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Challenges of Construction of Twin Bored MRT Tunnels in Singapore

Presenter: Ir. Er. Dr. ONG Chee Wee, Victor

Managing Director

P.Eng. (Geo) Singapore

P.Eng. (Civil) Singapore & Malaysia

ASEAN Chartered P.Eng., QECP

International Technical Committee Member (ISSMGE)

- *TC207 Soil-Structure Interaction and Retaining Walls*
- *TC 212 Deep Foundations*

Co-authors : Paul Ee, Thiri Su, Prof. K.Y. Yong, Kulaindran Ariaratnam

Acknowledgement: Prof. C. F. Leung

ONE SMART Engineering Pte Ltd

Geotechnical, Civil & Structural Engineering Consultancy

Singapore . Malaysia

GeoBuild Smart Infrastructure Asia
30 Sept 2015

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PROF. YONG KWET YEW

- Professor of Civil Engineering
- Vice-President, National University of Singapore
- Board and Exco Member, Land Transport Authority, Singapore
- Chairman, Engineering Advisory Panel, Land Transport Authority
- Non-Executive Independent Chairman of the board of Tritech Group Ltd
- Chairman, Accredited Checkers Selection Panel, Building and Construction Authority, MND
- President, Southeast Asian Geotechnical Society

DR. OOI TEIK AUN

- Accredited Checker, Arbitrator, Expert Witness, Chartered Engineer (UK)
- Professional Engineer (Malaysia), APEC Engineer
- International Professional Engineer
- President of Southeast Asian Geotechnical Society
- Immediate Past President of Association of Geotechnical Societies in Southeast Asia
- Chairman of IEM Tunnelling and Underground Space Technical Division 2002-2003 and 2006-2009

COMPANY DIRECTORS

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DR. ONG CHEE WEE, VICTOR
Managing Director

- B.Eng(Hons)Civil, M.Sc.(Civil), PhD(Geotechnical)
- PE(Civil), PE(Geo), QECP(Singapore)
- PE(Civil)(Malaysia), ASEAN Chartered Professional Engineer
- Lecturer (Part-time) BCA Academy
- Secretary of Professional Engineer Board (PEB) Task Force 5
- International Technical Committee Member
- SPRING Technical Committee for Civil & Geotechnical
- Recipient of the Young Consulting Engineer of the Year 2014, Hulme Prize Year 2009 and Best Contribution Award in 6th Asian Yong Geotechnical Engineers Conference Year 2008
- Nominated to represent Singapore at the Southeast Asia Geotechnical Conference (SEAGC) held in Taiwan Year 2010

ER. NG CHEW CHIAT, DAVID
Executive Director

- PE(Civil), Specialist PE(Geo)
- Recipient of the Innovation Award, NSTB Gold Award, The Yong Consulting Engineer of the Year 2013 and The First Prize of Hulme's Prize Technical Paper Competition Year 2000
- Published more than 35 technical papers in geotechnical engineering
- Member of the Institute of Engineers Singapore (IES) Civil and Geotechnical Technical Committee
- Elected as the Council Member of the Tunnelling and Underground Construction Society of Singapore (TUCSS)
- Involved in the planning, design, project management and instrumentation & monitoring, and Qualified Person of major infrastructure projects such as DTSS, KPE, CCL & DTL which involve deep excavation, mined tunnels and bored tunnels

IR. LAI WENG KEAT
Executive Director

- B.Eng(Civil)Hons
- PE(Civil)(Malaysia)
- Member of Institution of Engineers, Malaysia (IEM)

RECENT SEMINAR

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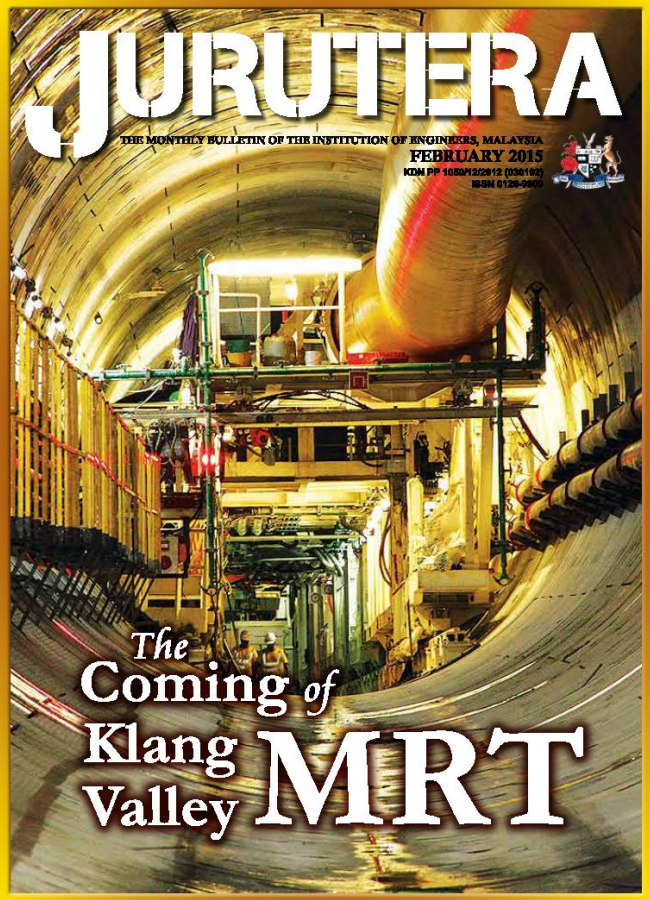


FORUM

Half-Day Seminar on Overview of Design & Construction of Deep Excavation & Tunnelling Projects in Singapore

TUNNELLING AND UNDERGROUND SPACE TECHNICAL DIVISION

By Ir. Dr Ooi Teik Aun

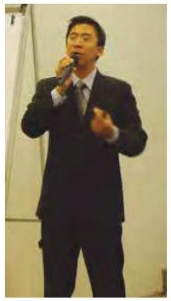
Ir. Dr Ooi Teik Aun is the Founder Chairman of the IEM Tunnelling and Underground Space Technical Division and an Organizing Chairman of the International Conference & Exhibition 2015 (ICE TUS 2015). He is also the current Chairman of Dispute Resolution Practice (DRP) Subcommittee. He is an Advisor for Consulting Engineering Special Interest Group (CESIG). Ir. Dr Ooi is an Honorary Fellow of IEM, Fellow of the Malaysian Institute of Arbitrators and Past President and is ICE Country Representative for Malaysia. He is President of Southeast Asia Geotechnical Society (2010-2016).

