TECHNICAL TALK ON TWO CASE STUDIES OF COLLAPSED TEMPORARY EXCAVATION USING CONTIGUOUS BORED PILED WALL

7 JULY 2020

10:00 AM - 12:00 NOON

SPEAKER

Ir. Liew Shaw Shong

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WEBINAR

ASSOCIATION OF CONSULTING ENGINEERS MALAYSIA

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SYNOPSIS

The investigation of temporary excavation failure can be deployed in a systematic manner using the principles of forensic engineering. The focus of this talk is on the investigation works carried out for two (2) temporary excavation failures. Both excavations utilised temporary steel struts propped against partially completed basement structure as lateral shoring supports along the peripheral earth retaining wall. The two investigations show that it is undoubtedly necessary to have appropriate and sufficient materials sampling and testing as part of the investigation processes if conclusive evidence regarding the failure cause is to be found. The method, combined with the experience of the investigator, adequate evidences of material defects and numerical simulation of construction processes by finite element analyses, provide great help in exploring the probable causes of the investigated collapse of temporary excavation and identify the major cause(s) accounted for the collapse. The excavation failure investigation methodology presented in this paper can serve as a simple guide for the investigation of similar failures and to serve as a lesson learnt for future excavation projects.

SPEAKER

Ir. Liew Shaw Shong obtained his Bachelor of Science Degree in Civil Engineering with First Class Honours from National Taiwan University at Taipei in 1991 and worked as a geotechnical engineer in Sino Geotechnology Inc. at Taipei for a year. In 1992, he continued his post-graduate study in University of New South Wales in Sydney, Australia and obtained his Master of Engineering Science in 1993. He then returned to Malaysia to work as a geotechnical engineer in a multi-discipline engineering consultant firm.In 1999, he jointly established a geotechnical specialist consulting firm with another two partners to continue the consultancy practice till now. He is now the Senior Director of G&P Geotechnics Sdn Bhd. In the past twenty five years of his professional career, he has been involved in a number of forensic investigations of landslide problems at mountainous roads and is one of the project team member in the National Slope Master Plan Study commissioned by JKR. Ir. Liew is now the President of Malaysia Geotechnical Society for Session 2019-2020. He has published more than 70 technical papers on geotechnical engineering in local and overseas conference and seminars.

ACEM Webinar 0n 7 July 2020

TWO CASE STUDIES OF COLLAPSED TEMPORARY EXCAVATION USING CONTIGUOUS BORED PILE WALL

Ir. Liew Shaw Shong

Outline of Presentation

- Common Probable Causes of Excavation Failure
- Investigation Procedures
- Case Study 1 & Case Study 2
  - Background
  - Chronological Events
  - Causes of Failures
  - Lessons Learnt

Common Probable Causes of Excavation Failure

- Probable Common Causation & Aspects of Geotechnical Failures

A) Natural Disasters : fire, earthquake, tsunami, tremor, wind, rainfall and flood

B) Act of Sabotage: explosive substances

C) Material Defects: reused steel strutting sections with poor conditions, concrete properties

D) Design: modelling and design parameters, robustness and ductility

E) Construction: sequences of works, excavation depth

F) Maintenance: drainage system, no timely review of instrumentation results

Investigation Procedures

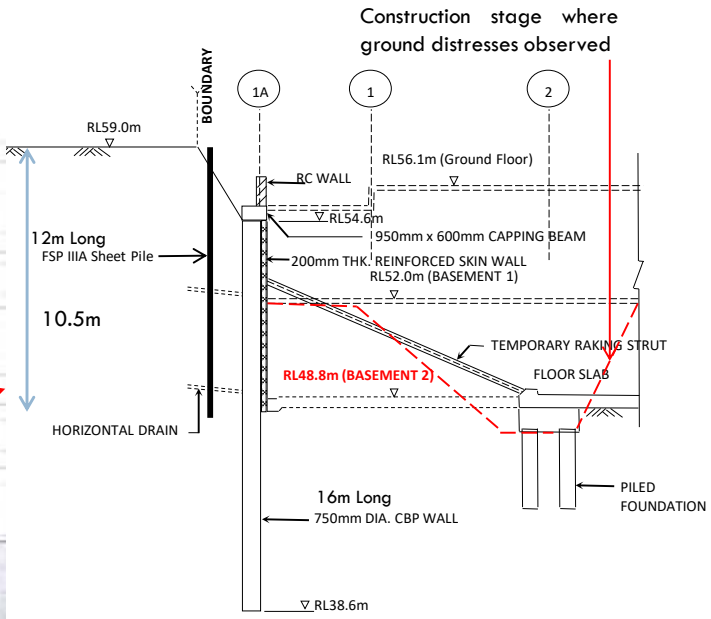
1. Check safety factor of the original design
2. Check the as-built construction for any deviations from original design
3. Identify design shortcomings, material defects, workmanship deficiencies, if any
4. Interview design team, construction management team, site personnel and eye-witnesses
5. Consult other experts if required, for matters beyond the investigator's expertise or knowledge of the facts
6. Identify possible collapse scenarios, rationalise conflicting facts and hierarchy of evidences
7. Determine the major contributory and triggering factors that cause the collapse
8. Conduct advanced/non-linear analysis/tests to ascertain the collapse mechanism
9. Confirm the collapse mechanism with those from identified facts and evidences
10. Forensic Report preparation

CASE STUDY 1 (CS1)

CS1: Excessive Movement of CBP Wall

- Two-Storey Basement
- Temporary Excavation with Berms & Raking Struts to Lower Basement Slab
- Distresses observed during the course of Temporary Excavation
  - Ground Distresses
  - CBP Wall tilted and Structurally damaged
- Remedial Works
- Summary of Findings & Lessons Learnt

CS1: Excessive Movement of CBP Wall



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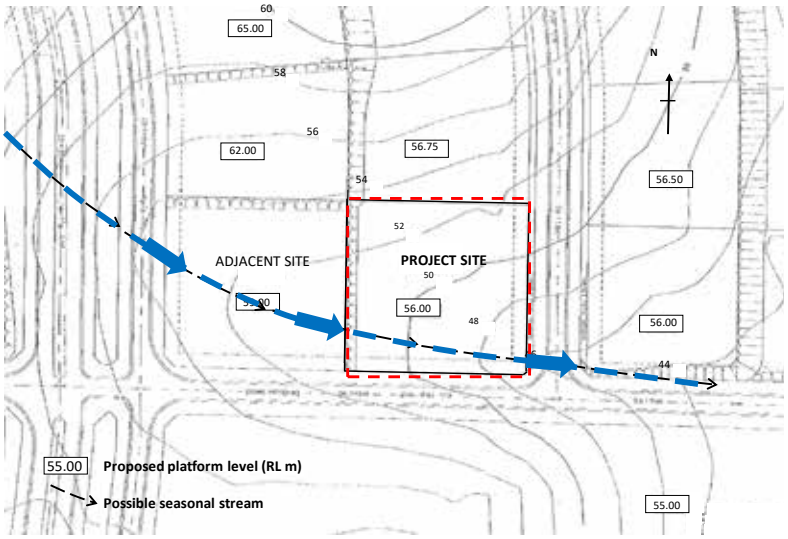

