- Eliminate the use of large scale formwork and falsework
- Workers worked in safe module working platform
- Construction time significantly reduced
  - Works simultaneously at ground level and at height





Construction Sequence

Construction Sequence

1. Pre-boring with guard-rail

2. Inserting H-pile

3. Grouting

Construction Sequence

4. Extracting Temporary Casing

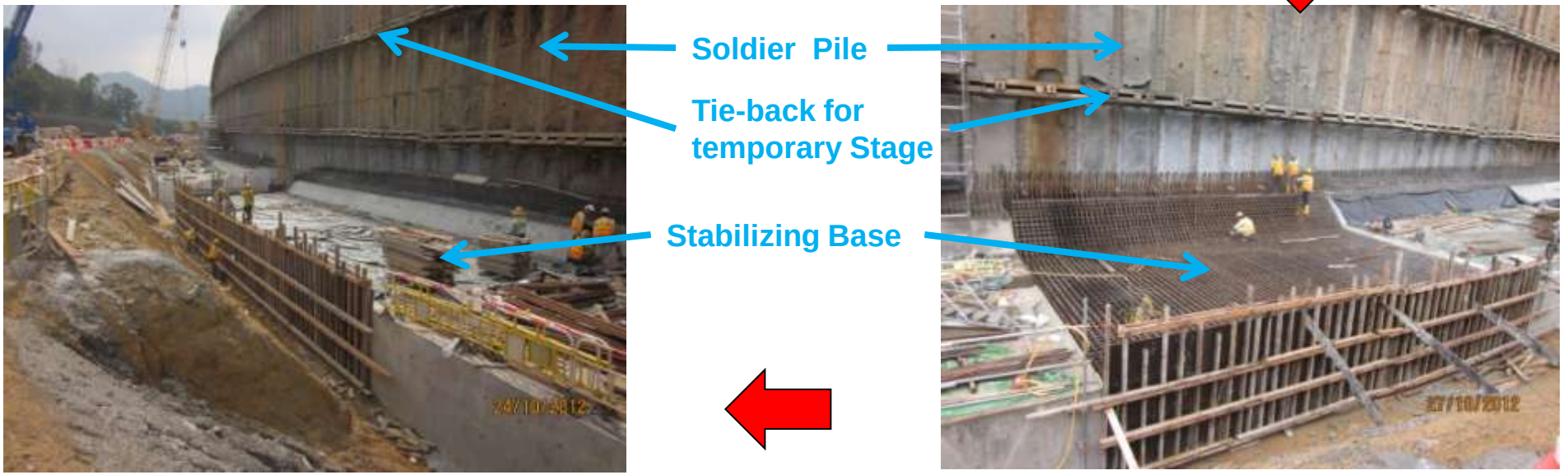
