



# GEO Publication No. 1/2023

## Deep Excavation Design and Construction

20 October 2023



**Raymond Koo**  
Working Group on the  
Revision of GCO Publication No. 1/90



**Civil Engineering and  
Development Department**

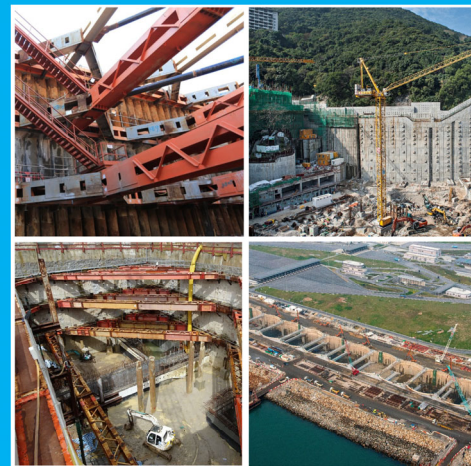
# GEO Publication No. 1/2023

## Design and Construction for Deep Excavations

- ❖ *Review of design standards*
- ❖ *Recommended practical solutions*
- ❖ *Enhanced control mechanism*

GEO Publication No. 1/2023

Deep Excavation Design and Construction



Geotechnical Engineering Office  
Civil Engineering and Development Department  
The Government of the Hong Kong  
Special Administrative Region

# GEO Publication No. 1/2023

## Design and Construction for Deep Excavations

Working Group on Revision of GCO Publication No. 1/90

Representatives from:

- HKIE Geotechnical Division
- Piling Contractors
- Architectural Services Department
- Buildings Department
- GEO

GEO Publication No. 1/2023

Deep Excavation Design and Construction



Geotechnical Engineering Office  
Civil Engineering and Development Department  
The Government of the Hong Kong  
Special Administrative Region

# GEO Publication No. 1/2023

- Design Standards
  - ❖ Updated Global and Partial Factor Approaches
- Practical Solutions
  - ❖ Novel construction
  - ❖ Pumping test requirements
  - ❖ Realistic estimation of groundwater level
- Enhanced Control Mechanism
  - ❖ Ground deformation control
  - ❖ Response actions



# Review of Guidance Documents / Practice Notes

GCO PUBLICATION No. 1/90

## REVIEW OF DESIGN METHODS FOR EXCAVATIONS



GEOTECHNICAL ENGINEERING  
Civil Engineering Department  
The Government of the Hong Kong  
Special Administrative Region

Buildings Department Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers APP-57

Requirements for an Excavation and Lateral Support Plan  
Building (Administration)

### Introduction

Bulk excavation, even if shallow, Authorized persons, registered structural engineers (RSE) are reminded to take adequate precautions whenever excavation is found necessary as put PNPAP APP-18 and PNPAP APP-137 on detail similar operations are included.

### Criteria for Submission of Excavation and Lateral Support Plans

2. In general terms, excavation at or under Building (Administration) Regulation 8 excavations of substantial depth are to be carried out with adequate precautions.

3. ELS plans will be required to (BD) for approval where the excavation works:

- deeper than 2.5 m and greater than 1.5 m wide;
- liable to affect any road, building or water main 75 mm in diameter defined as within the 45° line up the ground surface.

4. Where the above conditions apply, an ELS plan, as prescribed in Part 2 of the Appendix, must be submitted and approved.

5. Where ELS plans are required above, an RSE would be required to prepare an assessment report of the effect on adjoining structures. For ELS plans with excavations of substantial depth, an RSE would be required to prepare and sign the support assessment, geotechnical details and calculation reports or ground investigation reports, which shall be submitted with the ELS plan.

## Guidance on embedded retaining wall design



ciria

## Review Report on Design Methods for Excavations



Task Force on Review of Design Methods for Excavations  
Geotechnical Division, The Hong Kong Institution of Engineers

August 2021

HKIE  
The Hong Kong Institution of Engineers  
Geotechnical Division  
8/F, 80 Des Voeux Road, Central, Hong Kong

- ❖ **GCO Publication No. 1/90**  
Review of Design Methods for Excavation
- ❖ **Practice Notes for AP/RSE/RGE**
  - *PNAP APP 57 – Requirements for an ELS Plan B(A)R 8(1)(bc)*
  - *PNAP APP 137 - Ground-borne Vibrations and Ground Settlements Arising from Pile Driving and Similar Operations*
- ❖ **C760**  
Guidance on Embedded Retaining Wall Design
- ❖ **HKIE Technical Review Report (2021)**

# Design Standards

## Unified Global Factors for Ultimate Limit State (ULS)

<i>Limit States</i>		<i>New Publication</i>	<i>BD (PNAP APP-57)*</i>	<i>GCO Publication 1/90</i>
<i>ULS</i>	<i>Overturning and Toe instability</i>	<b>1.5</b>	2.0	1.5
	<i>Base heave</i>	1.5	1.5	1.5
	<i>Hydraulic failure (i.e. piping and uplifting)</i>	1.5	1.5	1.5

*\* Building (Construction) Regulation 15 was repealed in 2020, taking away the minimum FOS requirements for stability checks.*

# Design Standards

## Revised Partial Factors (ULS)

Strength Properties and Load Conditions		New Publication		Geoguide 1 (2nd Ed.)	BD (PNAP APP-57)
		ULS	SLS		
Partial material factor ( $\gamma_m$ )	Unit weight	1.0	1.0	1.0	1.0
	Effective shear strength	1.2		1.2	1.2
	Undrained shear strength	<b>2.0/1.5*</b>		<b>2.0</b>	<b>2.0</b>
	Shear strength of rock joint	1.2		1.2	1.2
Partial load factor ( $\gamma_f$ )	Dead load	1.0		1.0	1.0
	Surcharge	<b>1.3</b>		<b>1.5</b>	<b>1.5</b>
	Water pressure	1.0		1.0	1.0

\*  $\gamma_m$  could be reduced to 1.5 where sufficient site-specific representative field tests are carried out (e.g. CPT calibrated with representative laboratory test results).

# Design Standards

## Revised Partial Factors (ULS)

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		ULS	SLS		
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Partial load factor ( $\gamma_f$ )	Dead load	1.0		1.0	1.0
	Surcharge	<b>1.3<sup>#</sup></b>		<b>1.5</b>	<b>1.5</b>
	Water pressure	1.0		1.0	1.0

**<sup>#</sup>  $\gamma_f$  for surcharge could be reduced to 1.3 (temporary nature of ELS, site supervision and monitoring).**

# Design Standards

## Partial Factor Approach (ULS)

### Specific Requirements in Current Partial Factor Approach (PNAP APP-57)

#### 1. Post-construction Performance Review

#### 2. Sensitivity Check

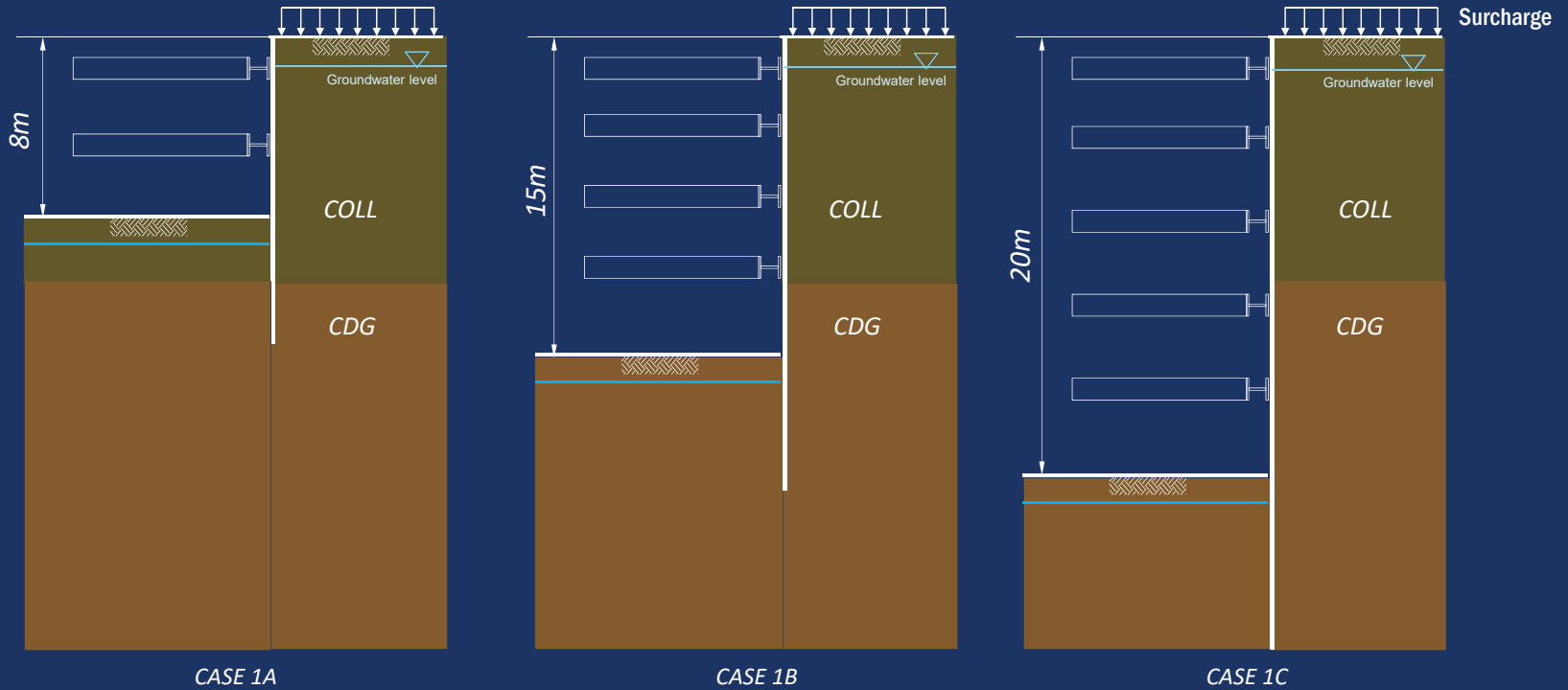
- unplanned excavation of max. 0.5 m;
- additional omitted prop level check;
- progressive failure assessment