Visit to KVMRT Site on 25th July 2014

On 26th July 2014, the Tunnelling And Underground Space Technical Division (TUSTD) of IEM organised a half-day seminar on "Overview of Design & Construction of Deep Excavation and Tunnelling Projects in Singapore" at Wisma IEM.

It attracted about 60 participants, including students from the ICE Student Chapter of University of Nottingham Malaysia Campus.

This seminar was made possible as the two speakers - Er. Dr Victor Ong Chee Wee and Er. David Ng Chew Chiat - made a special trip to visit KVMRT in Kuala Lumpur a day earlier so that they could share their expertise and experience on the subject matter with members of IEM.



Er. David Ng delivering his lecture on deep excavation at the seminar

Er. Dr Victor Ong delivering his lecture on boring tunnelling at the seminar

Some of the participants in the auditorium

The speakers are consultants based in Singapore and are involved in the MRT projects in both Malaysia and Singapore.

They elaborated on the design and construction of deep excavation and bored tunnelling projects in Singapore. They stressed that the design and construction of bored tunnelling and temporary works for deep excavation rely on moderately conservative ground parameters, robust design solutions and close engineer's supervision to limit movements of both the temporary works system and surrounding ground or structures to within acceptable limits, which is particularly true when working in an urban environment.

Instrumentation results also need to be precise and accurate to enable the construction works to proceed in a controlled manner and the instrumentation layout needs to be designed with careful consideration of the excavation and each instrument located with a specific purpose.

The talk ended with an active Q&A session as well as interactive discussion on the various issues of design and construction of deep excavation and bored tunnelling. Certificates of appreciation as well as IEM heritage books were presented to Er. Dr Victor Ong and Er. David Ng at the end of the session. ■

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2015 ASPIRING CATEGORY

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We provide ONE stop SMART engineering design solutions.

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ONE SMART Engineering Pte Ltd
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#06-75 WCEGA Tower
Singapore 658065
Tel: +65 6265 6766
Fax: +65 62817151

Malaysia:
ONE SMART Engineering Sdn Bhd
F-5-07, Block F, Neo Damansara, No. 1,
Jalan PJU 8/1, Damansara Perdana
47820, PJ, Selangor
Tel: +603 9283 6333
Fax: +603 9283 0333

TOP 100 SINGAPORE EXCELLENCE AWARD 2015 ASPIRING CATEGORY

OUR MAJOR EXPERIENCE

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INFRA & GEOTECHNICAL DESIGN

CIVIL & STRUCTURAL DESIGN

CONSULTANCY SERVICES

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SPECIALIST GEOTECHNICAL ENGINEERING DESIGN

- Tunneling

- Ground Anchor
- Slope Analyses
- Ground Improvement

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RETAINING WALL

CONSULTANCY SERVICES

SPECIALIST GEOTECHNICAL ENGINEERING DESIGN

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- Deep Excavation
- Basement Excavation
- Retaining Wall
- Piling Design
- Ground Improvement
- Reclaimation

CONSULTANCY SERVICES

SPECIALIST GEOTECHNICAL ENGINEERING DESIGN

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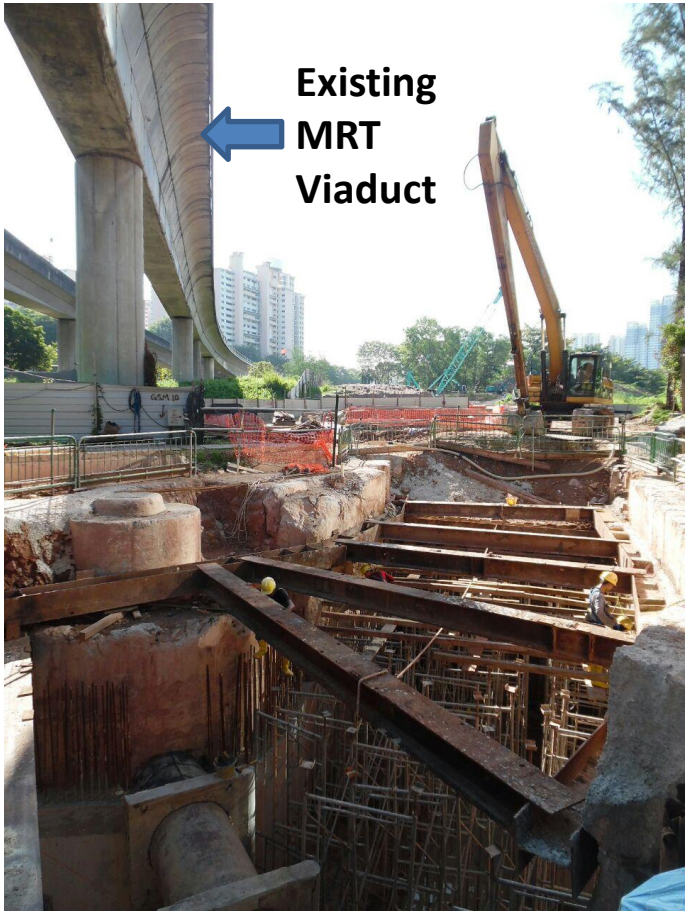
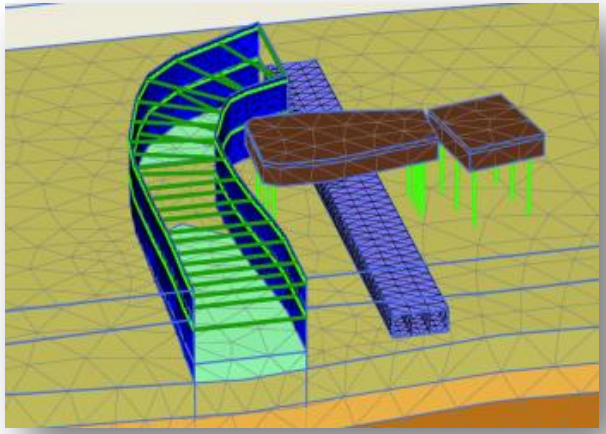


- Drainage Design
- Independent Checking Engineer for MRT Interface



OUR MAJOR EXPERIENCE

PIPE JACKING DESIGN / SEWERAGE DESIGN

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Pipe Jacking Works

- Sewerage Design
- Pipe Jacking Design

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DREDGING WORKS / WATER SYSTEM

Dredging Works

Marina Barrage Scheme

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INDEPENDENT CHECKING ENGINEER