5. Excavation in front of Soldier Pile

6. Installation of shear stud & Temporary Tie-back

7. Installation of waling

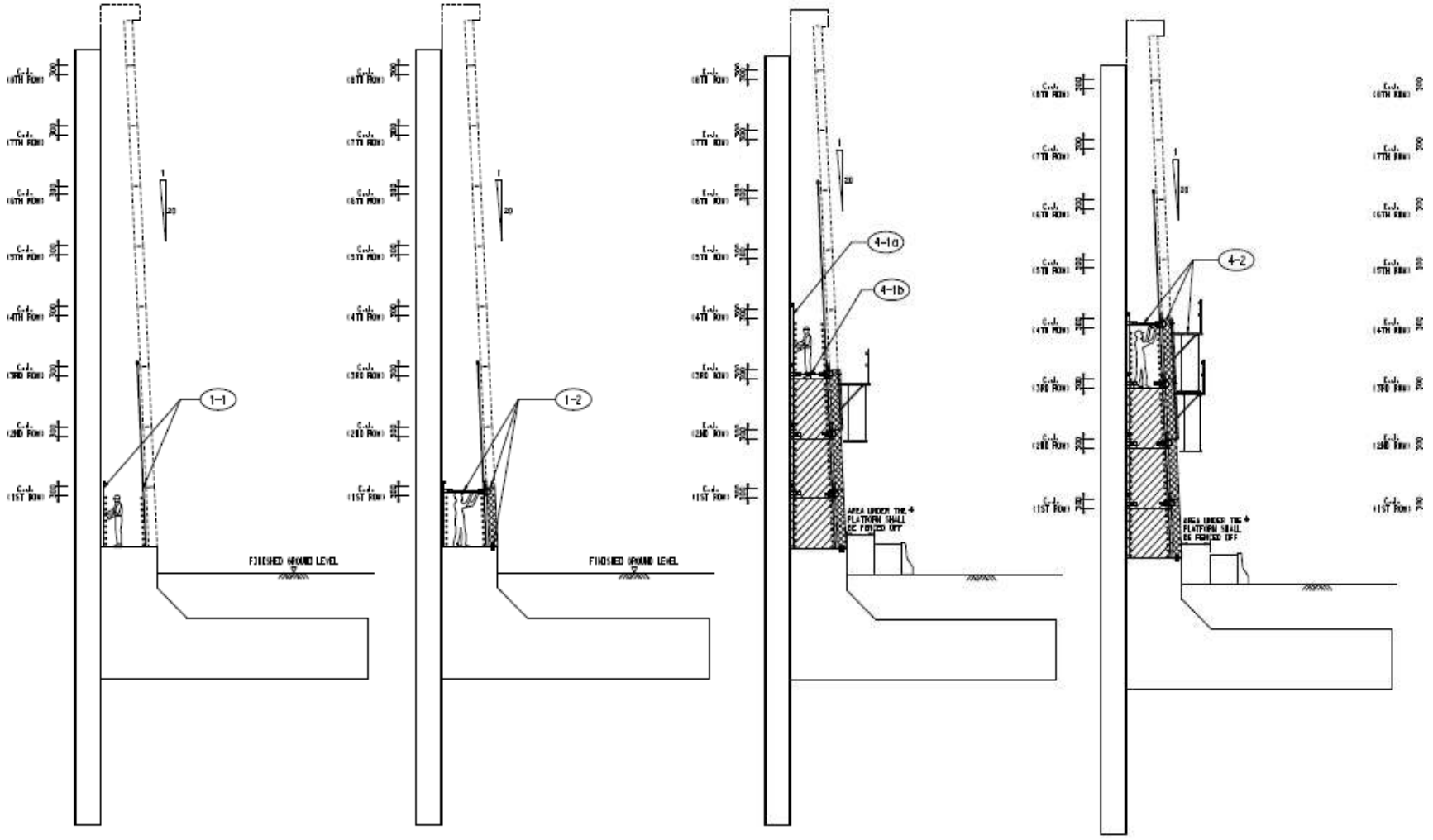
Construction Sequence

8. Excavation down to Formation Level of Stabilizing Base

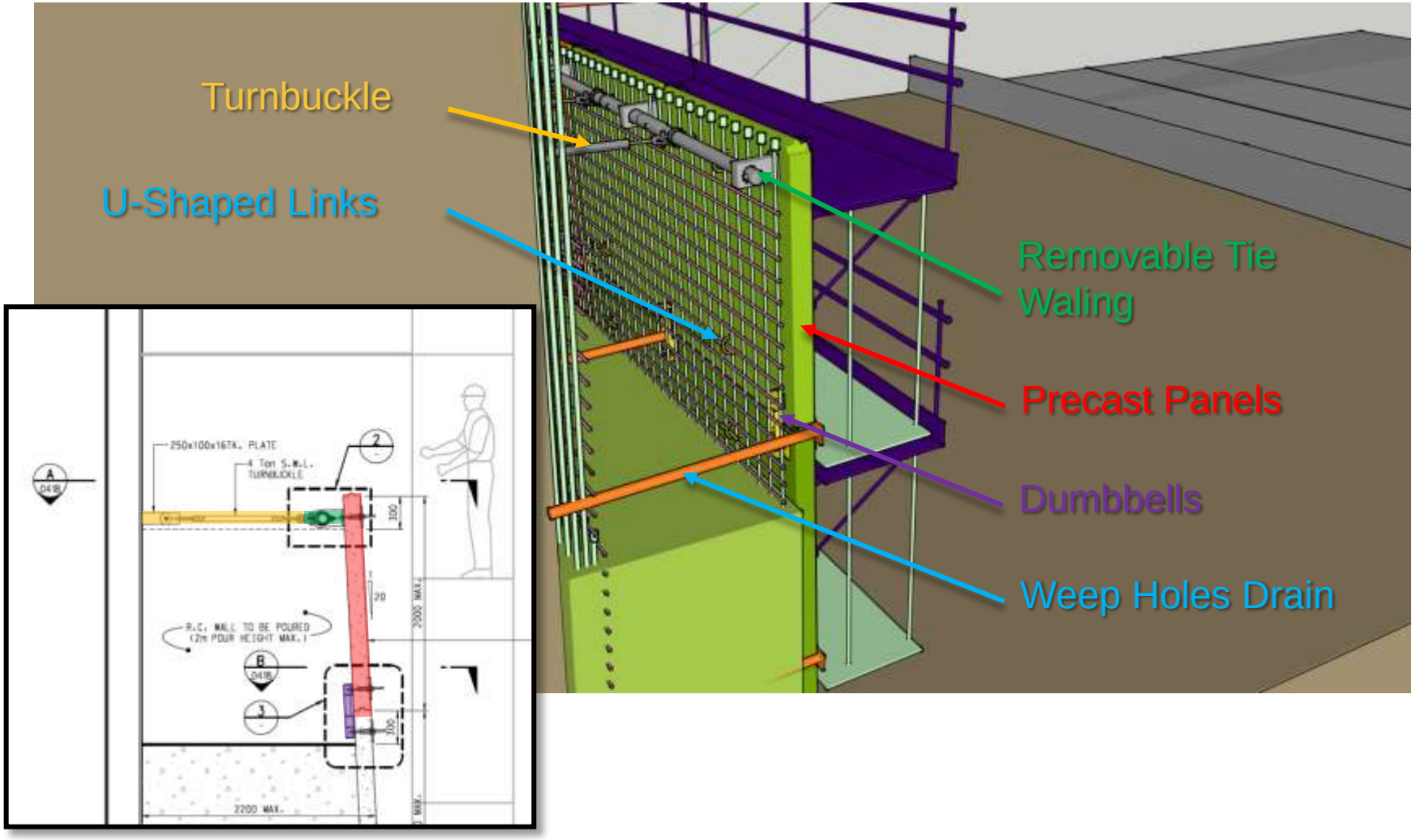


9. Construction of Stabilizing Base

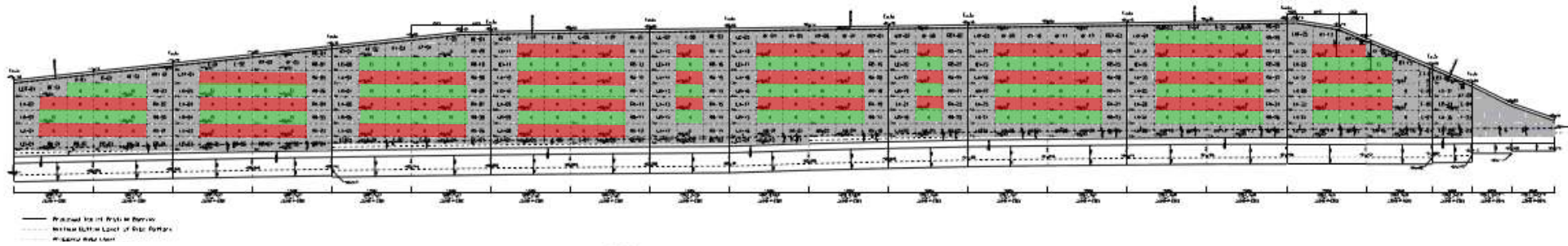
Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