#### Recommendation:

To **remove** these requirements as they should have been managed by the **imposed site supervision**.

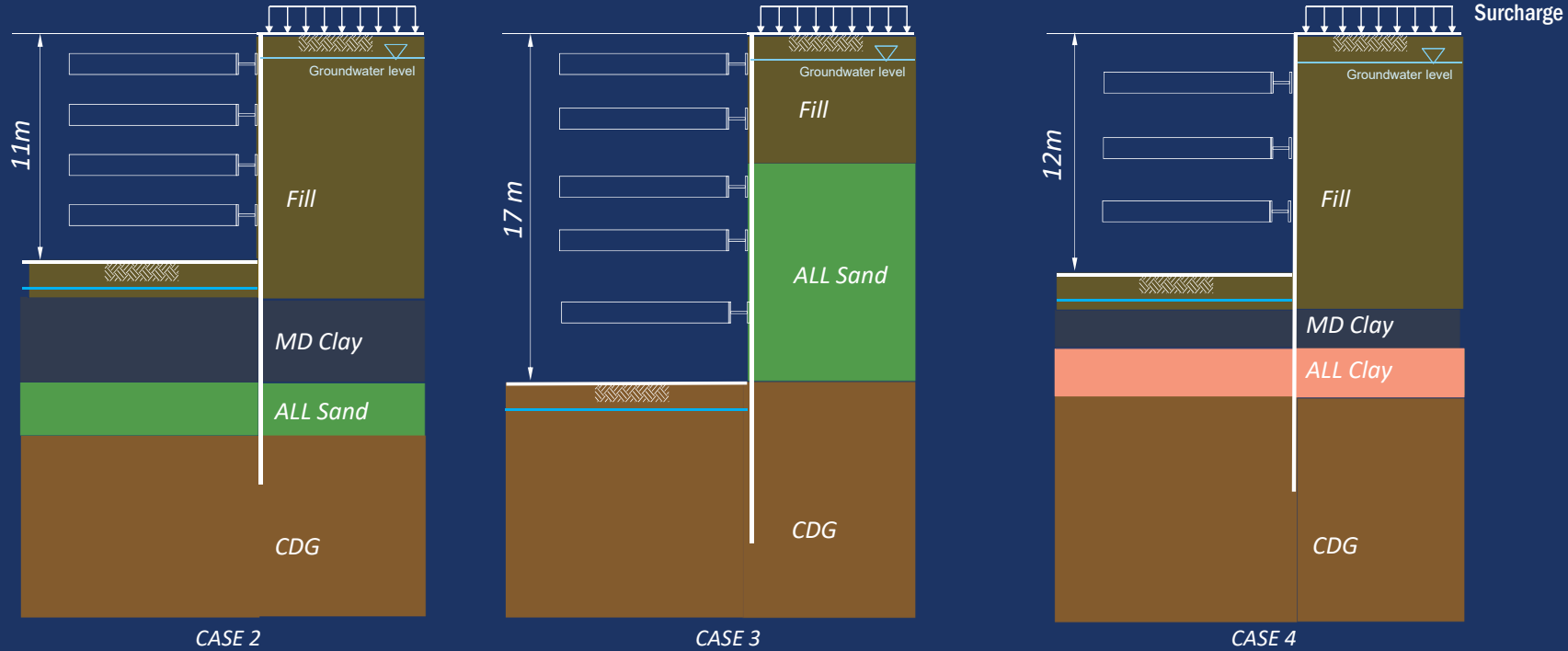
# Benchmarking Exercise

## Revised Partial Factors



# Benchmarking Exercise

## Revised Partial Factors



# Benchmarking Exercise

Required lengths of toe penetrations for different scenarios and design methods

Assumptions			New Publication		Current Practice (PNAP APP-57)	
Case	Surcharge	Excavation depth (m)	Global factor of 1.5*	Partial factor Surcharge PF = 1.3 & unplanned excavation <u>omitted</u>	Global factor of 2.0	Partial factor Surcharge PF = 1.5 with unplanned excavation
1A	20kPa	8	3.8	3.8	5.0	4.7
1B	20kPa	15	6.7	6.6	9.3	7.9
1C	20kPa	20	9.3	9.1	12.9	10.5
2	20kPa	11	13.4	13.0*	15.1	13.2
3	20kPa	17	9.2	8.9	12.2	9.9
4	20kPa	12	11.7	12.0*	12.8	12.4

\*Undrained shear strength PF reduced from 2.0 to 1.5

**How do we make  
changes for  
betterment of our  
engineering solution**

**Some of the  
challenges that  
we experienced**



# Novel Construction



TMCLKL Caterpillar shaft (2019)



Hopewell II development (2019)



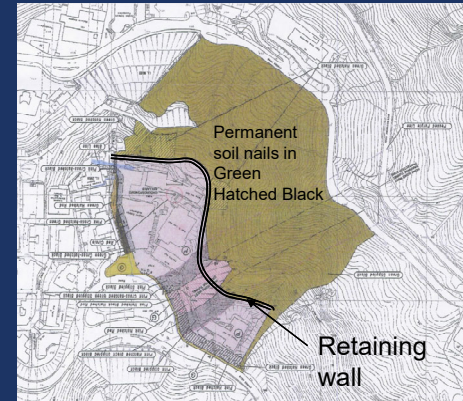
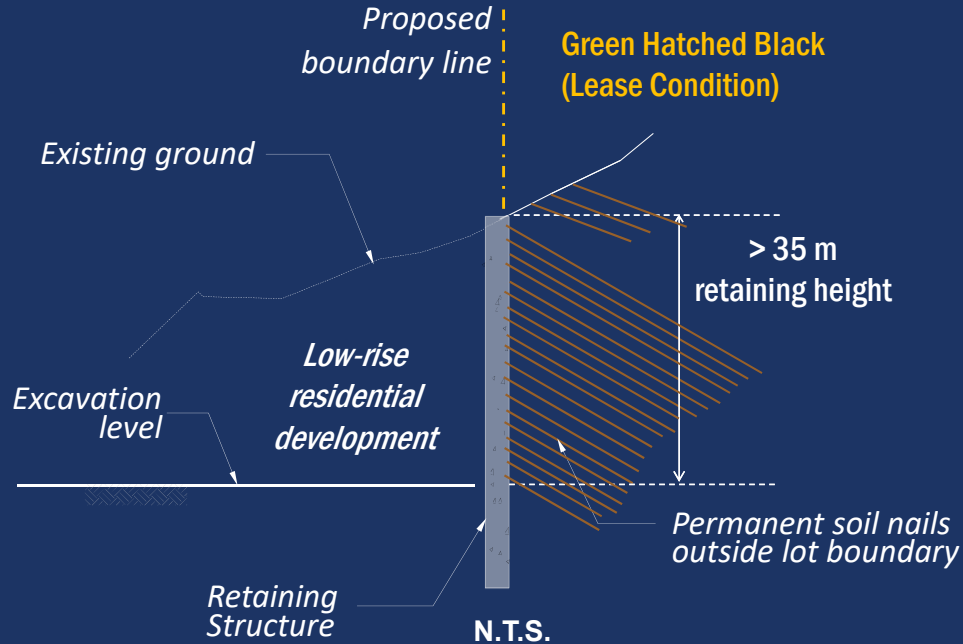
Trunk Road T2 (2022)