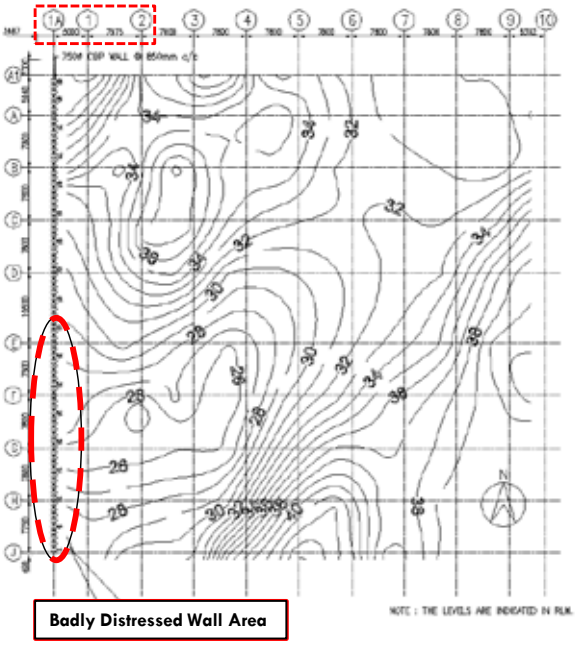

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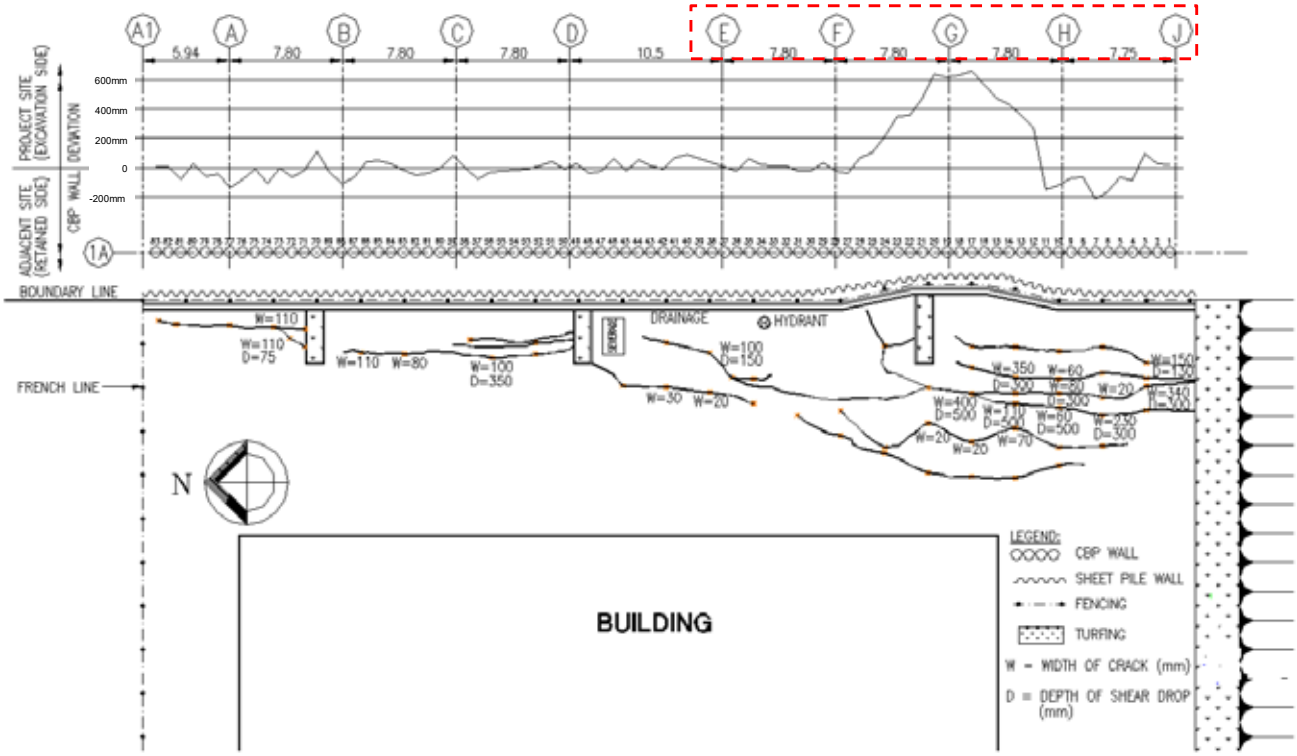

CS1: Excessive Movement of CBP Wall

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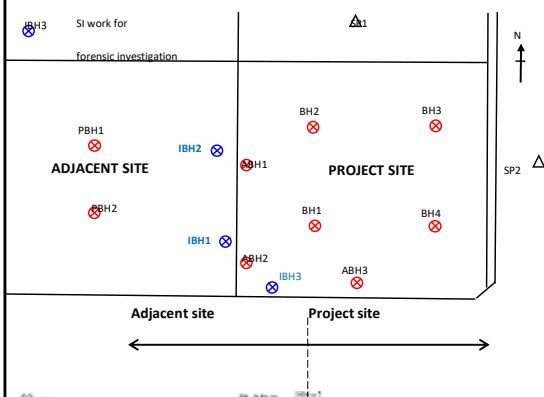
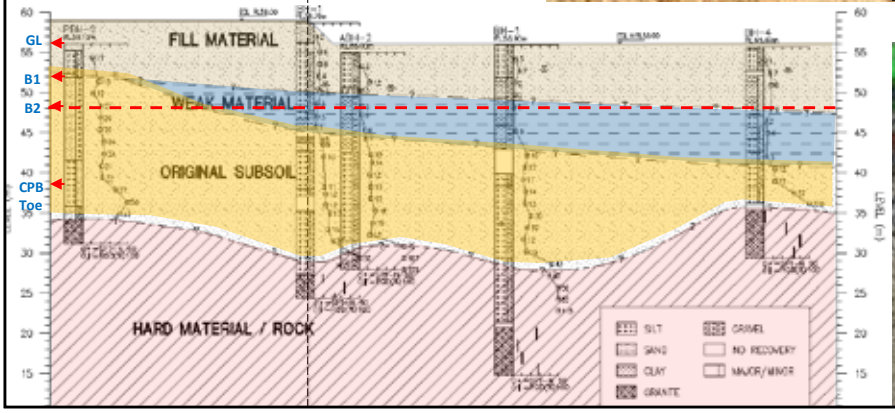
Ground Distress at Active Wedge

