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

<table>
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<tr>
<th>Year</th>
<th>2008</th>
<th>2011</th>
<th>2016</th>
<th>2021</th>
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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

Contract No. HY/2009/08
Widening of Tolo Highway /Fanling Highway
Between Ma Wo and Tai Hang
(3.5 km)
## Project Background

<table>
<thead>
<tr>
<th>Contract</th>
<th>HY/2009/08</th>
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<tr>
<td>Client</td>
<td>Highways Department, HKSAR</td>
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<td>Main Contractor</td>
<td>Gammon Construction Limited</td>
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| 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) |
Soldier Pile Wall with Stabilizing Base using Precast Panel (W56B)

Goose Shaped Wall (W56A)

Natural Terrain Study Area 3A
Rock Fill Slope & Soil Cut Slope upgraded by Soil Nailing Technique (S31A)

Natural Terrain Study Area 4

Soldier Pile Wall with Stabilizing Base (W57B & W57C)

Goose Shaped Wall (W59)

Bridge 12A
L-shaped RC Wall with Inclined Wall Base (W65A & W65B)

Existing Cut Slope 7NW-A/C35 upgraded by soil nailing technique

Natural Terrain Study Area 6-2

Rock Fill Slope in front of W65B

Existing Cut Slope 7NW-A/C35 upgraded by soil nailing technique
Existing Cut Slope 7NW-A/C35 upgraded by soil nailing technique

7NW-A/CR39 upgraded by soil nailing technique

Natural Terrain Study Area 6-1

L-shaped RC Wall with Inclined Wall Base (W66 & W67)
Reinforced Fill Wall

Bridge 18A

Soldier Pile Wall with Stabilizing Base (W69)

Existing Bridge to be demolished

Natural Terrain Study Area 6-2

S40

S41

S39

S42

S43

W67

W71
Soldier Pile Wall with Stabilizing Base (W69)

Counterfort Retaining Wall W72A

L-shaped RC Wall supported on Mini-piles (W72B)

L-shaped RC Wall with Inclined Wall Base (W73)
L-shaped RC Wall supported on Mini-piles (W72B)

L-shaped RC Wall with Inclined Wall Base (W73)

Counterfort Retaining Wall W72A

Rock Fill Slope (S44A)

Re-compacted Existing Fill Slope (S44B)

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

Retaining Wall W56B
Basic information
Geology of the Site

Granodiorite
Colluvium
Alluvium
Geological Model of W56B
Initial Condition (for Part of the Wall)

- Boundary of road after widening
- Large retained height
- Trunk road at toe

Retaining Walls
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
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)

  - Embedded bored pile retaining wall on the A406 North Circular Road at Waterworks Corner, South Woodford, London, UK (Constructed on 1974)
Literature Review (1)

  - Embedded bored pile retaining wall on the A406 North Circular Road at Waterworks Corner, South Woodford, London, UK (Constructed on 1974)

![Graph showing bending moments in stabilizing platforms of different lengths](image1)

![Graph showing percentage decrease in crest displacement against platform length/ embedment depth ratio](image2)
Literature Review (2)

  - 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

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Construction Sequence

1. Excavation in front of Soldier Pile
2. Installation of shear stud & Temporary Tie-back
3. Extracting Temporary Casing
4. Installation of waling
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

- Soldier Pile
- Tie-back for temporary Stage
- Stabilizing Base
Construction Sequence of Wall Stem using Precast Panel and Hanging Platform
Construction Sequence of Wall Stem using Precast Panel and Hanging Platform

- Turnbuckle
- U-Shaped Links
- Removable Tie
- Waling
- Precast Panels
- Dumbbells
- Weep Holes Drain
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 turnbuckle
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

Proposed Alignment

Outward  Rotated  Inward
Construction Difficulties

Not-uniform alignment of soldier piles

Proposed Alignment

Outward

Adopted Design Scheme

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
Proposed Retaining wall with Maximum Retained Height 17m

45 degree upslope above the wall top

12m Stabilizing Base
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