Permanent tie-back at development site at Stubbs Road

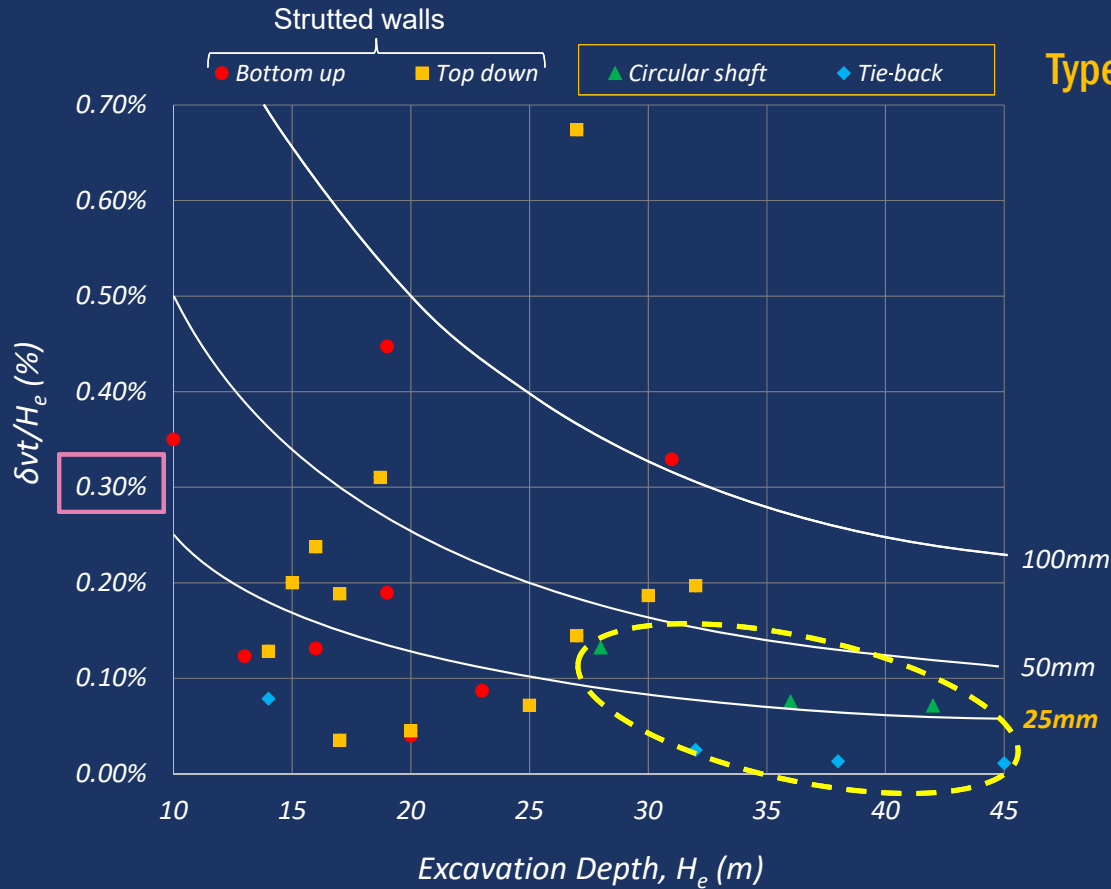
# Cost Effectiveness (Permanent Tied-back Wall)

## Hillside Developments (Existing Slopes at Stubbs Road)



**Smart geotechnical solution**

# Performance of ELS System



Type of excavation support system

Observation:

- Reasonable settlement induced by ELS works is about **0.3% $H_e$**
- Excavation with **circular shaft and tied-back system** gave **small ground deformation**

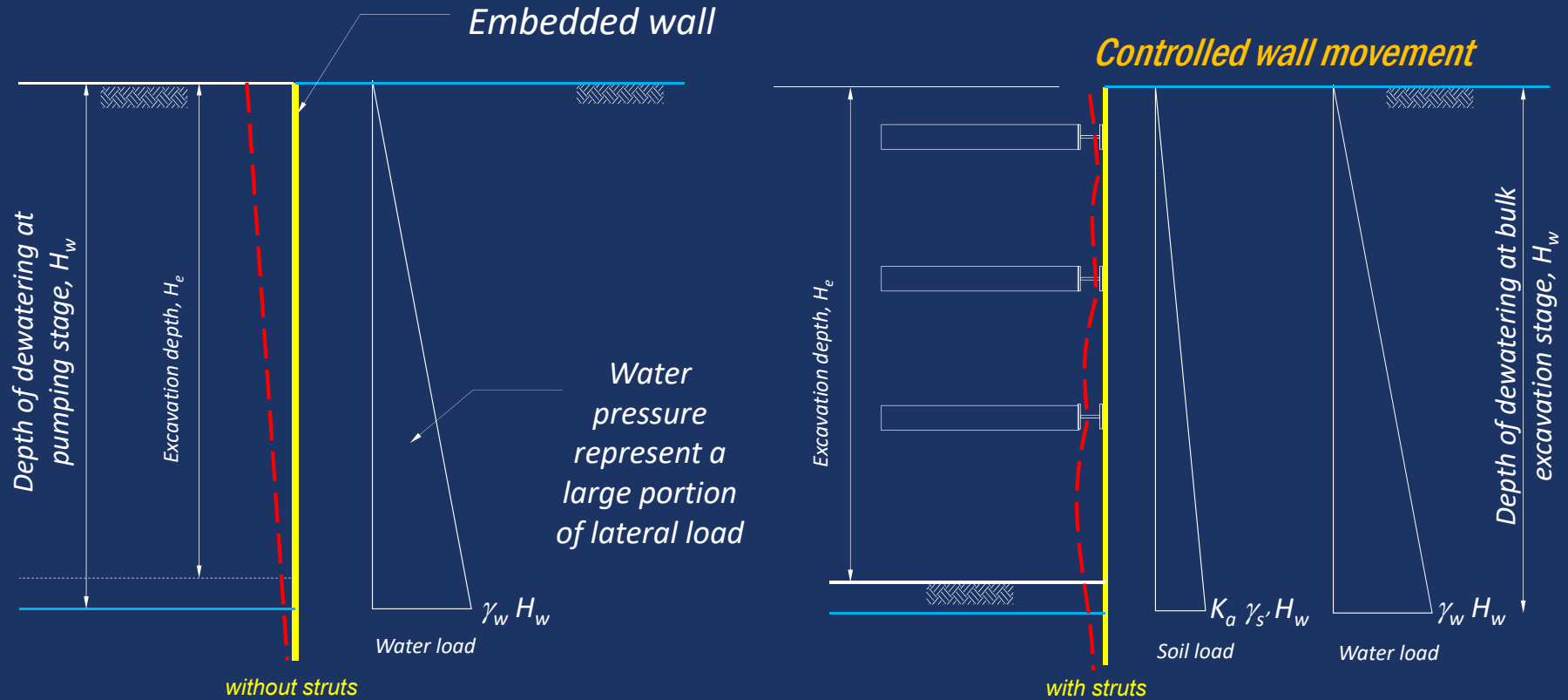
# Enhanced Practice

What are the **objectives** of **pumping tests**?

- prove water tightness ?
- verify assumptions and pumping well capacity ?
- ❑ *prove minimal impact to surroundings due to pumping (i.e. settlement control)*
  - ❖ **ascertain by adequate instrumentation & monitoring**
- ❑ *not to find the specific location of wall defects*