Bukit Bintang Station Site

MALAYSIA UG1

MRT PROJECT (LINE 1)

- Contractor's Independent Checking Engineer (CICE) for Design of deep Excavation (MRT Station,, Tunnel-Pile Interaction
- Main Contractor: MMC-Gamuda
- Contract Sum: RM8.82Billion

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INDEPENDENT CHECKING ENGINEER

Pasar Seni MRT Station Site

MALAYSIA UG1

MRT PROJECT (LINE 1)

- Contractor's Independent Checking Engineer (CICE) for Design of deep Excavation (MRT Station,, Tunnel-Pile Interaction
- Main Contractor: MMC-Gamuda
- Contract Sum: RM8.82Billion

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INDEPENDENT CHECKING ENGINEER

Merdeka MRT Station Site

MALAYSIA UG1

MRT PROJECT (LINE 1)

- Contractor's Independent Checking Engineer (CICE) for Design of deep Excavation (MRT Station,, Tunnel-Pile Interaction
- Main Contractor: MMC-Gamuda
- Contract Sum: RM8.82Billion

COCHRANE MRT STATION

INDEPENDENT CHECKING ENGINEER

ONE SMART

COCHRANE MRT STATION

Preparation of Impact Analysis of 3 parts of infrastructure <u>within MRT 2nd Reserves</u>:

- On Jalan Cochrane – Entrance Vehicular Ramp to MyTOWN
- On Jalan Cochrane – Pedestrian Tunnel Between MyTOWN and MRT
- On Jalan Nakhoda Yusoff – MEX Highway Off-ramp

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FOUNDATION DESIGN ABOVE MRT TUNNELS

OUR MAJOR EXPERIENCE

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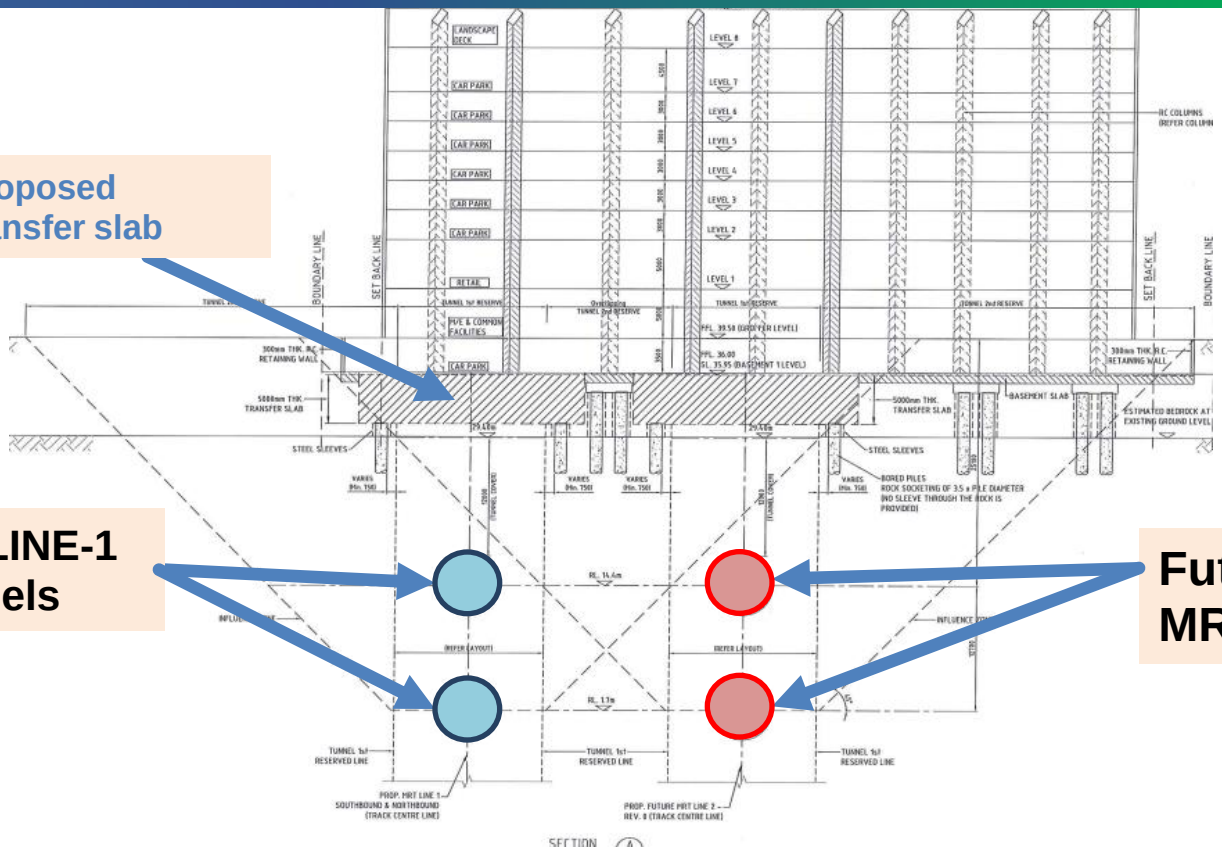
FOUNDATION DESIGN ABOVE MRT TUNNELS



Cross-section showing the proposed transfer slab and the existing LINE-1 and future LINE-2 tunnels.