Repairing of CBP Pile

CS1: Excessive Movement of CBP Wall



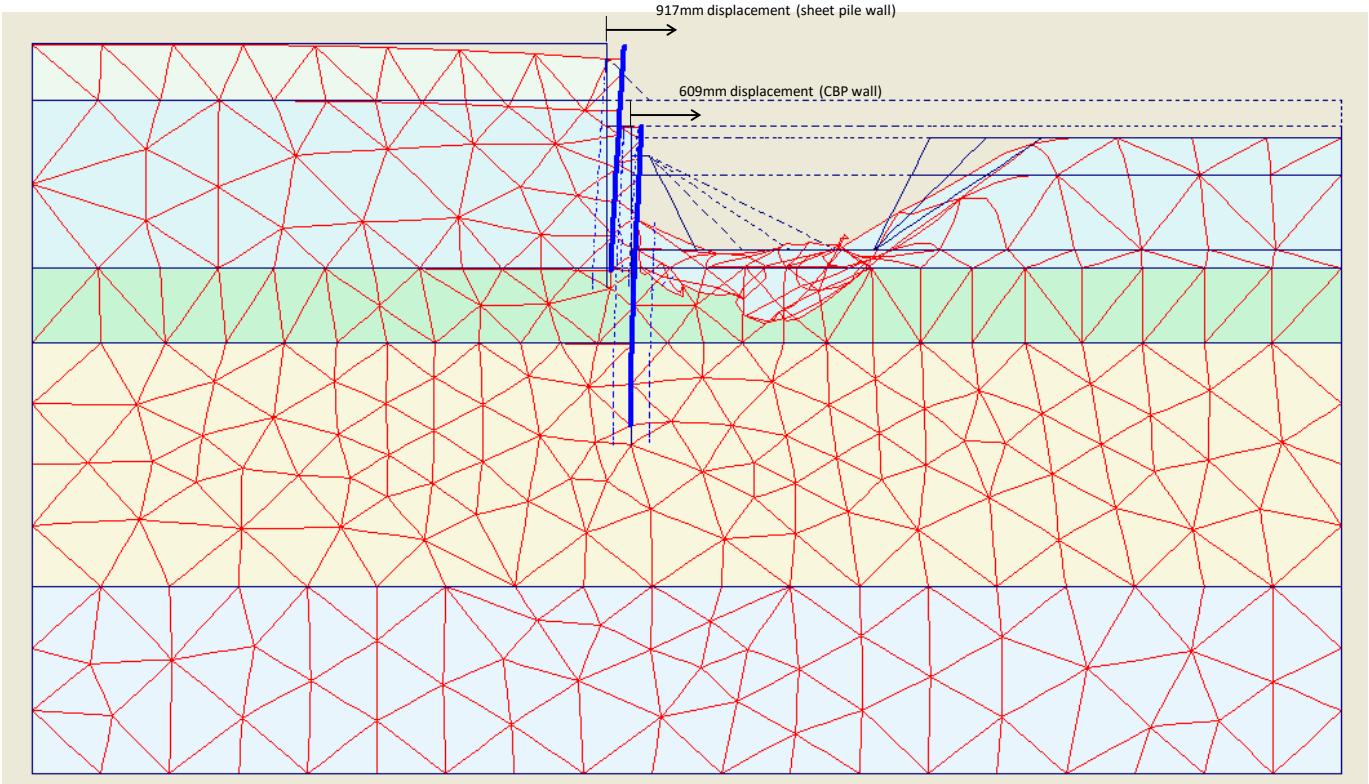


CS1: Excessive Movement of CBP Wall

Back Analysis

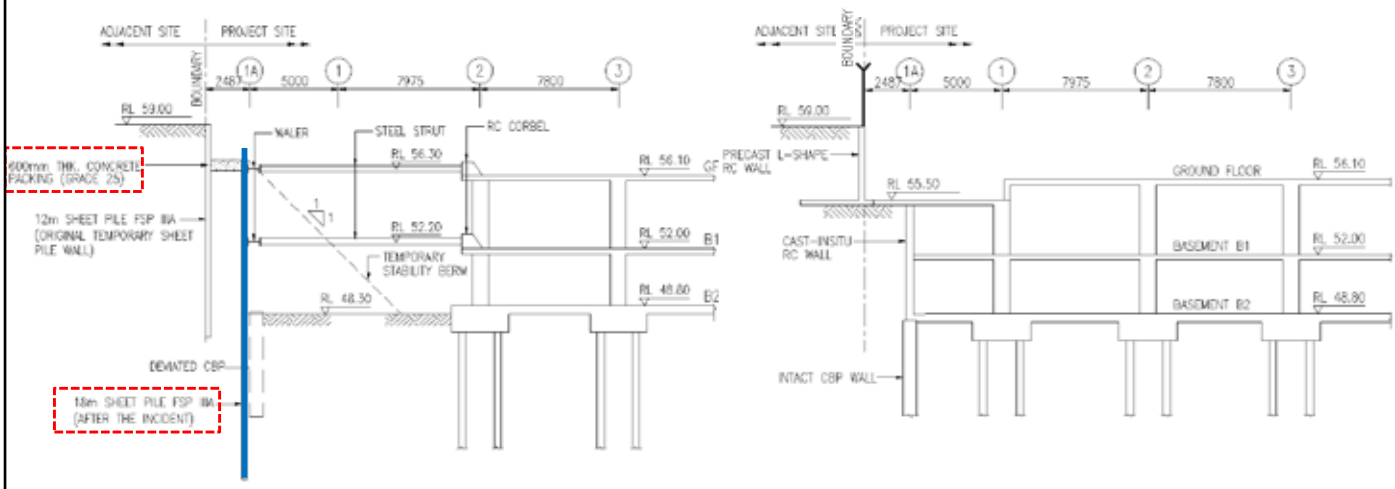
- Finite Element analysis (PLAXIS) to simulate the construction sequences of excavation & to investigate the probable causes of ground distresses & wall movements.
  - Excavation in front of the wall → the retained earth platform displaced excessively in the horizontal & vertical (settlement) directions with the temporary sheet pile wall moving forward
  - Over-excavation of passive berm before installing raking struts → reduce lateral resistance to sheet pile wall & subsequently mobilise structural strength of the CBP walls beyond serviceability state condition & reaching ultimate limit state condition
  - Excessively displaced temporary sheet pile wall → induced additional lateral force & flexural stress to the installed contiguous bored piles (CBP) walls unavoidably damaged the CBP piles.
- The results of FE analyses agree reasonably well with the measured wall movements and ground deformations (e.g. tension cracks, settlement and depression)