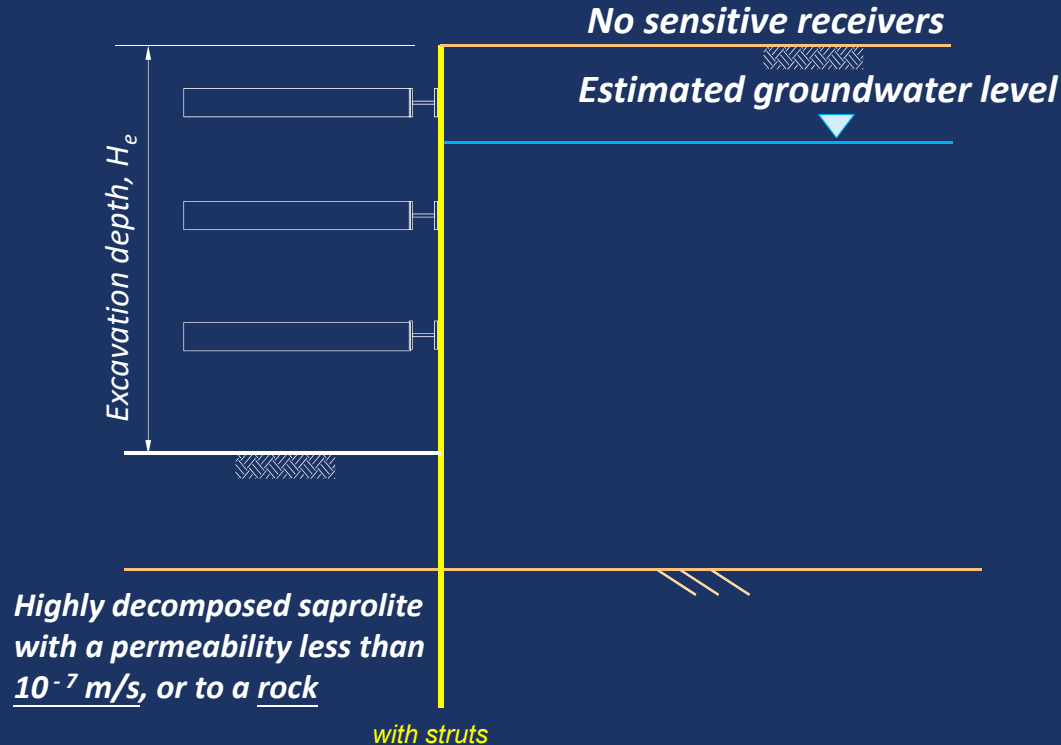
# Peripheral Grouting and Pumping Tests



Water Load on the Wall Deflection (without or with struts)