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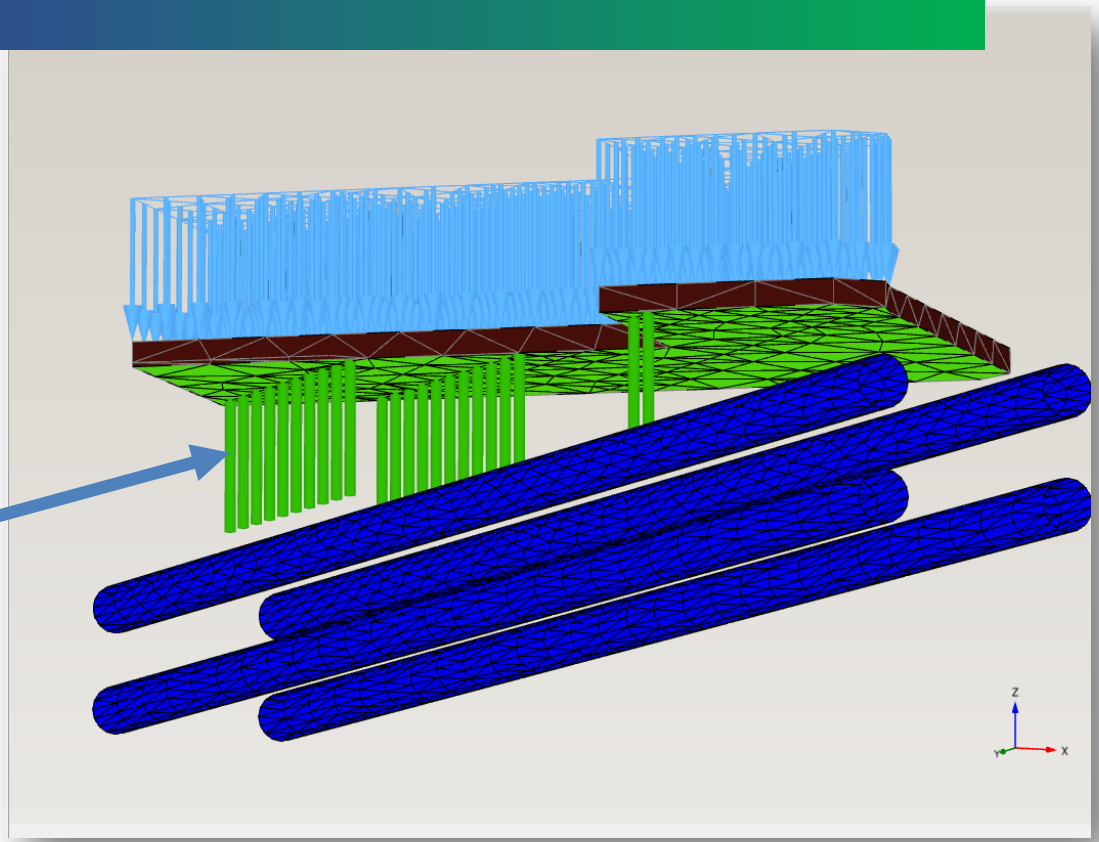
FOUNDATION DESIGN ABOVE MRT TUNNELS

Corresponding 3D FEM mesh showing the bored piles and the existing LINE-1 and future LINE-2 tunnels.

Φ2.2m bored piles with pile toe @17mRL and 4.4m c/c spacing 1m outside the LINE-1 tunnel 1st Reserve Zone



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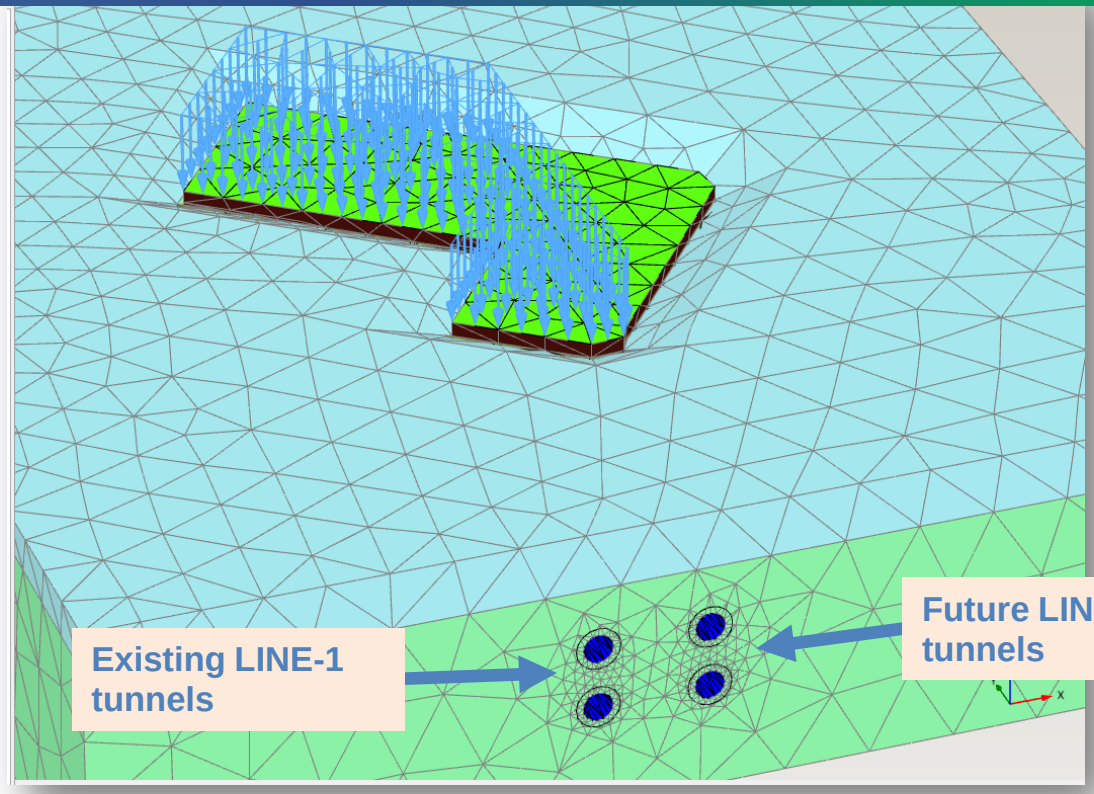
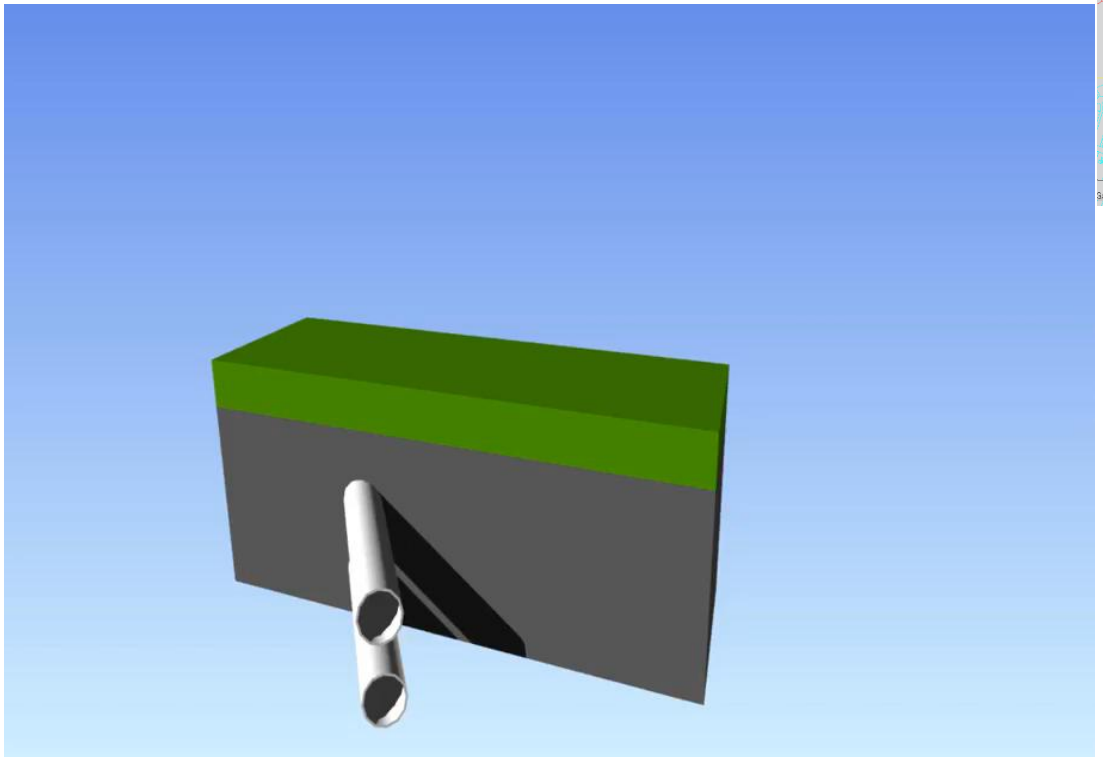
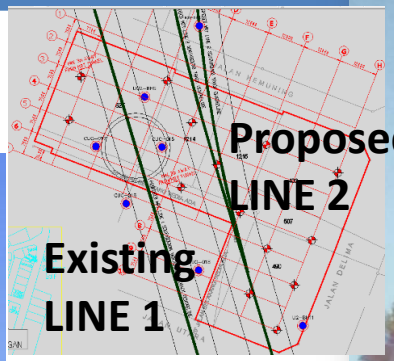
FOUNDATION DESIGN ABOVE MRT TUNNELS