CS1: Excessive Movement of CBP Wall



CS1: Excessive Movement of CBP Wall

- Remedial Solution



CS1: Excessive Movement of CBP Wall

Repairing Crushed CBP

Shear Failure of Corbel Support

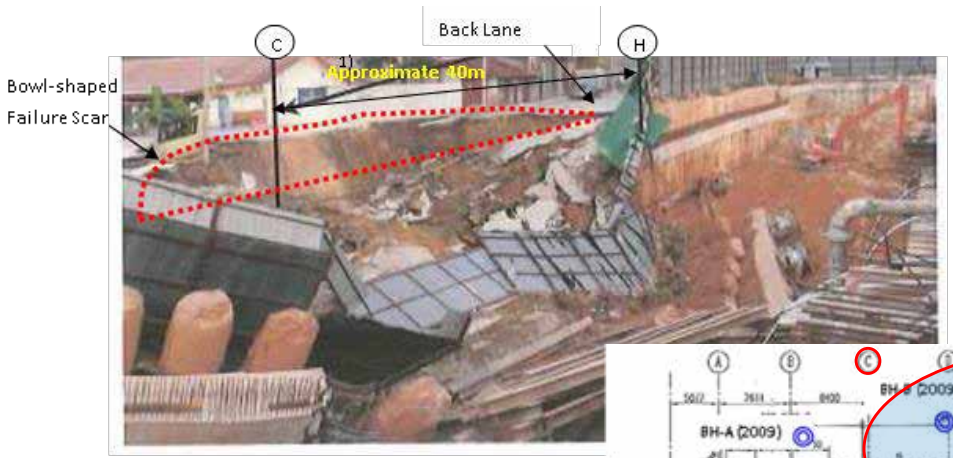
CS1: Excessive Movement of CBP Wall

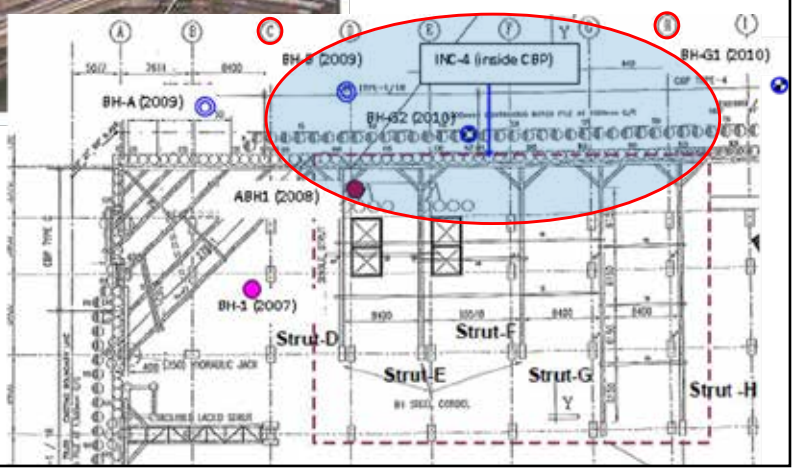
- Summary of Findings & Lessons Learnt
  - Building platform formed over natural valley containing thick fill over previous soft deposits provides prerequisite condition for ground distresses during temporary localized deep pile cap excavation & removing passive berm excessively without planned strut supports.
  - Occurrence of tension cracks during initial open excavation and installation of sheet piles suggested that the underlying subsoil at the valley area are inherently vulnerable to ground disturbance and hence are prompted to distressing.
  - Perched groundwater regime can occur in backfilling over natural valley leading to unfavourable behaviour of backfill.
  - Desk study of pre-development ground contours is highly recommended.

Q&A
FOR
CASE STUDY 1 (CS1)

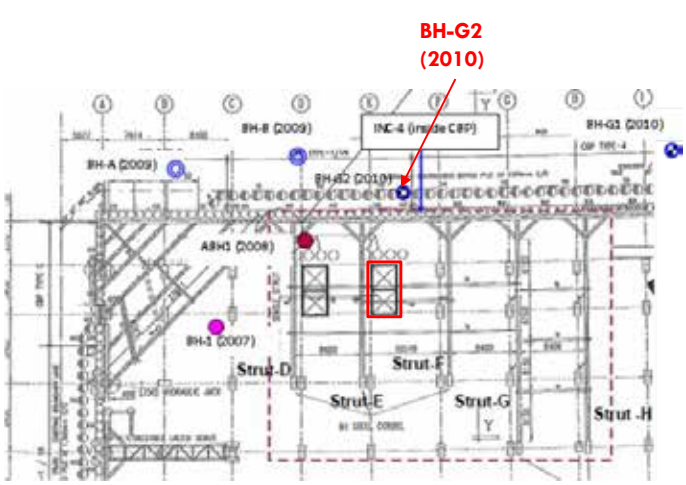
CASE STUDY 2 (CS2)