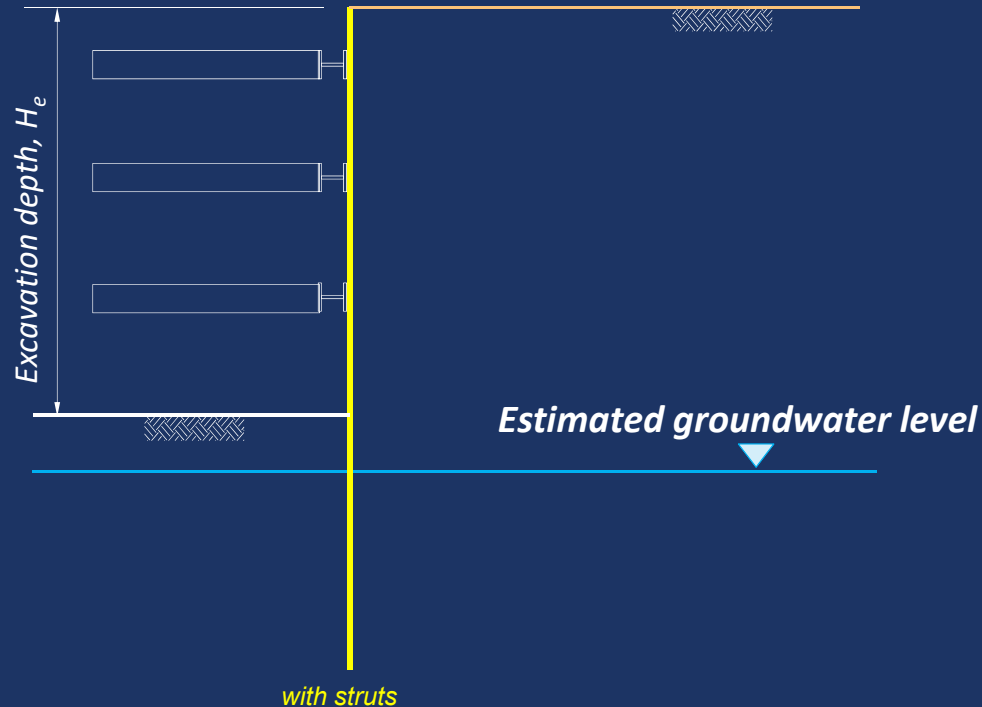
# Peripheral Grouting and Pumping Tests

Pumping tests are generally unnecessary in the following circumstances

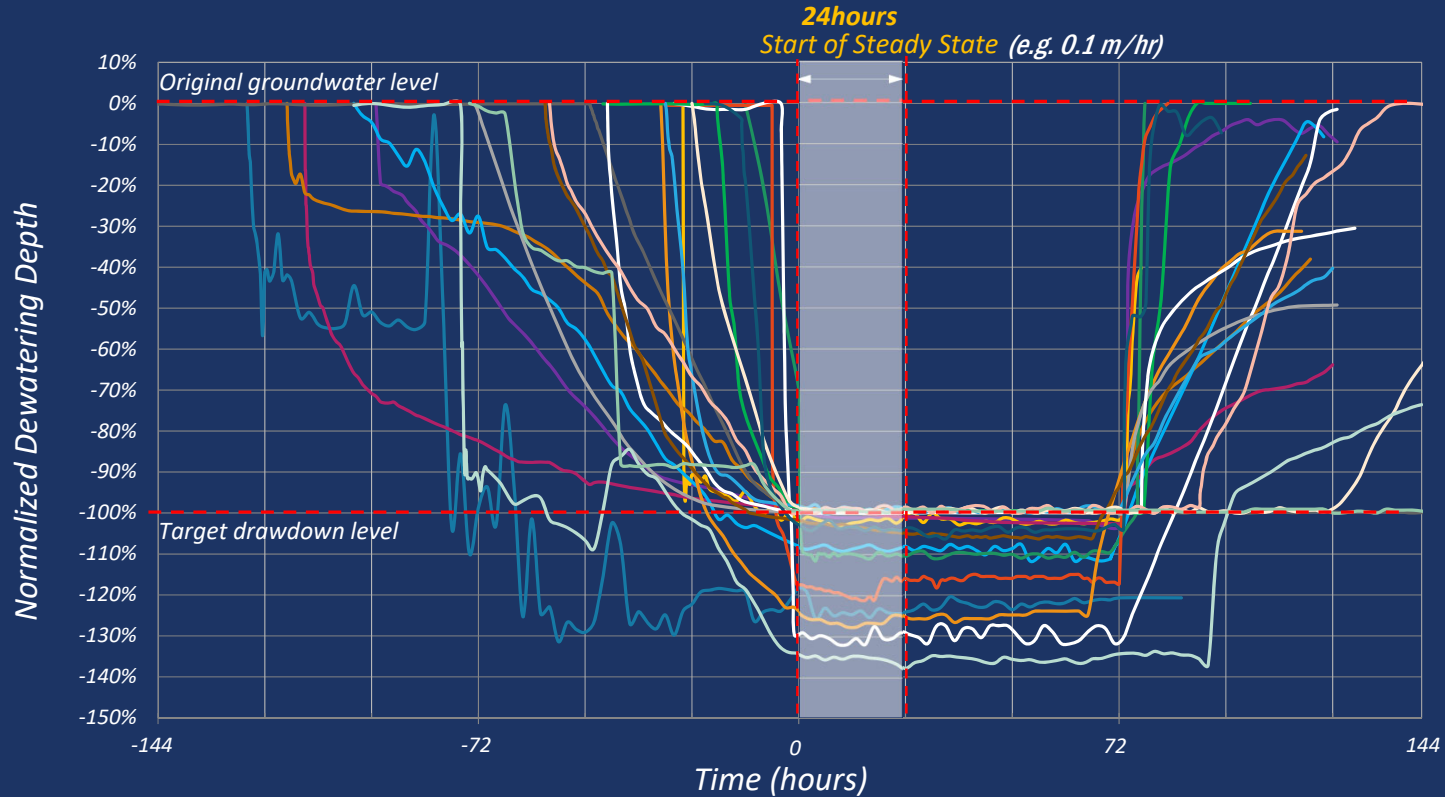


# Peripheral Grouting and Pumping Tests

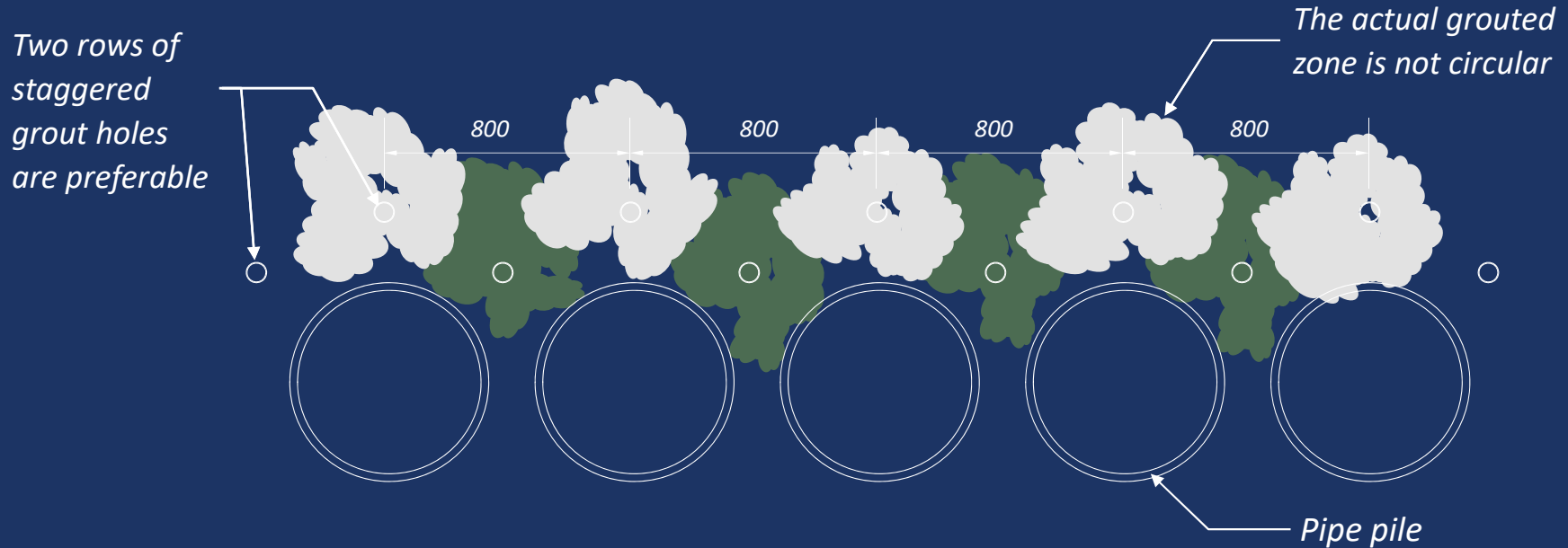
Pumping tests are generally unnecessary in the following circumstances



# Peripheral Grouting and Pumping Tests



# Peripheral Grouting and Pumping Tests



***Recommended 2 Rows of Staggered Peripheral Grouting***

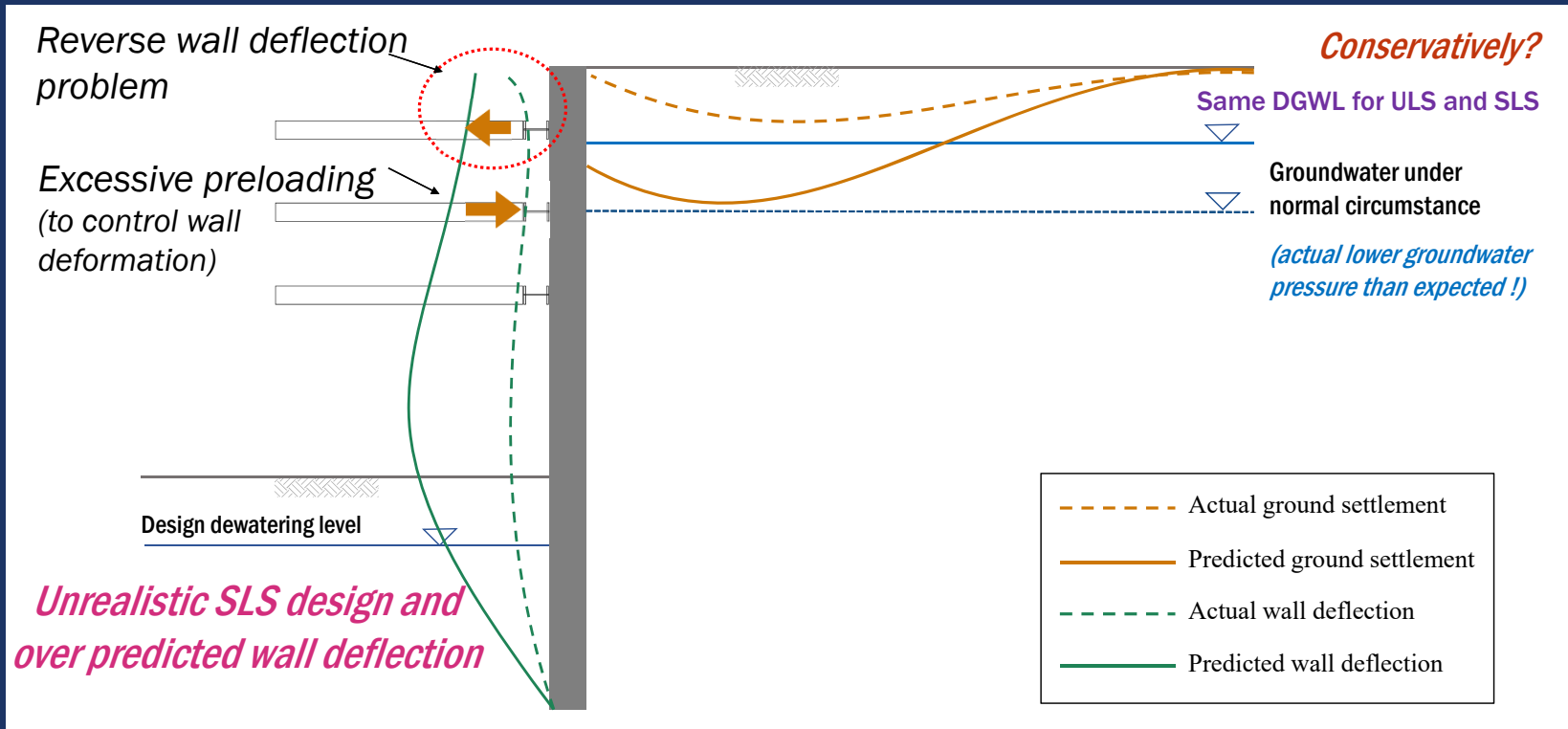
# Peripheral Grouting and Pumping Tests

**Full scale pumping test** for deep excavation is **not recommended**, and

- minimise active pumping duration by reducing the steady state period to **24 hours**
  - ❖ provision of **monitoring and control mechanism** (e.g. automatic systems)
- provide **two staggered rows of grout holes (grout curtain)**
  - ❖ retain provision for **re-grouting** (e.g. durable/reusable grout pipe)

# Enhanced Practice

## Design Groundwater Level (DGWL) Estimation



# DGWL Estimation and Control

**Adequate review  
on groundwater regime**

**Highest Anticipated GWL for ULS  
including a possible rise of 2 m from  
observed highest GWL**  
*(usually cannot cover entire wet season)*

**Lowest Allowable GWL for SLS  
evaluating from  
observed lowest GWL and  
impact assessment**



Note:

1.  $T_{upper}$  and  $T_{lower}$  : Groundwater trigger levels for response actions
  - ❖ Suspension of works solely due to exceeding  $T_{upper}$  or  $T_{lower}$  is unnecessary if no adverse effect on the nearby sensitive receivers
2. **Site-specific consideration** on hydrogeological conditions (rise  $\gg$  2 m) (e.g. damming effect, sloping ground, natural terrain, tidal effect)

Design dewatering level

# Enhanced Control Mechanism

# The 25mm STOP ALL WORKS magic figure

## Sinking project at Tin Wing light rail station to resume after Hong Kong government nearly doubles acceptable subsidence level

- Buildings Department nearly doubles level of acceptable sinkage – from 80mm to 150mm
- Construction to resume on May 31 contingent on protection measures



Carrie Yau [+ FOLLOW](#)

Published: 10:11pm, 24 May, 2019

[Why you can trust SCMP](#)



Subsidised housing is to be built above the Tin Wing light rail station in Yuen Long. Photo: Sam Tsang

Opinion / Hong Kong

## Hong Kong MTR subsidence worries must be addressed

Public safety has to be assured following the disclosure by rail giant that 131 locations on troubled Sha Tin-Central link require follow-up action



SCMP Editorial [+ FOLLOW](#)

Published: 7:05pm, 4 Sep, 2018

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Public safety has to be assured following the disclosure by rail giant MTR that 131 locations on troubled Sha Tin-Central link require follow-up action. Photo: Felix Wong

[on.cc 實境](#) | 30k 人追蹤 | [☆ 追蹤](#)

## 九龍站至奧運站鐵路沉降復工 停工標準放寬4成



2021年10月26日 · 3 分鐘文章



東網



# Enhanced Control Mechanism



Providing preload to meet the empirical value of **25mm of ground settlement**

Typical jack capacity:  
~400 ton/jack = 3,924 kN/jack

Typical preloading range:  
Up to max. 3,000 kN/m → Requires 4 nos. of jacks  
(assume strut spacing of 5m)

# Enhanced Control Mechanism



Providing struts at close intervals

# Enhanced Control Mechanism



## Non-compliance of ELS Works

# Enhanced Control Mechanism

**25** mm ground settlement for all types of works

regardless of depth of excavation. Despite the estimated ground movement is larger than 25 mm, the Action Level is still provisionally set at the empirical limit of 25 mm (THB, 2020)

*Is it sensible and practical?*

# Enhanced Control Mechanism

What are the main concerns of the different stakeholders?