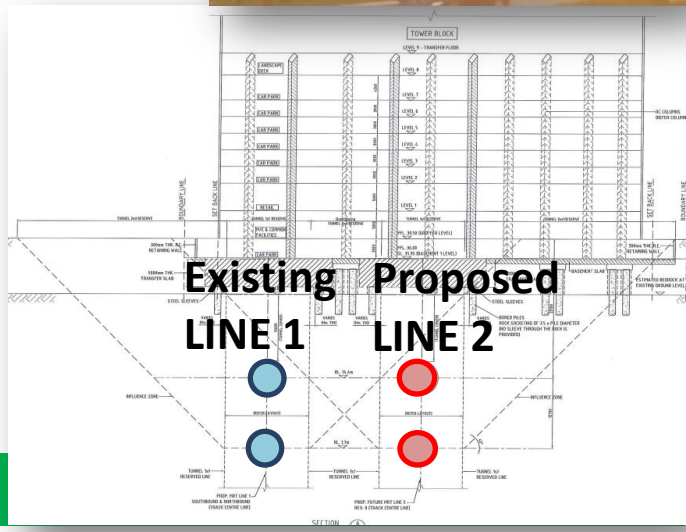


Another view of 3D FEM mesh showing the bored piles and the existing LINE-1 and future LINE-2 tunnels.

FOUNDATION DESIGN ABOVE MRT TUNNELS







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TUNNELING

C902
(Promenade Interchange Station)

Scope:
Qualified Person (Civil) (Supervision)

Contract Sum: S$231.9Million

OUR MAJOR EXPERIENCE

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TUNNELING

C902 (Promenade Interchange Station)

Scope:
Qualified Person (Civil) (Supervision)

Contract Sum: S$231.9Million

OUR MAJOR EXPERIENCE

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TUNNELING

C933 (Bendemeer Station)

Scope:
Qualified Person (Civil) (Supervision)

Contract Sum:
S$215.24Million

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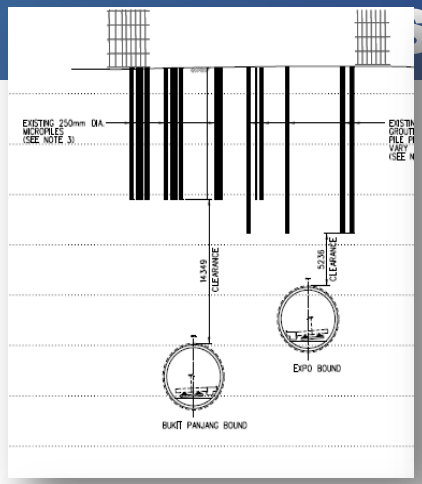
TUNNELING BELOW EXISTING



C933 (Bendemeer Station)

Scope:
Qualified Person (Civil) (Supervision)

Contract Sum:
S$215.24Million

Bored Tunnel: 2.27km x 2, 4 nos. of TBM

OUR MAJOR EXPERIENCE

TUNNELLING (60m deep)

SINGAPORE CABLE TUNNEL – CONTRACT NS2

Contract No. 9120379
Design and Construction of North-South Transmission Cable Tunnel – **Contract NS2**

Notes:

- Consists of a single bored tunnel with an internal diameter of 6m in the Bukit Timah granitic rocks, residual soils and rock soil interface
- Excavation is approximately 70m deep.

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BASEMENT EXCAVATION ADJACENT TO MRT TUNNEL

FUSIONOPOLIS 5 SINGAPORE

Study of Earth Retaining or Stabilising Structures (ERSS) and Debonding of Pile Within RPZ