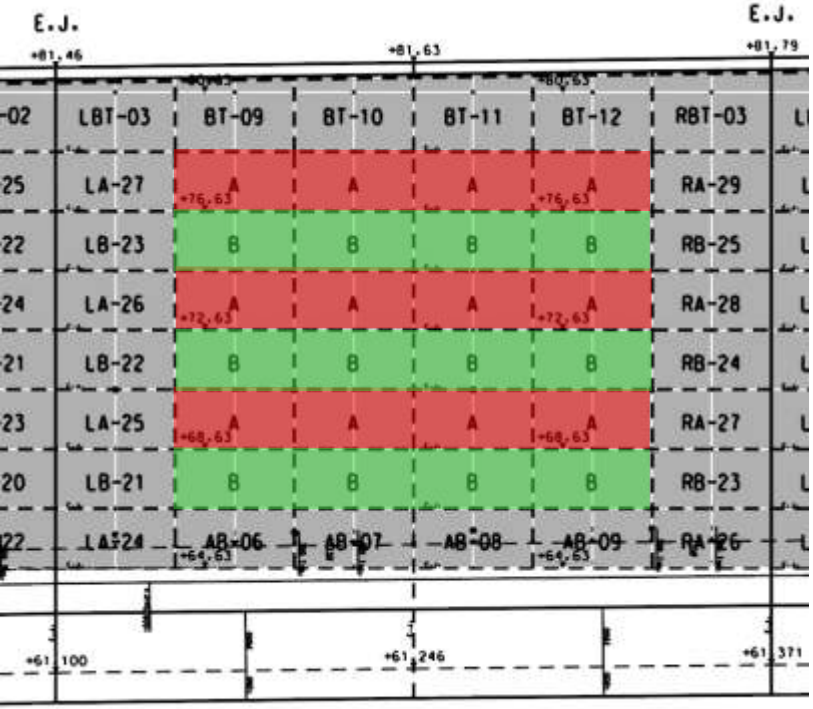


Construction Sequence of Wall Stem using Precast Panel and Hanging Platform



Construction Sequence of Wall Stem using Precast Panel and Hanging Platform



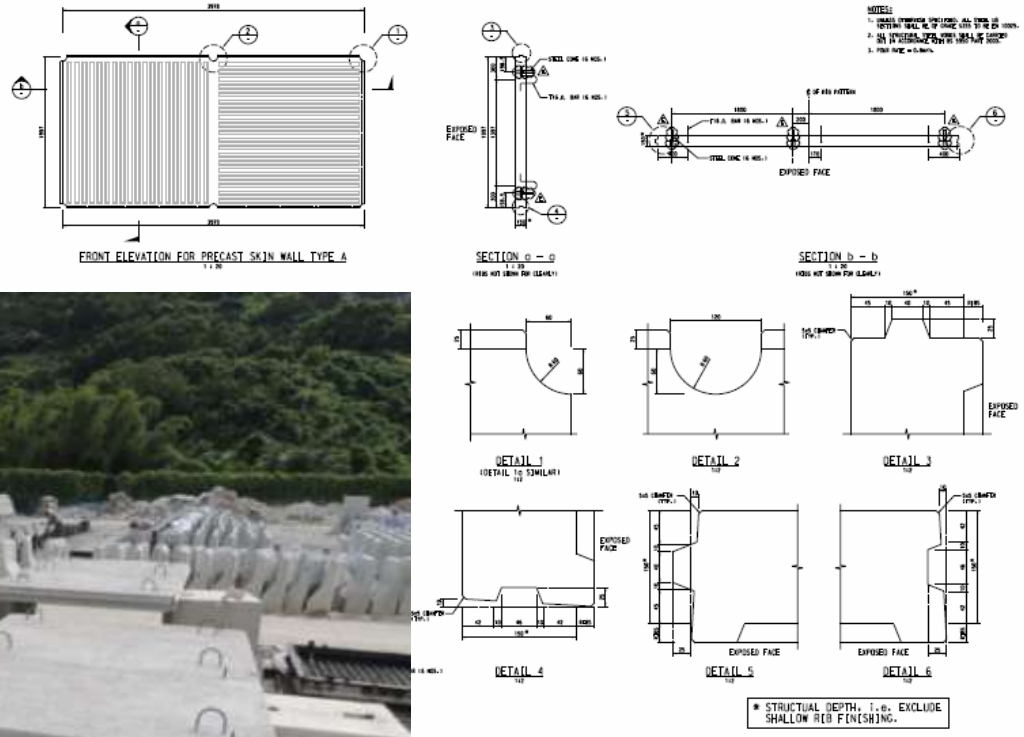


Step 1. Production of Precast Panel

- Total 10 Bays
- Approx. 450 Panels
- Type A / Type B (Different in Pattern)
- Custom Type around each bay

Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 1.
Production of Precast Panel

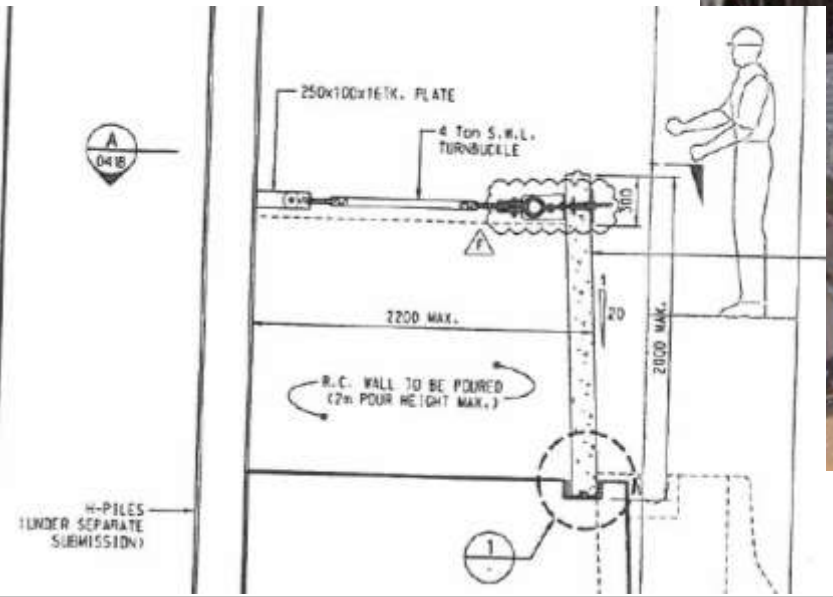


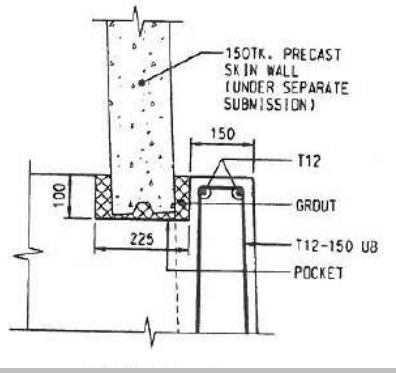
Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 2.
Transportation and Storage of Precast Panel

Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 3.
Install first layer of precast panels on the recess at “kicker portion above base slab”





Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

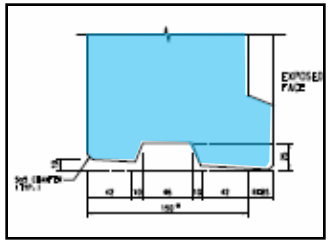
Step 4.
Lifting

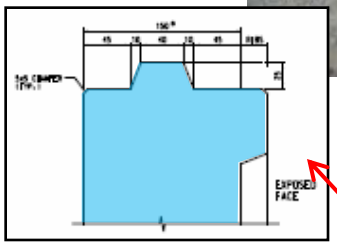
Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

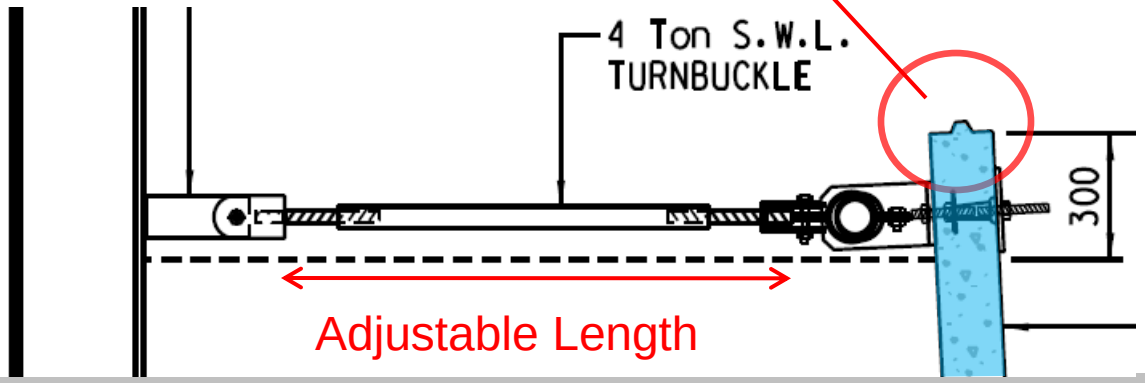
Step 5.
Connect the upper portion of Precast Panel to H-piles by a removable tie waling system

Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 6.
Adjust Precast Panel by adjustable push & prop system

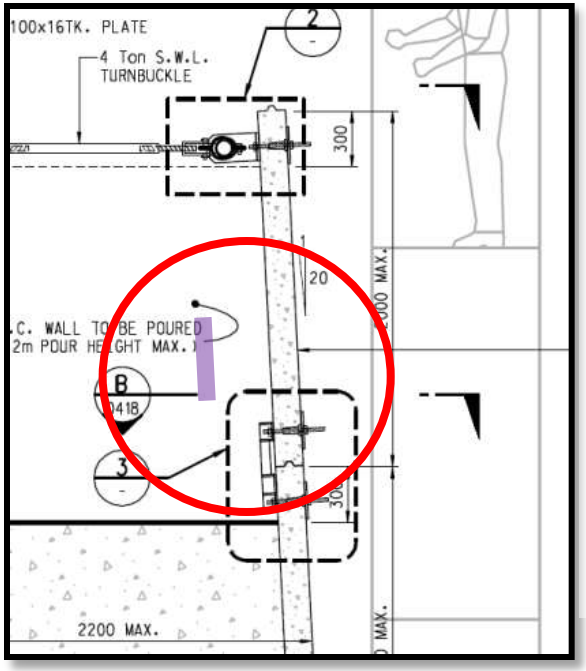


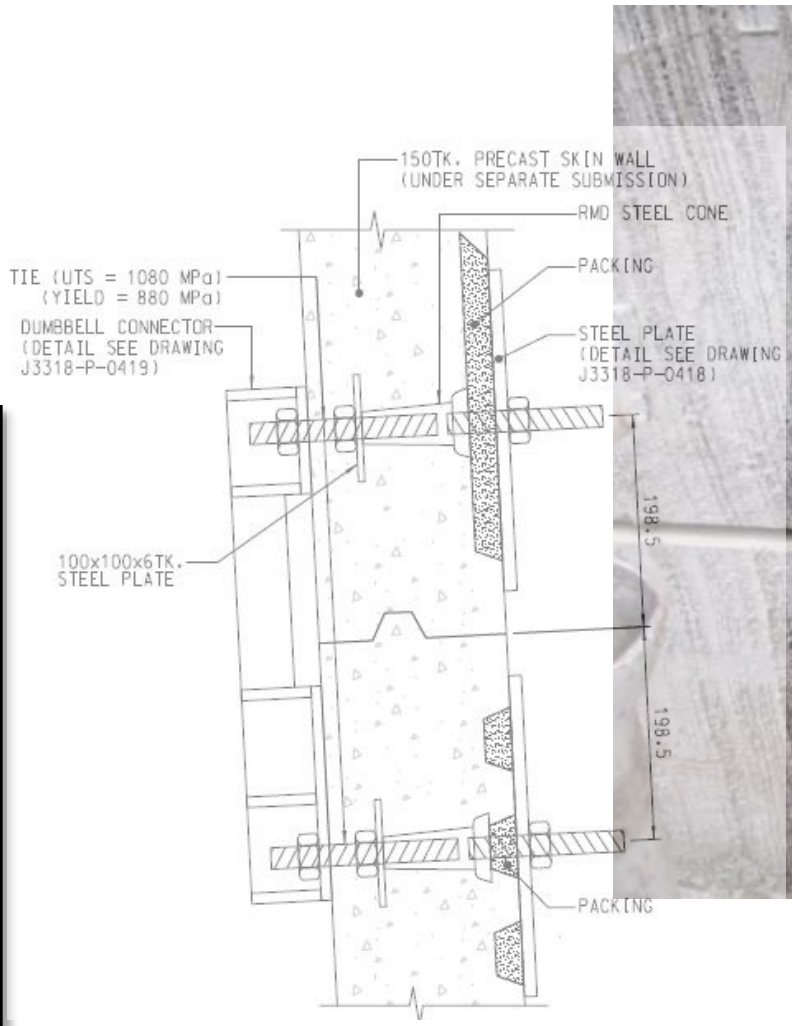




Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 7.
Fix the lower portion of Precast Panel by a dumbbell connector





Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

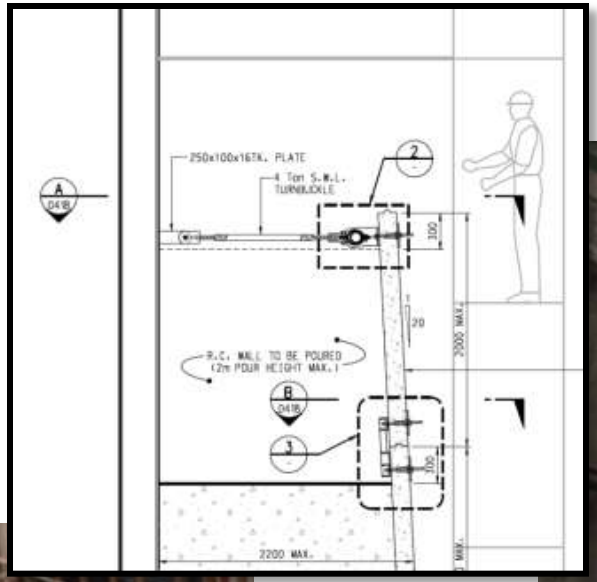
Step 8.
Loading Test

Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 9.
Carry out the reinforcement fixing works, fix geocomposite drainage layers & hydrophilic strips, install weepholes, etc.

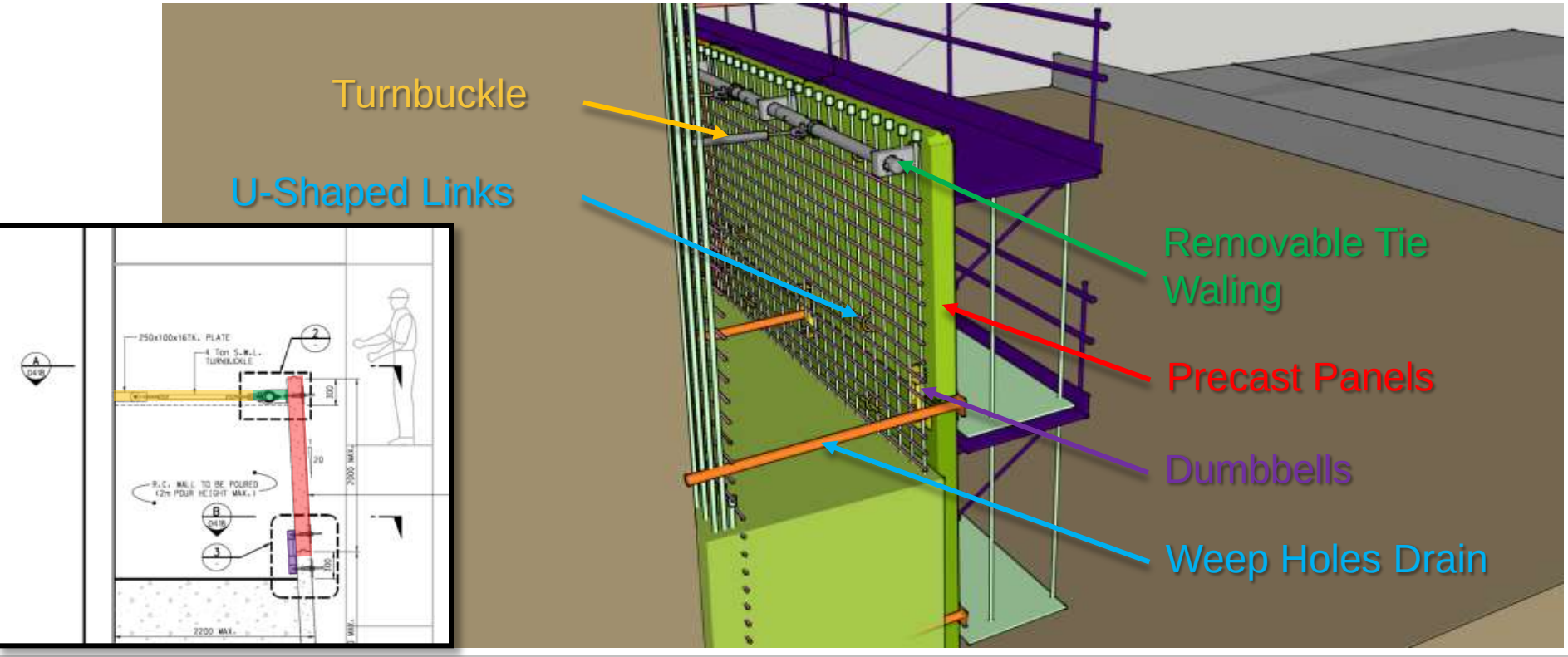
Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

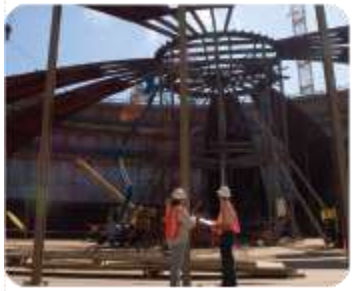
Step 10.
Concreting to the level below turnbuckile



Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

Step 11. Remove the tie waling system for re-use
Step 12. Repeated step 4 -7 for another layer of precast panel
Step 13. Detach the lower hanging platform attached on the previously cast panel and make good the tie bolt holes