**Serviceability or Safety Issues**

# Enhanced Control Mechanism

## DevB Task Force on Improving Control Mechanism

### Stakeholders consulted

Project and maintenance divisions of CEDD, ArchSD, HyD, WSD, DSD, HD, EMSD, BD

# Enhanced Control Mechanism

## Joint Utilities Policy Group

China Mobile Limited	HKC Network Limited
China Telecom Global Limited	HK Telephone Company Limited
China Light & Power Company Limited	HK Broadband Network Limited
Hong Kong Electric Company Limited	HKBN Enterprise Limited
The HK & China Gas Company Limited	HK Cable Television
Transport Department	HK Tramways Limited
Highways Department	HGC Global Communications Limited
Water Supplies Department	Village Telephone Limited
Drainage Services Department	Towngas Communications Fixed
MTR Corporation Limited	Networks Limited

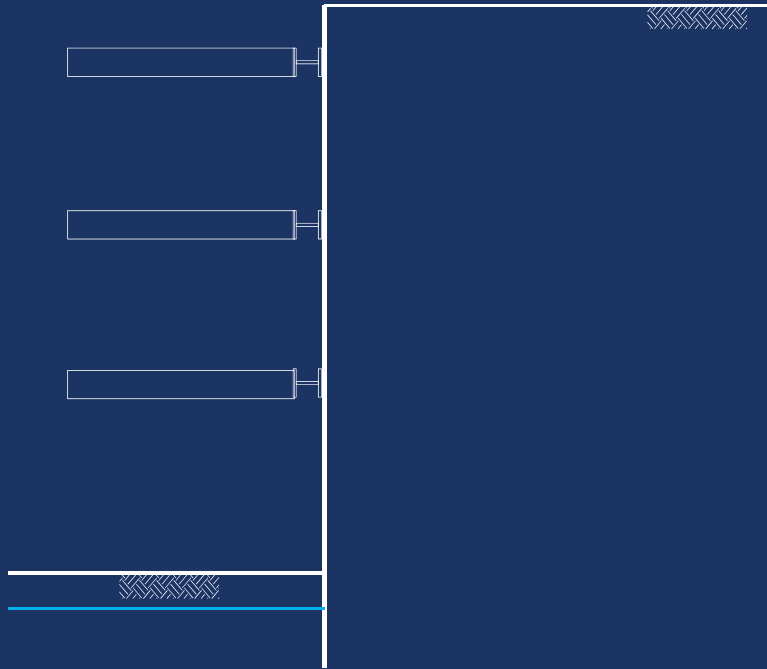
# Enhanced Control Mechanism

What are the main concerns of the different stakeholders?

## Serviceability or Safety Issues

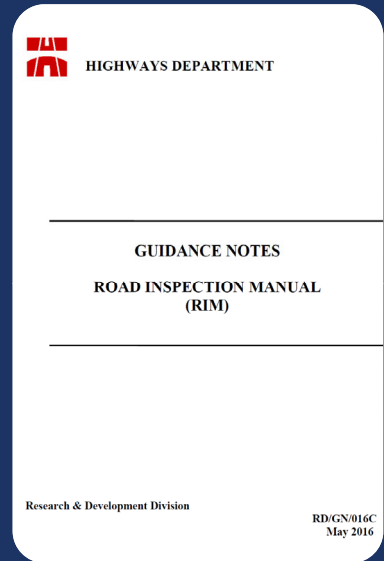
- *Most of the problems are serviceability aspects*
- *Utilities undertakers and Highways concern that they were not informed of incidents at early stage; no mechanism of formulating agreed actions and was ignored by Contractors*

# Enhanced Control Mechanism

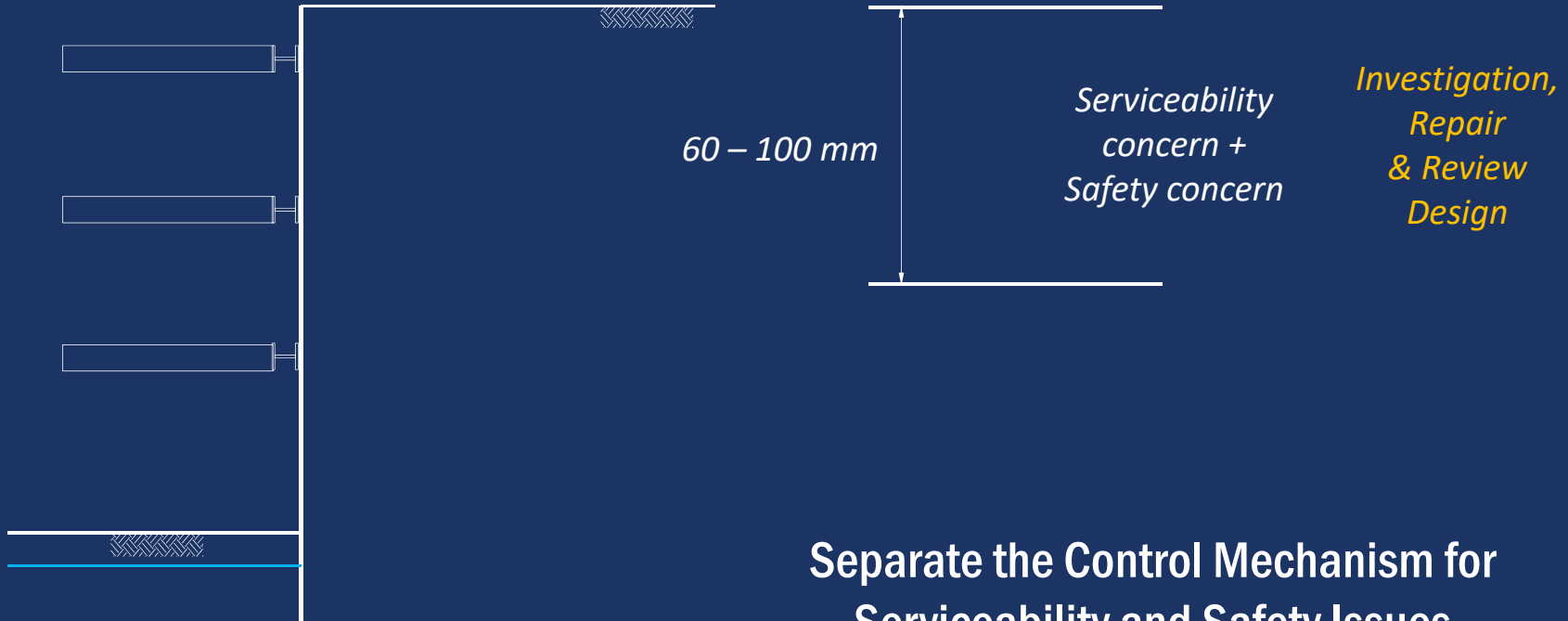


20 mm  
*Serviceability concern*

*Quick Repair*



# Enhanced Control Mechanism



Separate the Control Mechanism for Serviceability and Safety Issues

# Enhanced Control Mechanism



Pragmatic actions to prevent suspension of works due to ground settlement

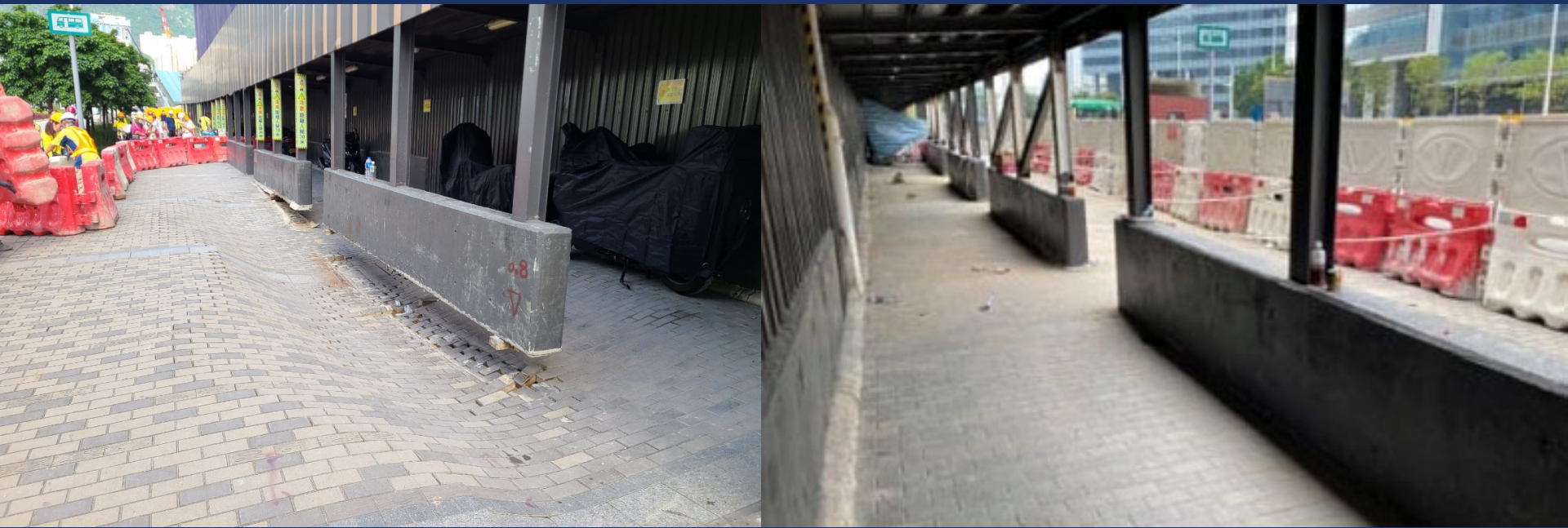
*Quick repaving of road surface and pavement*