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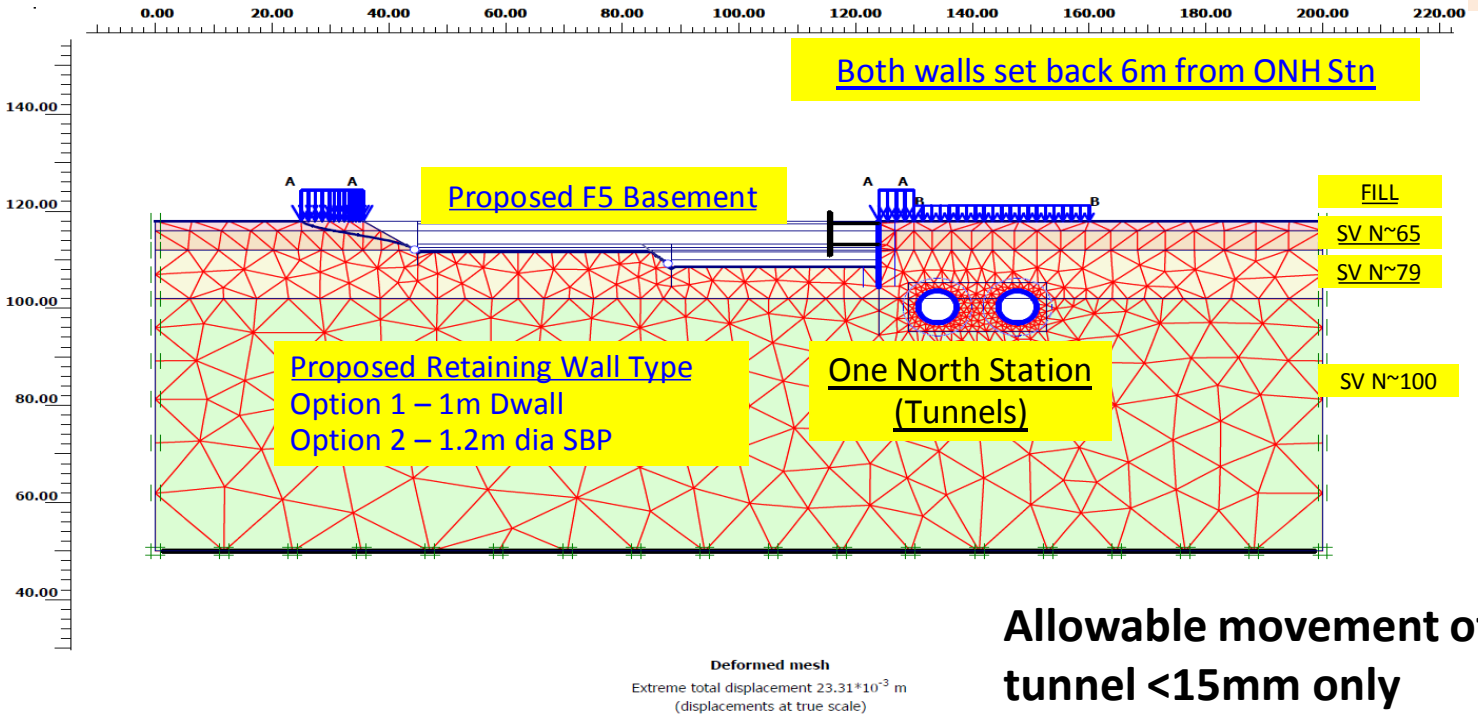
BASEMENT EXCAVATION ADJACENT TO MRT TUNNEL

Study 1 – Type of Retaining Wall



Allowable movement of tunnel <15mm only

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BASEMENT EXCAVATION ADJACENT TO MRT VIADUCT

Jurong Gateway
SINGAPORE

Located at Jurong Gateway Road / Boon Lay Way

OUR MAJOR EXPERIENCE

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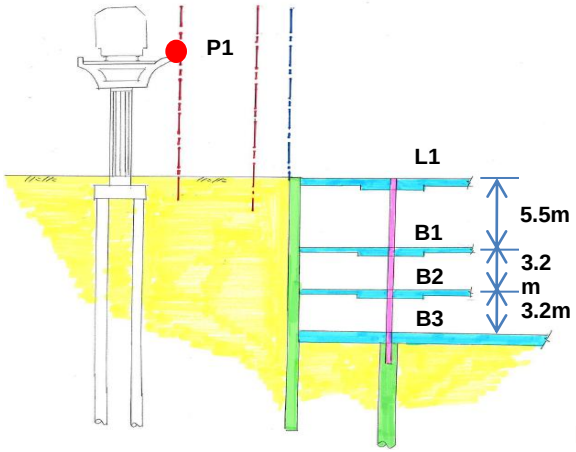
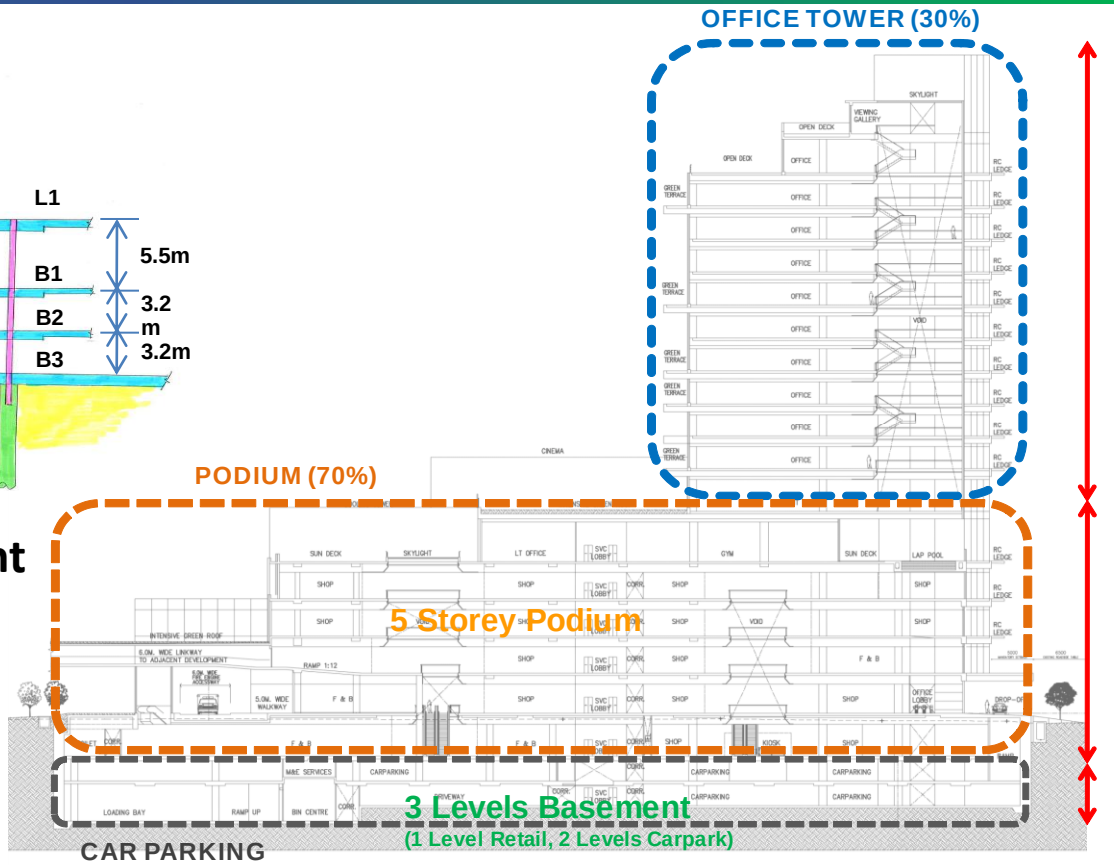
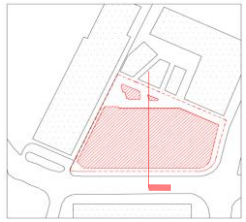
BASEMENT EXCAVATION ADJACENT TO MRT VIADUCT