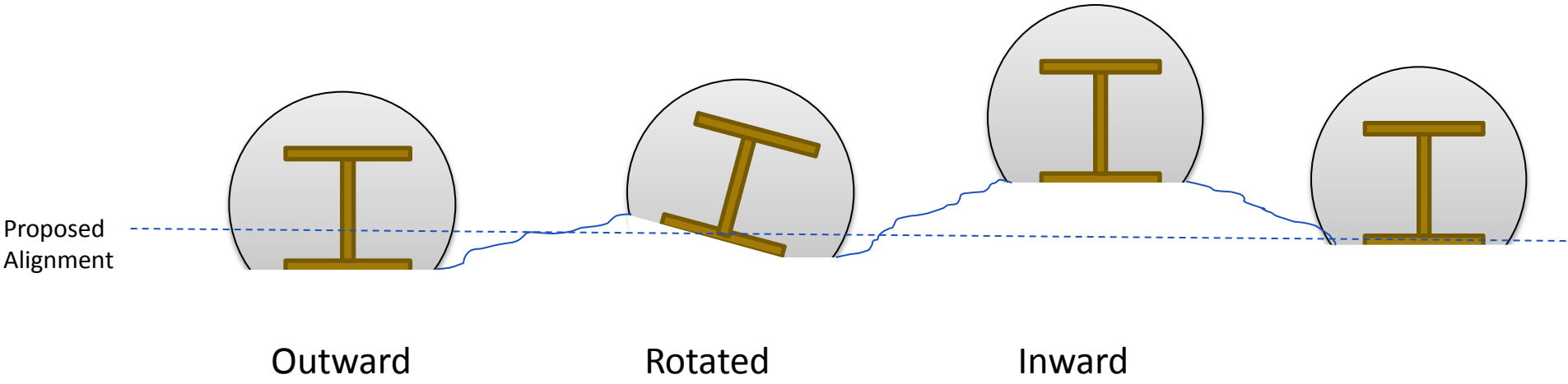




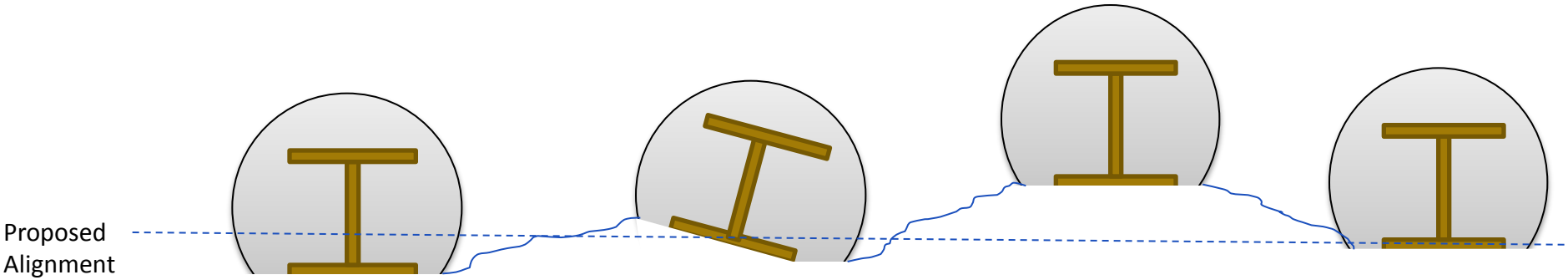


Construction Difficulties

Construction Difficulties
Not-uniform alignment of soldier piles

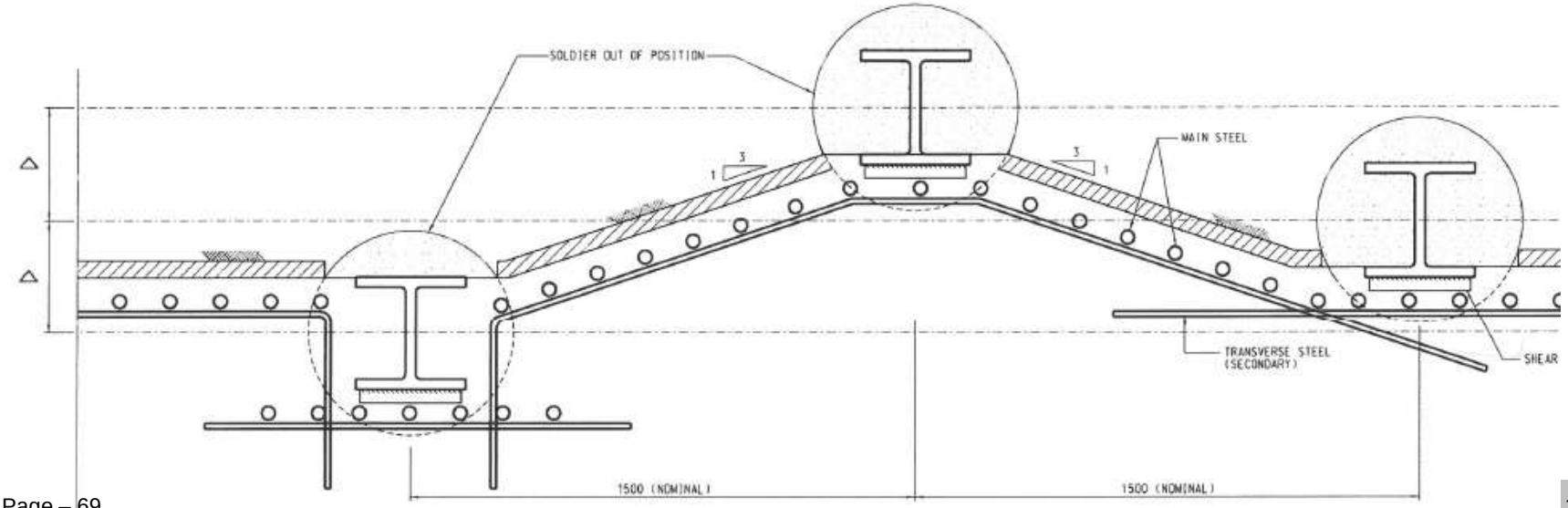


Construction Difficulties
Not-uniform alignment of soldier piles

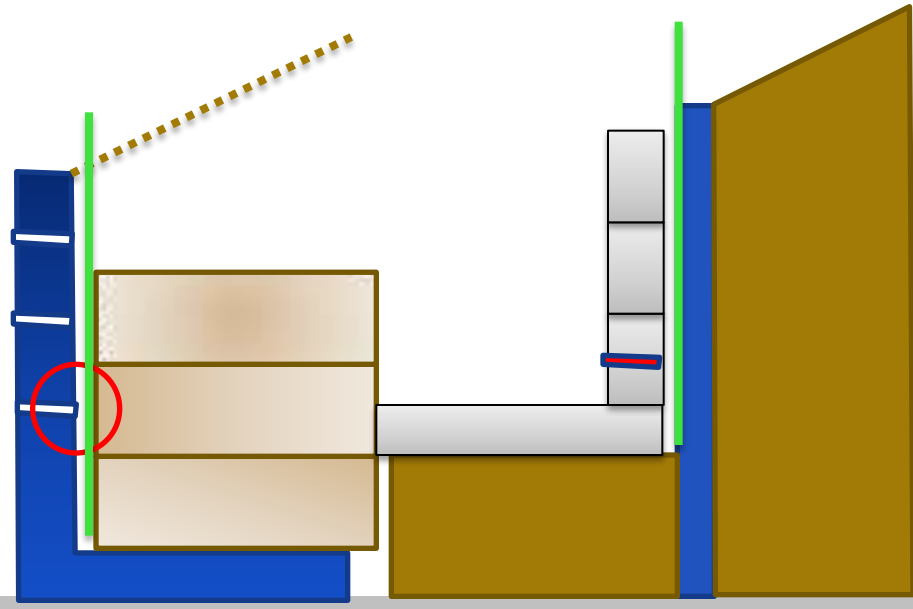


Adopted Design Scheme

Outward Rotated Inward



Construction Difficulties
Drainage Layer - C-drain



Construction Difficulties
Drainage Layer

Construction Difficulties
Drainage Layer

- C-drain fixing