# Enhanced Control Mechanism



Quick repaving of road surface and pavement

# Enhanced Control Mechanism



Quick repaving of road surface and pavement

# Enhanced Control Mechanism



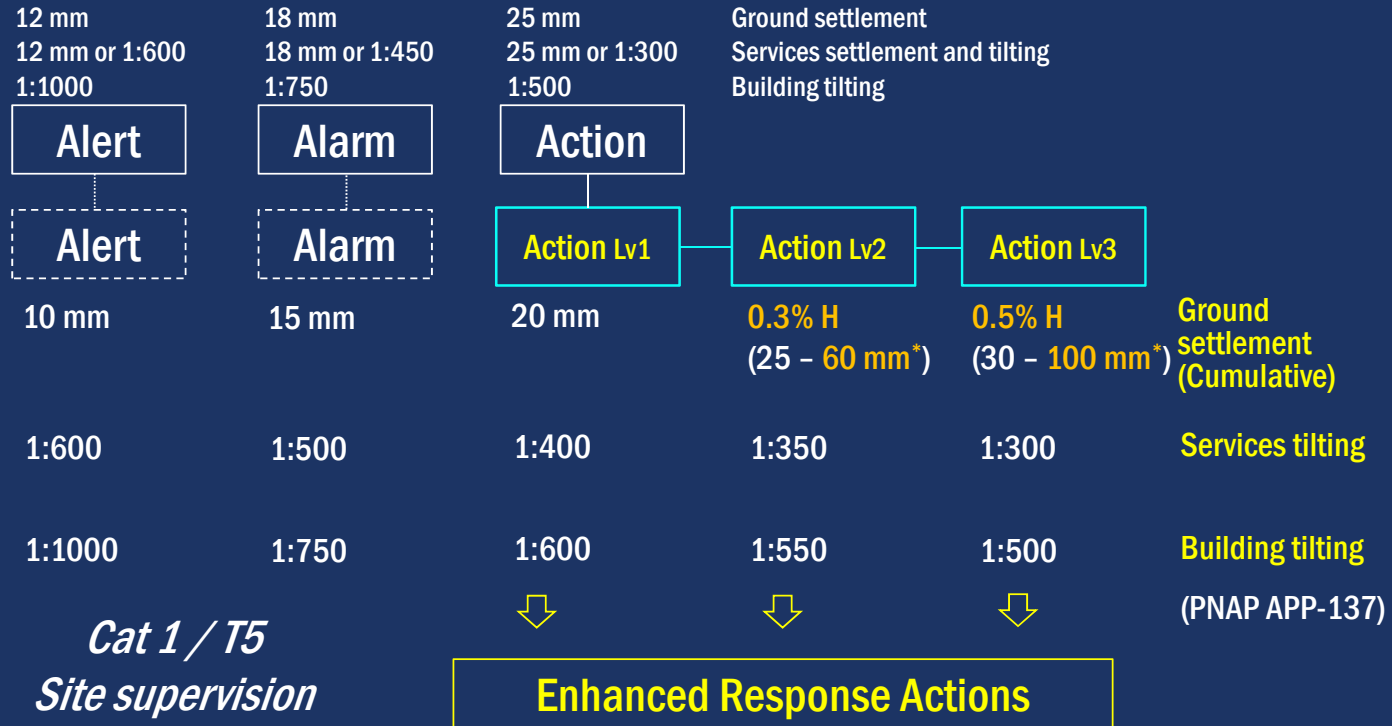
Emergency repair for burst water carrying services

# Enhanced Control Mechanism

## Improved mechanism on ground deformation:

- **Mutual trust** with the stakeholders to establish **realistic and practical** Action Levels
- **Communicate** with Utility undertakers, maintenance departments and authorities to agree on response actions at appropriate levels
- **Plan ahead** and **prompt action** to reduce serviceability issues and eliminate unnecessary suspension of works

# Enhanced 5-Level (5A) Control Mechanism



# Enhanced 5-Level (5A) Control Mechanism

## Fore-warning & Preparation

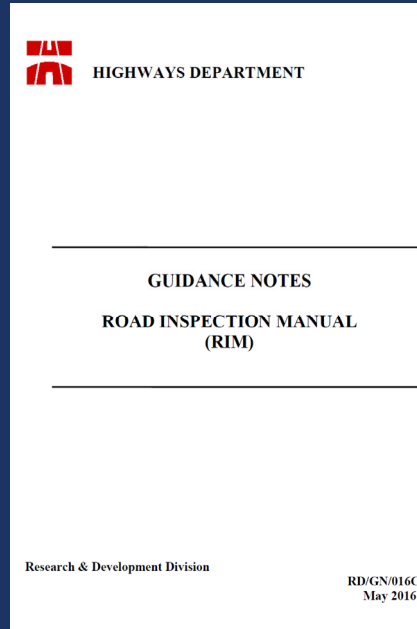
- **Alert Level** – inspect and carry out **condition survey** on the affected sensitive receivers and provide continuous updated records
- **Alarm Level** - prepare **response plan** to review and implement any necessary additional instrumentation (e.g. settlement markers) and get ready the stakeholder consultation list

## Actions

- **Action Level 1** – **communicate** with the affected stakeholder to agree whether to carry out the **pre-determined response action** to address serviceability issues
- **Action Level 2** - implement **detailed investigation** of the road and pavement conditions to detect any cavities and voids
- **Action Level 3** – **stop** and **critically review** the excavation system

# Enhanced 5-Level (5A) Control Mechanism

**Action Level 1** (cumulative → 20 mm)



*Formulate the **Action Plan** for reaching **Action Level 2***



Action before reaching **60 mm** for an example of excavation deeper than 20 m

Joint site inspection/survey with stakeholders and implement pre-determined remedial works (e.g. repaving, releveling paving blocks)

# Enhanced 5-Level (5A) Control Mechanism

## *Formulate the Action Plan for reaching Action Level 2*

1. Requirements on additional serviceability checks (e.g. inspection at 40 mm cumulative settlement) before reaching Action Level 2.
2. Necessary further remedial works before and when the Action Level 2 is reached.
3. Detailed investigation works (e.g. ground radar survey, GCO probe, open pit/trench) when Action Level 2 is reached.
4. Works to be suspended, if necessary (e.g. specific utility concern).



# Enhanced 5-Level (5A) Control Mechanism

**Action Level 2** (cumulative → 60 mm for 20 m excavation)

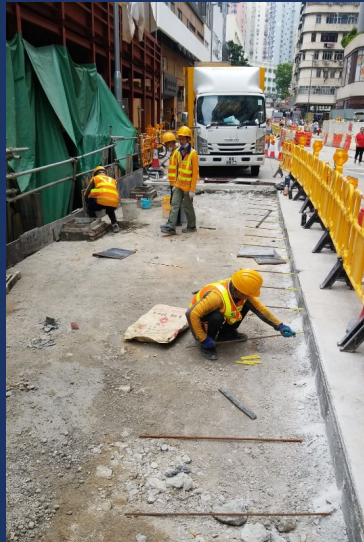
GCO probing



Ground penetration radar



Open trench & repair



*Formulate the  
Emergency Plan for  
reaching Action Level 3*



Action before reaching **100 mm**  
for an **example of excavation**  
**deeper than 20 m**

- ❖ Carry out the remedial works and detailed investigation agreed in Action Plan
- ❖ Review trigger value of Action Level 3

# Enhanced 5-Level (5A) Control Mechanism

## *Formulate the Emergency Plan for reaching Action Level 3*

1. Requirements on additional serviceability checks (e.g. inspection at 80 mm cumulative settlement) before Action Level 3 is reached.
2. Necessary further remedial actions before and when the Action Level 3 is reached.
3. Full scale investigation works (e.g. additional GI, remedial works, design review) when Action Level 3 is reached.
4. Works to be suspended (e.g. within 50 m of the affected sensitive receivers) when Action Level 3 is reached.