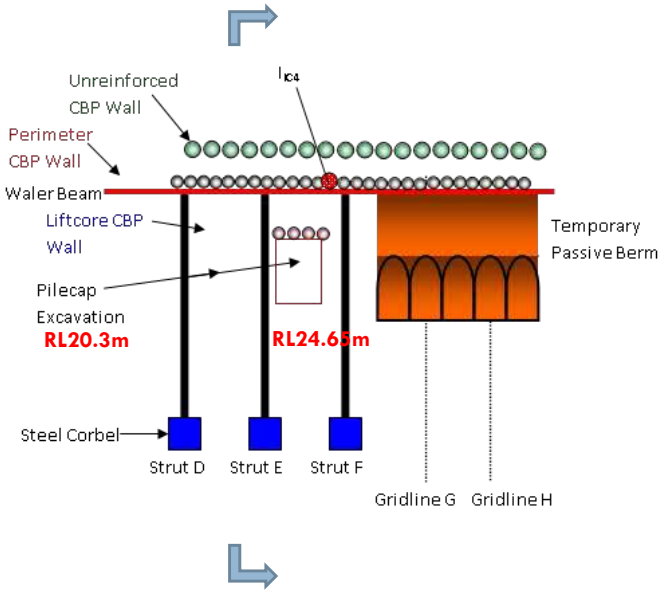
CS2: CBP Wall Failure





CS2: Retaining Wall System





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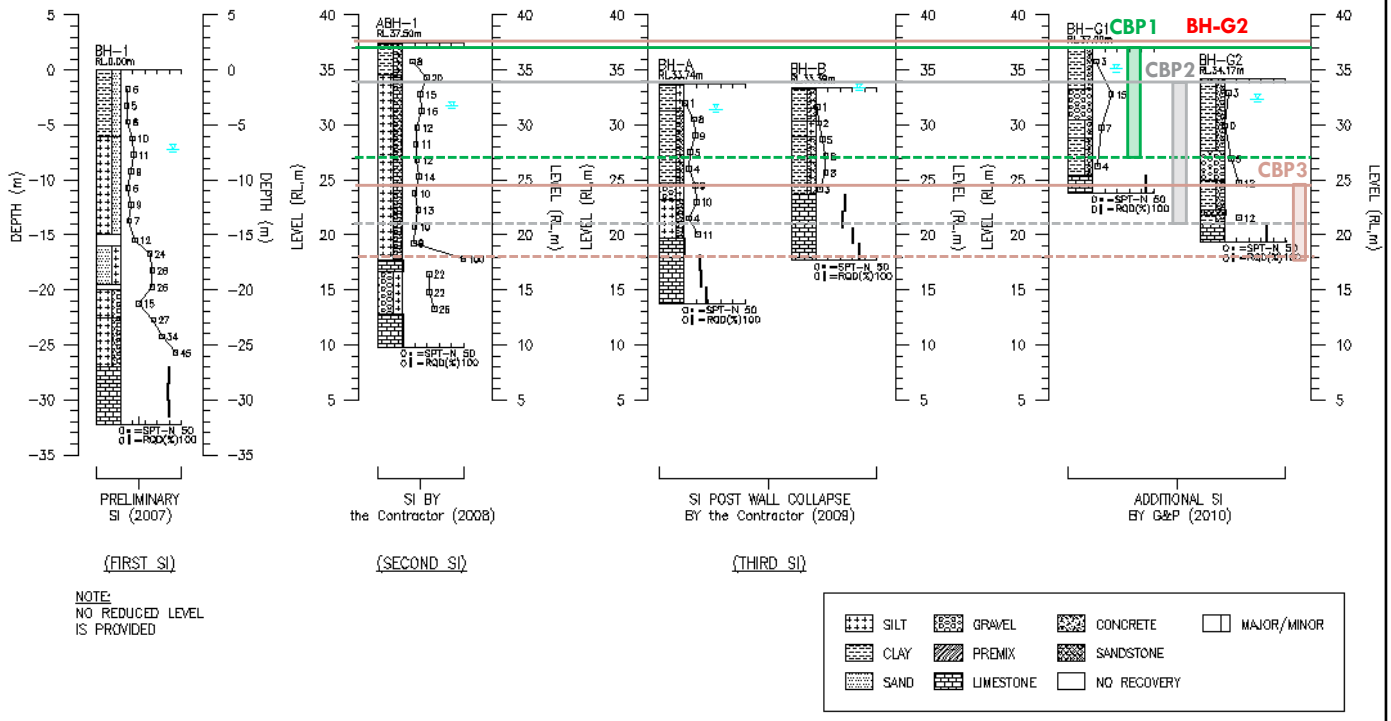

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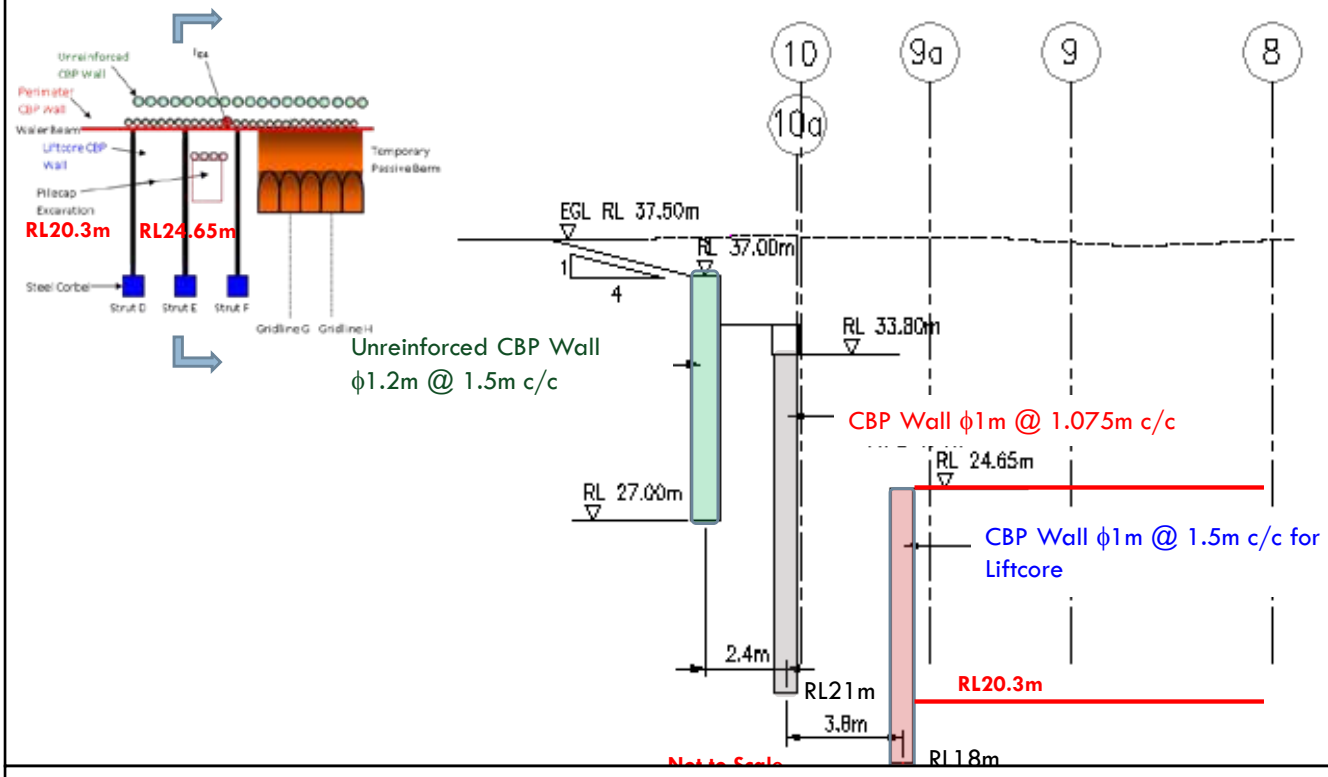
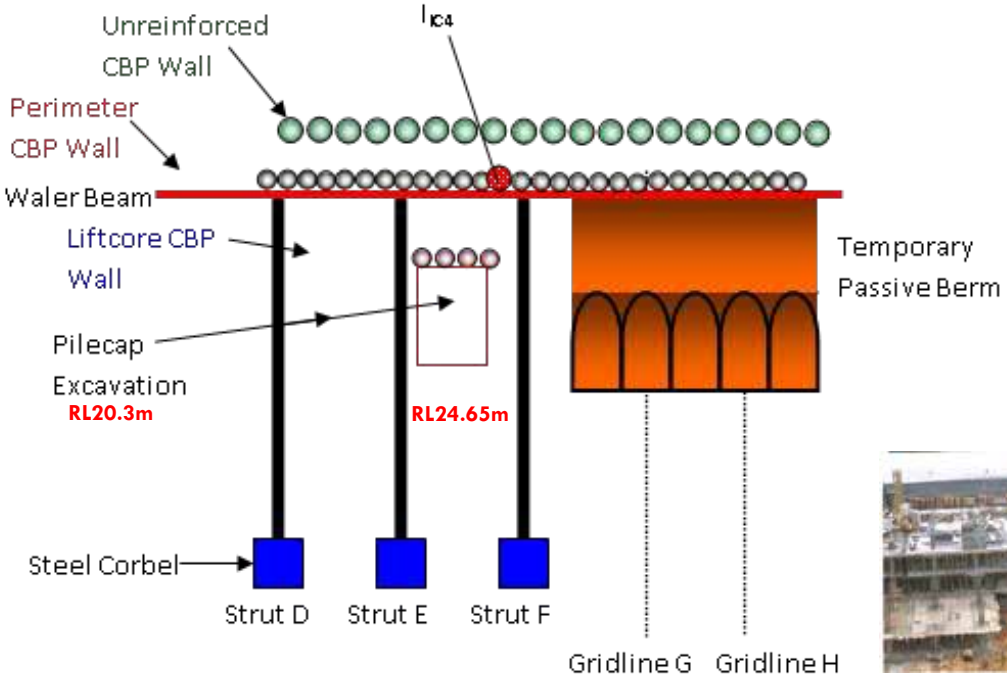