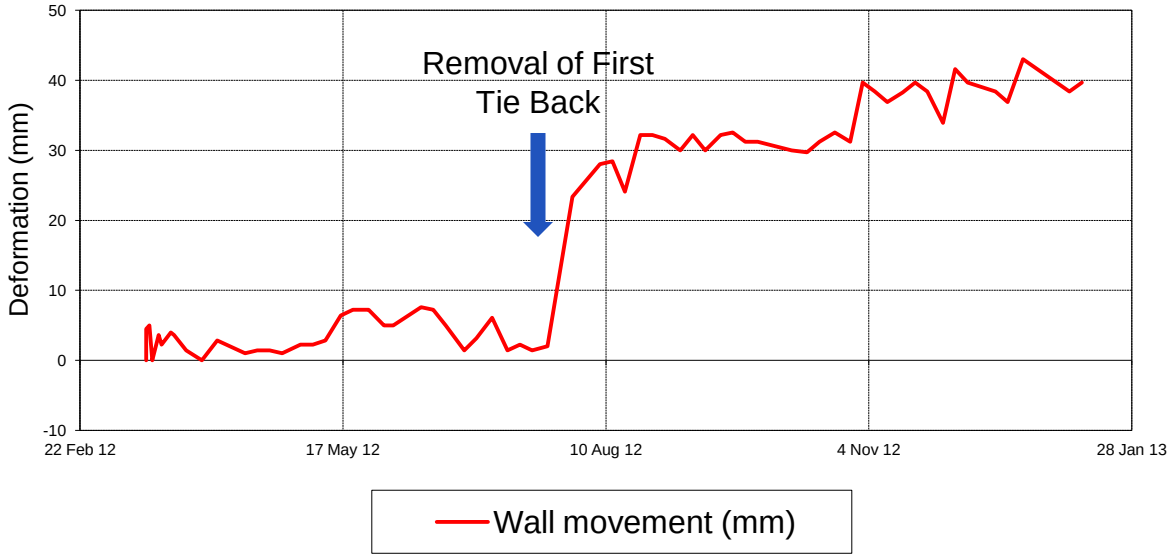
Construction Difficulties
Installation of Precast Panel in Accurate Position

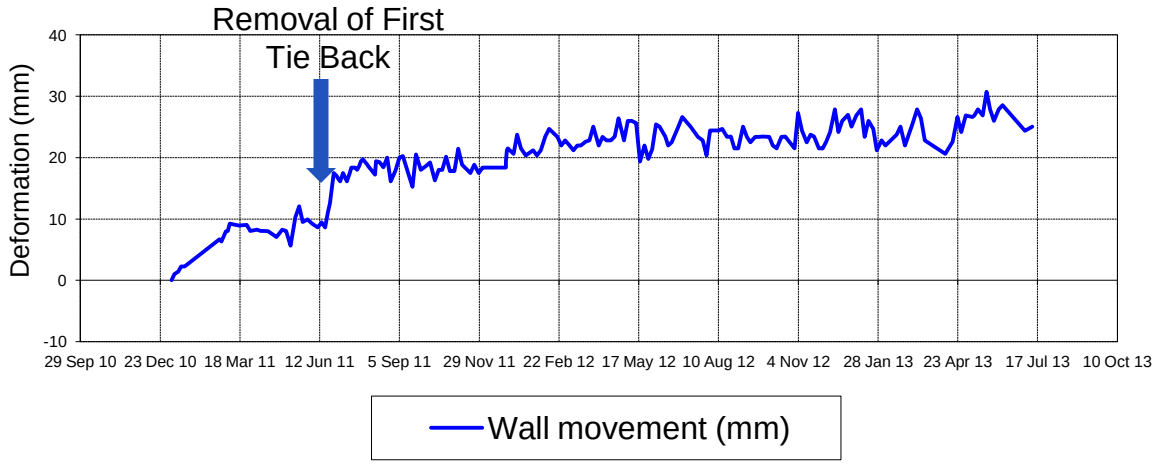
Programme and Progress

- W69 (Length = 100m, Max. Height of Wall Stem = 16m)
  - Construction Time for Wall Stem = 10 months
- W38 (Length = 148m, Max. Height of Wall Stem = 17m)
  - Construction Time for Wall Stem = 8 months
- W56B (Length = 240m, Max. Height of Wall Stem = 19m)
  - Construction Time for Wall Stem using Precast Panel and Hanging Platform = 7 months