# Enhanced 5-Level (5A) Control Mechanism

**Action Level 3** (cumulative → 100 mm for 20 m excavation)

Additional necessary GI & monitoring



Comprehensive remedial works (e.g. grouting)



*Formulate the **Works Resumption Plan** after **Action Level 3** reached*



Works suspension and carry out full scale investigation, design review and remedial works as agreed in Emergency Plan

# Enhanced 5-Level (5A) Control Mechanism

## *Formulate the Works Resumption Plan after reached Action Level 3*

1. Condition survey of the affected sensitive receivers after remedial and/or strengthening works
2. Revised design and method statements as approved by the relevant authorities.
3. Trigger values for further response actions.
4. Details of further response actions.

Re-examine and revise the ELS design & construction



# Enhanced 5-Level (5A) Control Mechanism

## Ground settlement control limits

	Fore-warning and preparation		Serviceability	Serviceability and road safety	
<b>Example case:</b>					
<b>For deep excavation (e.g. <math>\geq 20</math> m)</b>	Alert 10 mm	Alarm 15 mm	Action Level 1 20 mm	Action Level 2 60 mm	Action Level 3 100 mm
<b>For shallow excavation (e.g. 6 m)</b>	Alert 10 mm	Alarm 15 mm	Action Level 1 20 mm	Action Level 2 25 mm (0.3% $H_e$ )	Action Level 3 30 mm (0.5% $H_e$ )
				ELS performance against design prediction (ULS safety concern)	

# Enhanced 5-Level (5A) Control Mechanism



Undue settlement, **damages on pavement** – **Action Level 3**

# Enhanced 5-Level (5A) Control Mechanism

1. **Regular potential sinkhole survey**
  - Prior to and after completion of piling works
  - Regular intervals (e.g. once every 3 months)
2. **Improved guidance** on piling operation control
3. **Regular check** on site monitoring measurements by **qualified land surveyor**



# Enhanced 5-Level (5A) Control Mechanism



**Significant water seepage**  
→ Action Level 2



**Excessive water ingress**  
→ Action Level 3

# Enhanced 5-Level (5A) Control Mechanism

Improved mechanism affecting private developments

- **Same principle** can be applied to pavement and road of private developments.
- **Talk to the owners and property management agent and agree** the respective action, including repairs to address serviceability issues
- If such agreement **cannot** be obtained, follow the **PNAP APP 137**

# Enhanced 5-Level (5A) Control Mechanism

Lesson Learnt – adequate instrumentation and monitoring are essential

Increased joint opening



Pile foundation    Shallow footing



Differential settlement

*Missed opportunity for early action as there were no monitoring stations on the highway structures within the influence zone of adjacent ELS works*

# Enhanced 5-Level (5A) Control Mechanism

GEO Technical Guidance Note No. **XX** (TGN **XX**)  
 Guidelines on Ground Deformation Control Mechanism for  
 Geotechnical Works

Issue No.: 1 | Revision: - | Date: xx.12.2023 | Page: 4 of 5

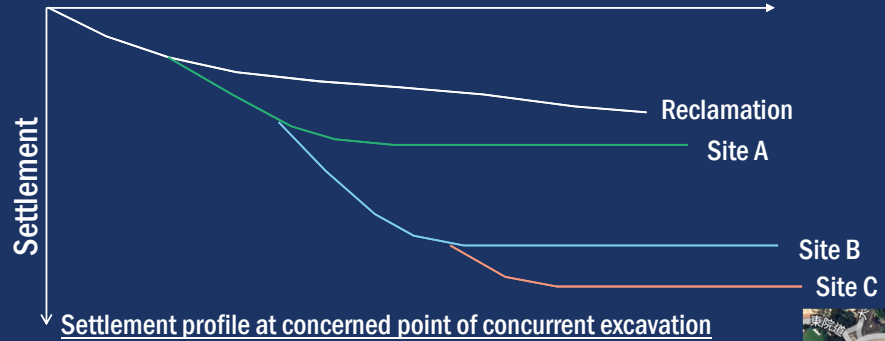
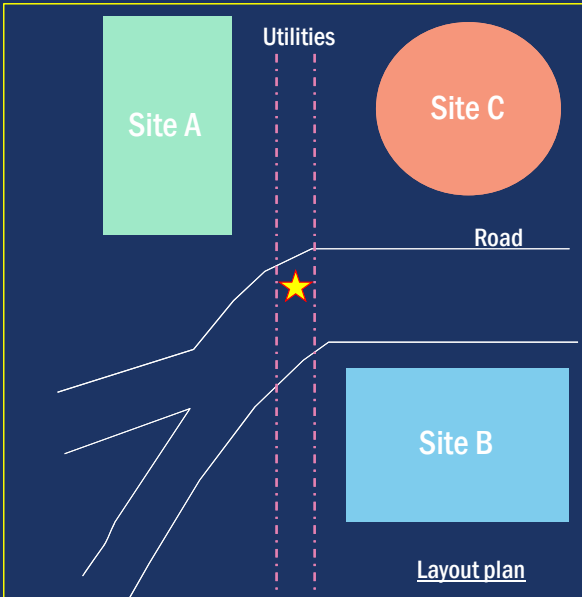
Table 1 - Recommended Empirical Limits for Setting Trigger Levels in 5A Approach for Geotechnical Works

Instrument	Criterion	Alert	Alarm	Action		
				Level 1	Level 2	Level 3
Ground monitoring marker <sup>1</sup>	Total settlement	10 mm	15 mm	20 mm	i. 25 mm (Piling) ii. 0.3% H <sub>c</sub> (ELS)* iii. 1% VL (TBM)*  *subject to the range of 25 mm to 60 mm	i. 30 mm (Piling) ii. 0.5% H <sub>c</sub> (ELS)# iii. 2% VL (TBM)#  #subject to the range of 30 mm to 100 mm
Services monitoring marker <sup>2</sup>	Angular distortion	1:600	1:500	1:400	1:350	1:300
Building monitoring marker <sup>3</sup>	Angular distortion	1:1000	1:750	1:600	1:550	1:500

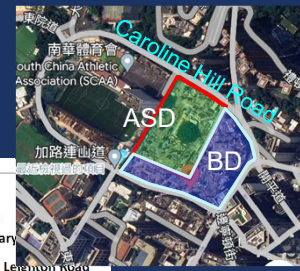
where H<sub>c</sub> is the maximum excavation depth of the ELS works and VL is the maximum tunnel excavation volume loss by using TBM. The calculated values of ground movement should be rounded to integer.

*A draft Technical Guidance Note is under preparation and the 5A approach will be applied to all geotechnical works including piling and TBM works*

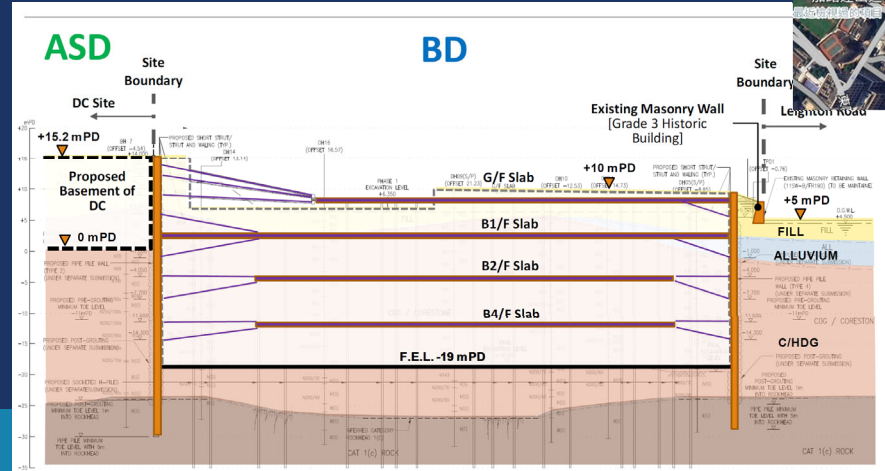
# Concurrent Construction Activities



*Recent example case:  
Concurrent ELS works near Caroline Hill Road*



➤ **Resolve potential issues** of concurrent construction activities at early project stage



# Successful ELS Works

- ❖ *To have good planning*
- ❖ *To have proactive manner*
- ❖ *To have good communication*
- ❖ *To have mutual trust*
- ❖ *To have prompt response actions*
- ❖ *To have diligent mindset throughout the works*



# Wide Consultation

**Civil Engineering and Development Department**  
The Government of the Hong Kong Special Administrative Region

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### GEO Publication No. 1/2023 (DRAFT)

Report No. : GEO Publication No. 1/2023 (DRAFT)

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# Views and Discussions