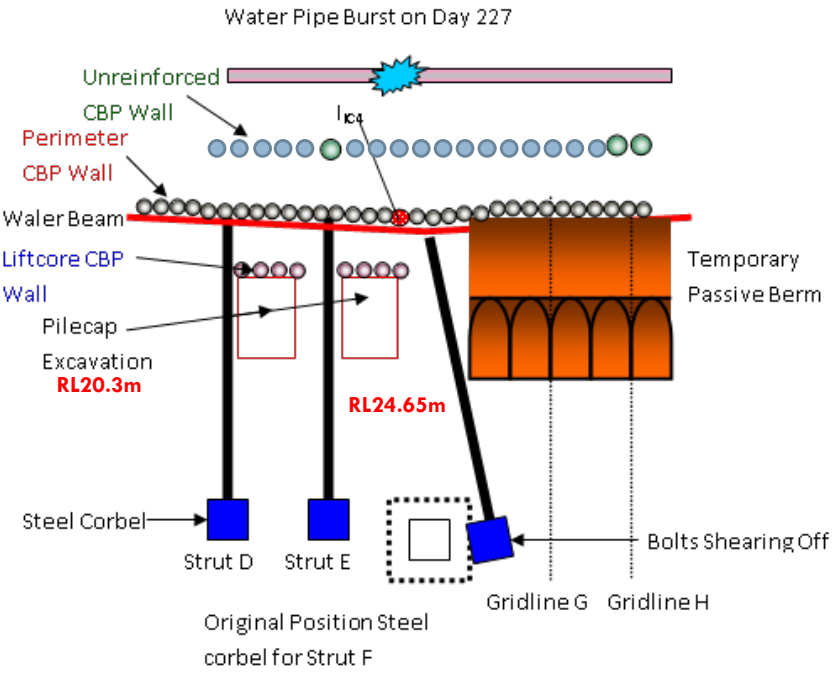
CS2: Important Events Before Collapse

Original struts position for Struts D, E and F with passive berm retained at Gridlines G and H.



CS2: Important Events Before Collapse

Water pipe burst incident on Day 227 which caused the steel corbel for strut F being sheared off as reported.



Observations of investigator:

Although strutting subcontractor did not design the strutting system for one strut failure scenario, the retaining wall system still managed to distribute the loads from Strut F vertically to soil and laterally to Struts D & E and passive berm safely but with large incremental movement registered at Inclinometer I_{IC4}.

The water pipe burst incident on Day 227 could have weaken the strut corbel connection for Strut F and stressed the CBP walls towards its structural ultimate limit state.

CS2: Important Events Before Collapse

Day 227

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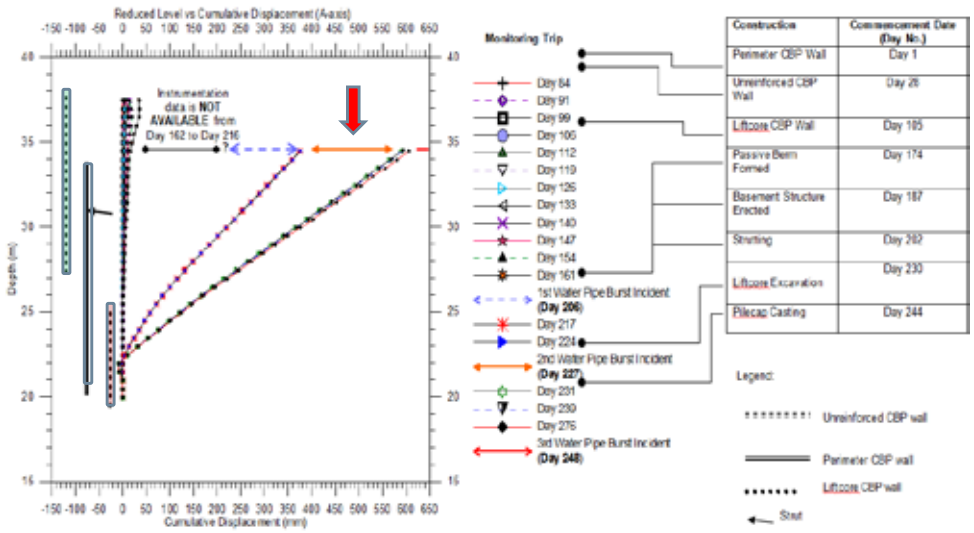

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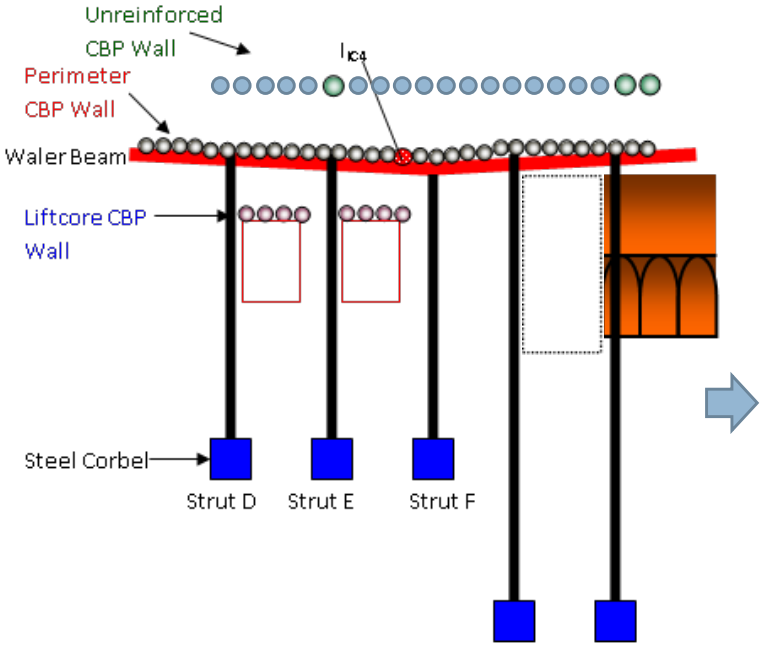
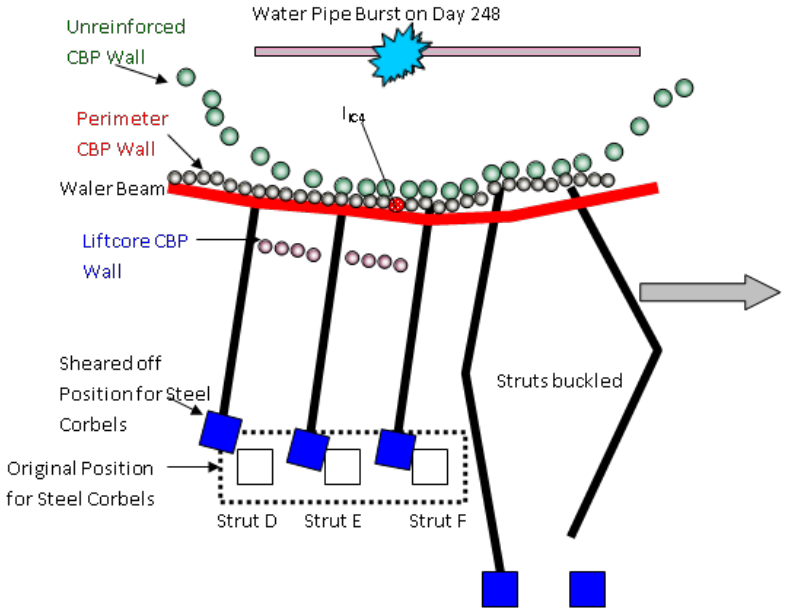
CS2: Important Events Before Collapse