Allowable movement <15mm only





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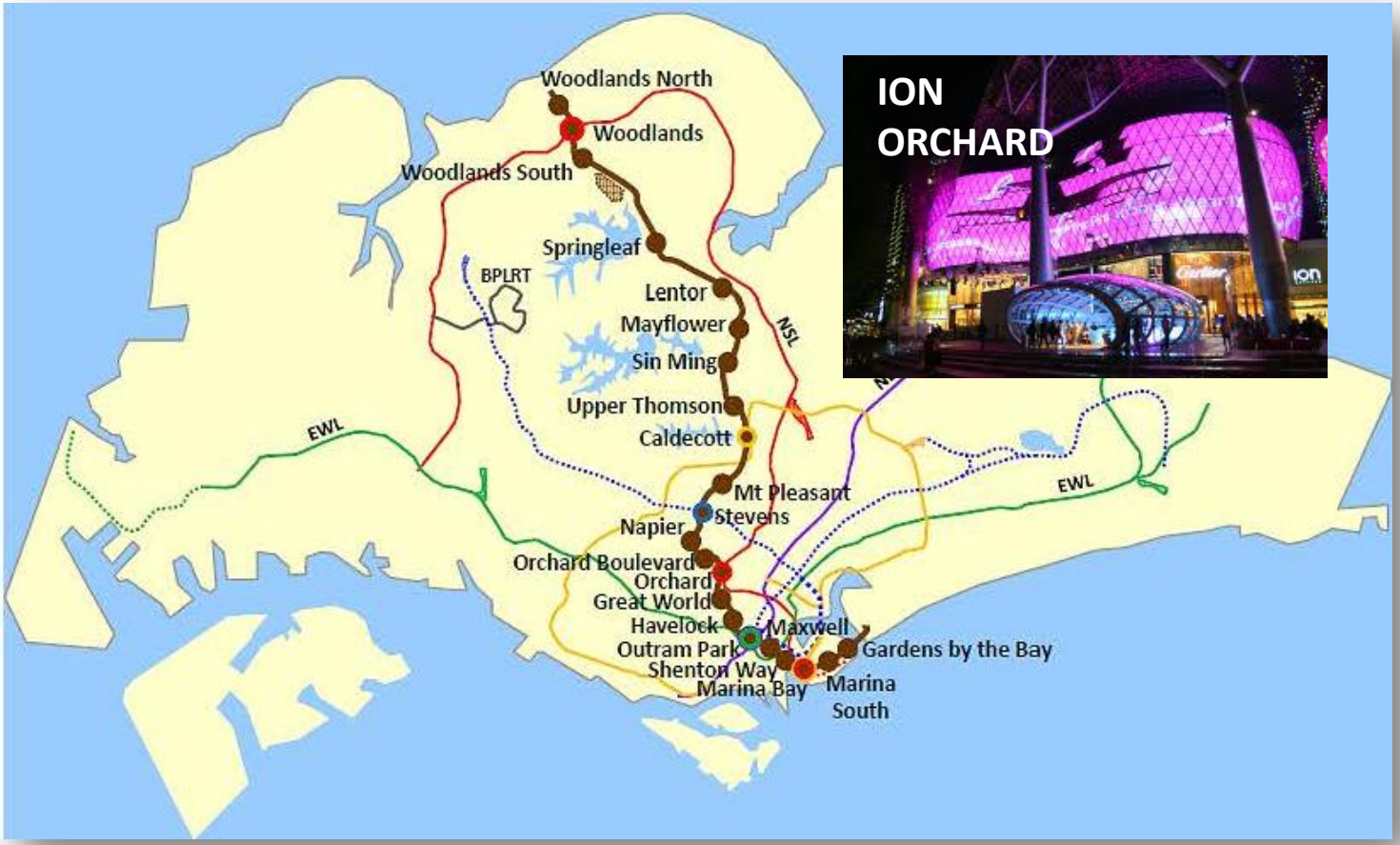
TUNNELING



SINGAPORE THOMSON LINE

- **T203** (Woodlands)
- **T213** (Caldecott)
- **T219** (Orchard)
- **T220** (Great World)
- **T221** (Havelock)

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CIVIL & STRUCTURAL DESIGN

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CIVIL & STRUCTURAL ENGINEERING DESIGN

- High Rise Building Design
- Viaduct Structure
- Underground Structure

CONSULTANCY SERVICES

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CIVIL & STRUCTURAL ENGINEERING DESIGN

- **Curtain Wall, Cladding, Skylight, Facade, Canopy and Railing**
- **Design of Water, Tidal Gate, Drainage and Sewer**

CONSULTANCY SERVICES

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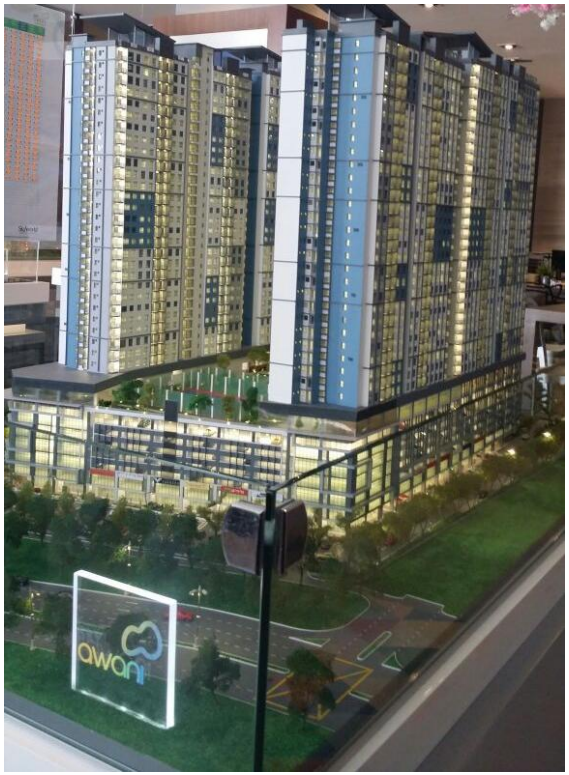
CIVIL, STRUCTURAL AND PILING DESIGN



SKY AWANI
SENTUL, KUALA LUMPUR

CONSULTANCY SERVICES

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CIVIL, STRUCTURAL AND PILING DESIGN

SKY ARENA
SETAPAK, KUALA LUMPUR

COMPANY CERTIFICATES

ONE SMART

ISO 9001 & SAFETY CERTIFICATES

GUARDIAN INDEPENDENT CERTIFICATION

CERTIFICATE OF REGISTRATION

The Quality Management Systems of

One Smart Engineering Pte. Ltd.