Monitoring

- Horizontal Movement at Wall Top Less than 0.25% of Retained Height
- Horizontal Movement at Wall Top Significantly Increase after removal of First Layer of Tie Back





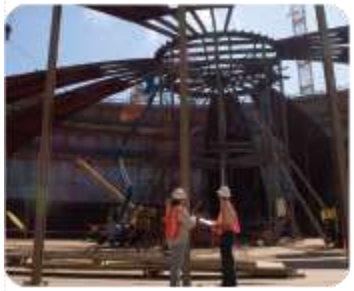
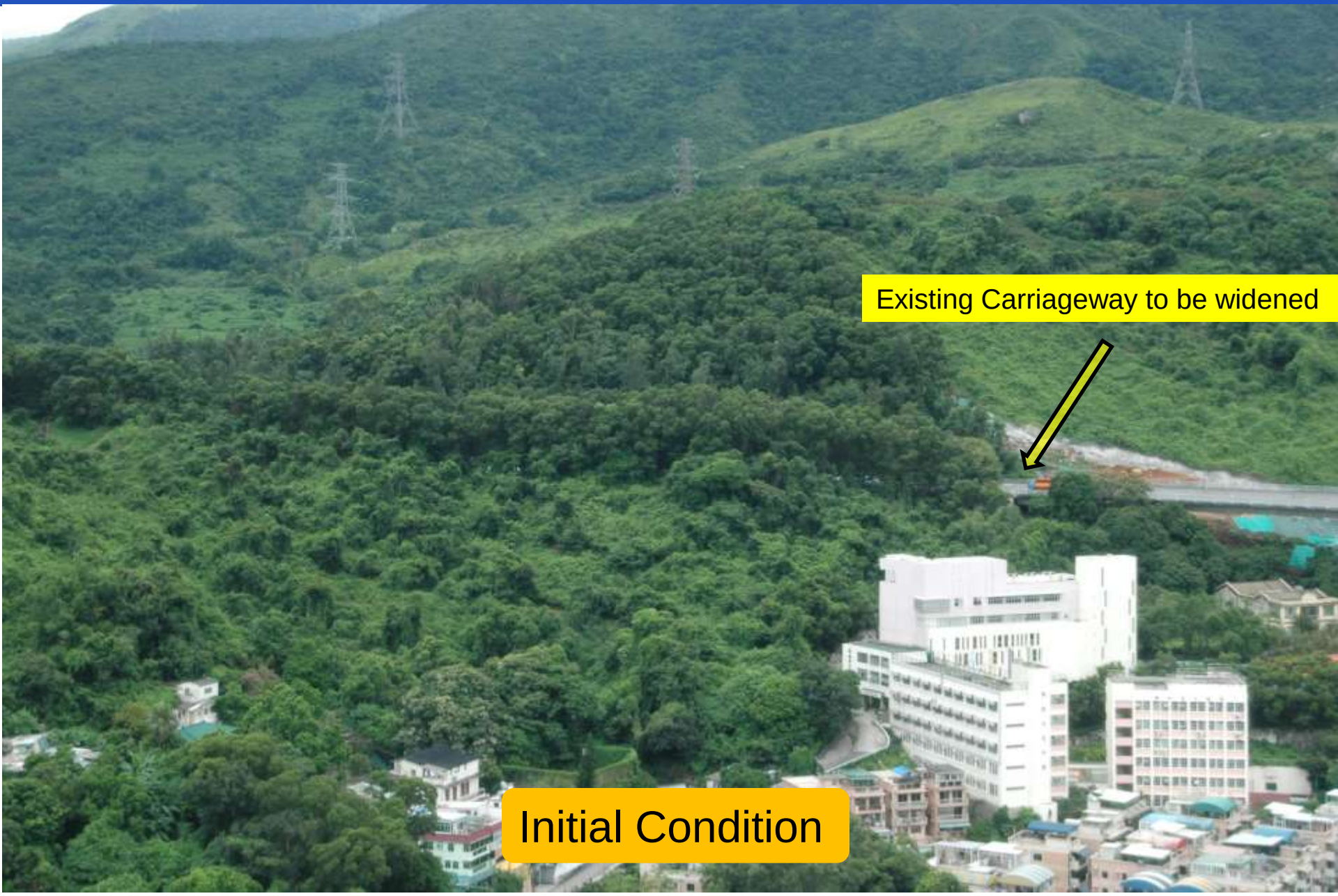




Photo Highlights


Existing Carriageway to be widened
Initial Condition


06/12/2011


31/01/2012


28/10/2011


27/08/2012 14:44


30/08/2012 09:55

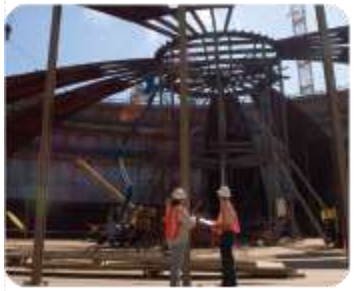

27/01/2012 11:13


45 degree upslope above the wall top
Proposed Retaining wall with
Maximum Retained Height 17m
12m Stabilizing Base


05/02/2013 14:33


25/01/2013 10:41

20130421-0930am, W56B (1)

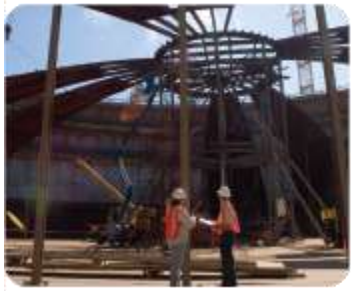




Conclusions

Conclusions

- Pre-bored H-pile Wall with Stabilizing Base
  - Suitable for large retaining height
  - No heavy equipment and large piling platform required, especially useful for construction of retaining wall at existing slopes
  - Cost Saving
- Precast Panel and Hanging Platform
  - Prefect Wall Face
  - Good Concrete Quality
  - Avoid large scale formwork and falsework
  - Safe
  - Significant Time Saving





Thank You
Q & A