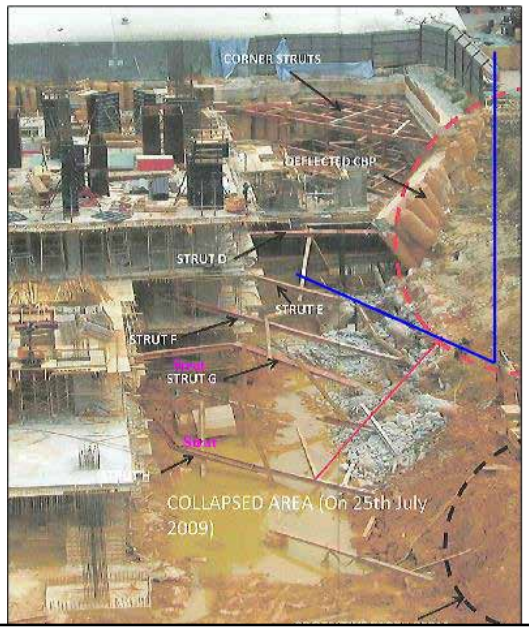
Strut F was reinstated. After installation of struts G and H, temporary passive berm along Gridlines G and H were progressively removed.



CS2: Important Events Before Collapse

The removal of temporary passive berm has caused incremental ground movement that led to another water pipe burst incident on Day 248. This water pipe leakage had triggered CBP wall collapse tragedy on Day 248.





CS2: Video Clip on Wall Failure

CS2: Video Clip on Wall Failure

CS2: Flow of Wall Failure on Day 248

1) Water pipe burst (behind the CBP Wall)
2) Steel corbel connection at Strut F sheared-off
3) Failure of strutting system to re-distribute the failure load to adjacent struts
   - Steel corbel connections at Struts D and E sheared off due to sudden increased in strut force
   - Struts G and H buckled due to sudden increase in strut force
4) Failure of CBP walls due to loss of lateral supports (struts)
5) CBP wall failed rotationally and retained earth at active soil wedge into the excavation site

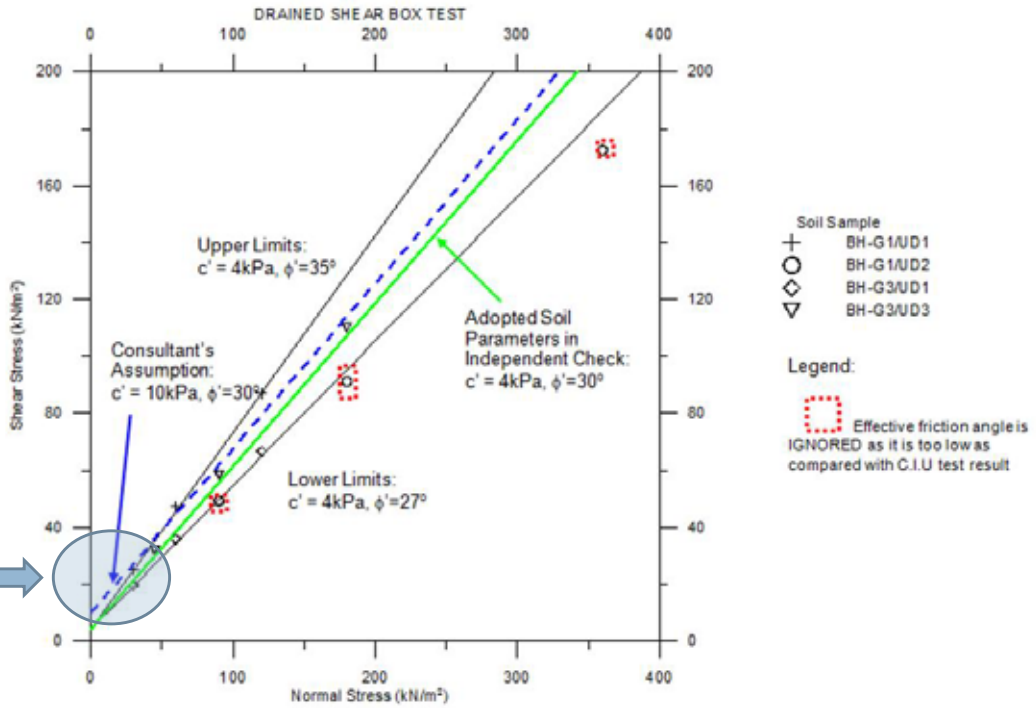
CS2: Why Wall Collapse

Triggering Factor of Wall Collapse: Increase of water pressure due to repetitive water pipe burst incidents happened at the back lane

Causes of Wall Collapse ??

CS2: Causes of Wall Collapse

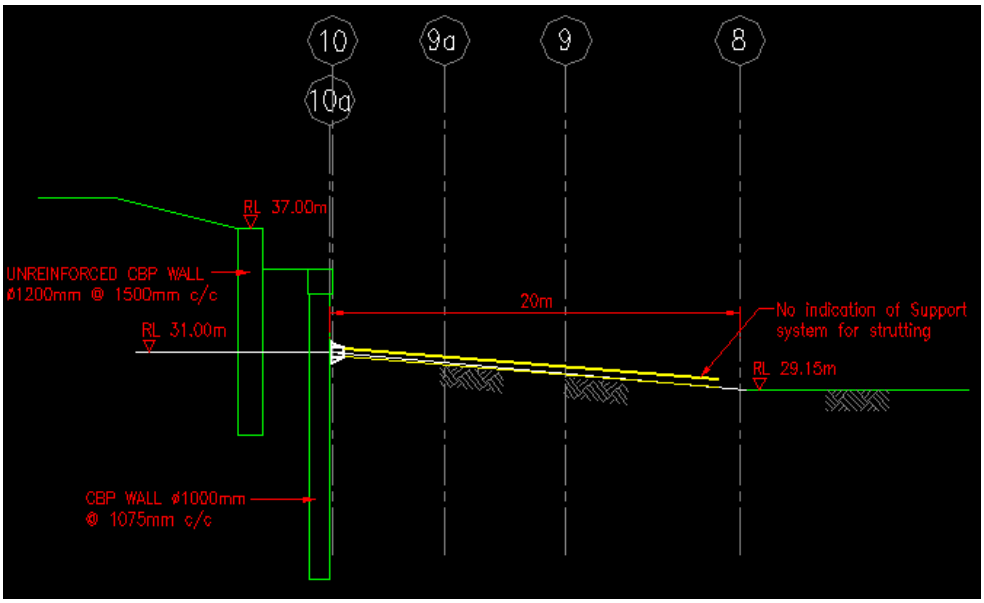
1) Adoption of optimistic cohesion parameter by the temporary work designer



Over-estimation of cohesion for subsoil at shallower depth

CS2: Causes of Wall Collapse

2) Inconsistency of design intent and site execution between temporary work designer and contractor



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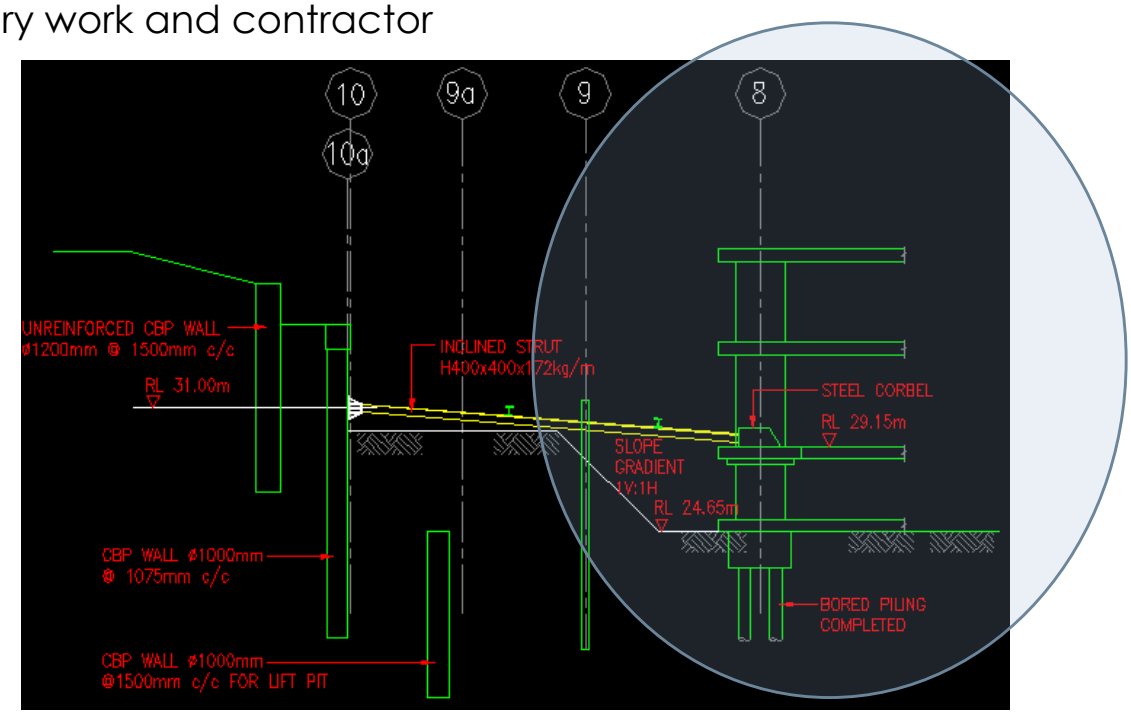
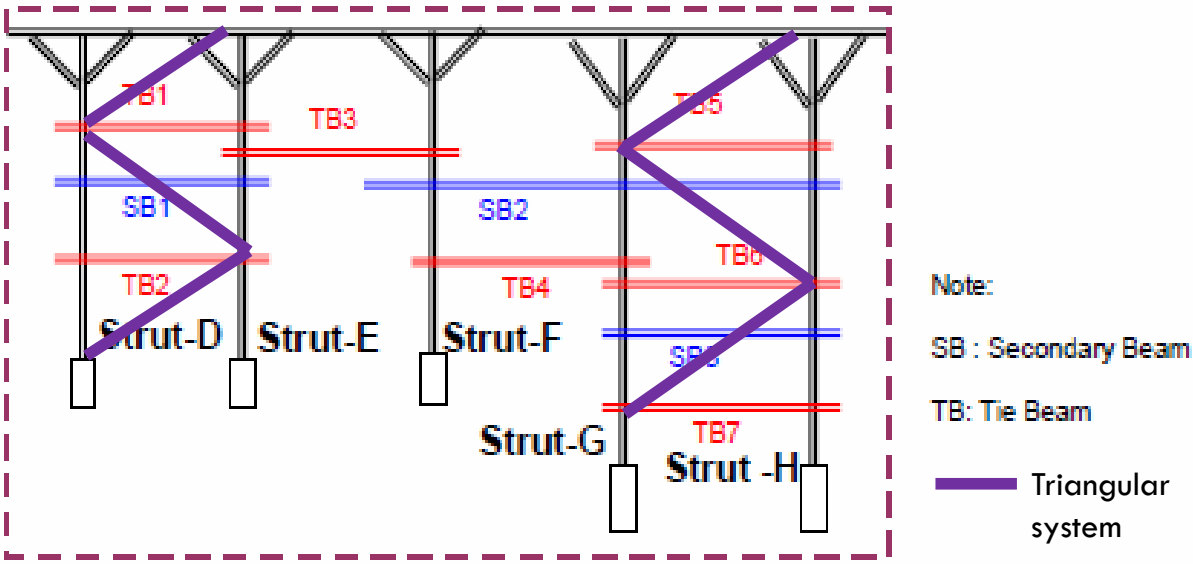


CS2: Causes of Wall Collapse

3) Inadequate lateral restraint bracing system and non-compliance on hole cutting at steel corbel by strutting sub-contractor and no timely review of the retaining wall and strutting designs.



CS2: Causes of Wall Collapse

3) Inadequate lateral restraint bracing system and non-compliance on hole cutting at steel corbel by strutting sub-contractor and no timely review of the retaining wall and strutting designs.

Bolt shear off

Steel Corbel with Post-installed Bolting Connection was Lifted-up After Wall Failure

Post-installed Bolts After Wall Failure

CS2: Lesson Learnt & Recommendation

- Timely review on instrumentation monitoring results is important
- Selection of soil parameters shall be carefully acquired and interpreted based on sufficient lab testing results and local experiences
- Site supervision team to make sure the consistency between the design intent and site execution
- Pay attention on the connection details and strut bracing system

CS2: Which connection detail is better?

VS

Q&A
FOR
CASE STUDY 2 (CS2)

Full paper can refer to
https://gnpgroup.com.my/wp-content/uploads/2017/03/2011_02.pdf

THANK YOU

Q&A

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