21 Bukit Batok Crescent #06-75 WCEGA Tower Singapore 658065

has been audited and found to conform to

ISO 9001:2008

for the following activities

Provision of Engineering Consultancy for Geotechnical, Civil and Structural Engineering

Date of Issue: 22 September 2014 **Date of Expiry: 21 September 2017**

Initial Certification: 22 September 2014

Certificate No. 760927

Guardian Independent Certification Pte Ltd
10 Ubi Crescent #04-52 Ubi Techpark
Singapore 408564

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Member of the IAF MLA for QMS

S 00821

Building and Construction Authority

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OF
SUCCESSFUL COMPLETION

It is hereby certified that

Ong Chee Wee

(NRIC/Passport: S7578402C)

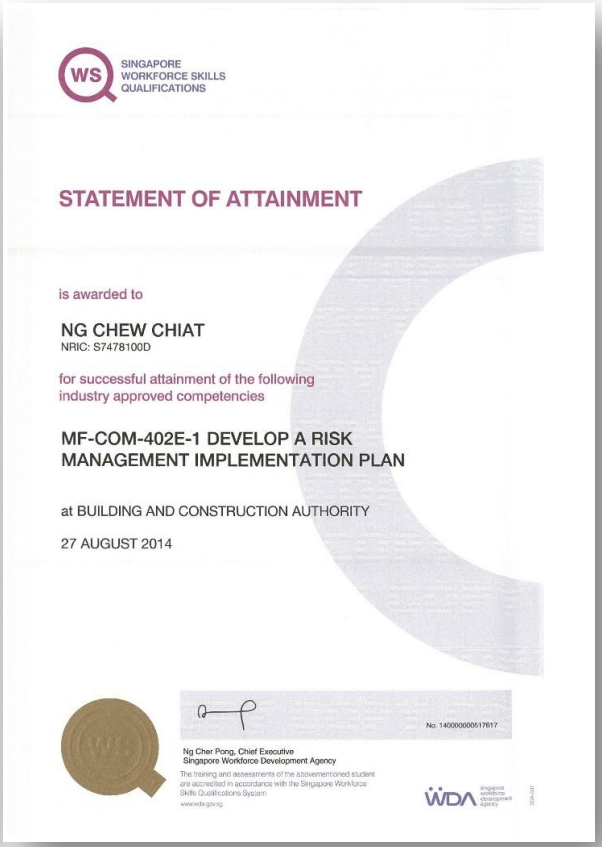
has successfully passed the course work assessments in

bizSAFE Level 1 Workshop for company CEO/Top Management

on 11 December 2012

DEPUTY DIRECTOR
School of Graduate & Management Development
BCA Academy

Certificate No. RM1/12/00162
11 December 2012



SINGAPORE WORKFORCE SKILLS QUALIFICATIONS

STATEMENT OF ATTAINMENT

is awarded to

NG CHEW CHIAT
NRIC: S7478100D

for successful attainment of the following industry approved competencies

MF-COM-402E-1 DEVELOP A RISK MANAGEMENT IMPLEMENTATION PLAN

at BUILDING AND CONSTRUCTION AUTHORITY

27 AUGUST 2014

No. 1400000000517617

Ng Cher Pong, Chief Executive
Singapore Workforce Development Agency

The training and assessments of the abovementioned student are accredited in accordance with the Singapore Workforce Skills Qualifications System
www.wda.gov.sg

WDA

COMPANY CERTIFICATES

REGISTERED WITH LEMBAGA JURUTERA MALAYSIA & PROFESSIONAL ENGINEERS BOARD

ONE SMART

REPUBLIC OF SINGAPORE
PROFESSIONAL ENGINEERS BOARD

PROFESSIONAL ENGINEERS ACT
(CHAPTER 253)

LICENCE TO SUPPLY PROFESSIONAL ENGINEERING SERVICES

ONE SMART ENGINEERING PTE. LTD.

having its principal place of business at

21 Bukit Batok Crescent #06-75 WCEGA Tower, Singapore 658065

is issued a licence to supply professional engineering services in Singapore subject to the following conditions as stipulated in section 21 of the Professional Engineers Act:

1) The licensee shall supply professional engineering services in Singapore through a professional engineer —

(a) who shall be responsible for the professional engineering works;
(b) who has in force a practising certificate authorising him to engage in professional engineering work to which those services relate; and
(c) who is —
(i) in the case of a corporation, a director or an employee of the corporation;
(ii) in the case of a partnership, a partner or an employee of the partnership; or
(iii) in the case of a limited liability partnership, a partner or an employee of the limited liability partnership.

PROFESSIONAL ENGINEERS BOARD SINGAPORE

professional liability in accordance with the Professional Engineers Act and the rules made thereunder.

shown below and shall expire on

19 September 2015

Licence issued on: 24 October 2014
Licence No: L2014-172
Reference No: PEB210/13-L

Registrar
Professional Engineers Board
Singapore

Licence Fee received: $500.00

(Borang F)

AKTA PENDAFTARAN JURUTERA 1967
PERATURAN-PERATURAN PENDAFTARAN JURUTERA 1990
(PERATURAN 35)

No. Perakuan: 1515-1000-BC-1389

LEMBAGA JURUTERA MALAYSIA

PERAKUAN PENDAFTARAN SEBAGAI AMALAN JURUTERA PERUNDING

INI ADALAH UNTUK MEMPERAKUI BAHAWA

Nama: Pertubuhan Perbadanan
ONE SMART ENGINEERING SDN. BHD.

Alamat: NO. 26A JALAN SUNGAI BESI
BATU 1
57100 KUALA LUMPUR W. PERSEKUTUAN (K.L)

Cawangan Kejuruteraan: ** CIVIL **

yang telah mematuhi kehendak-kehendak Akta Pendaftaran Jurutera 1967 dan telah membayar fee pendaftaran didaftarkan sebagai suatu AMALAN JURUTERA PERUNDING dalam cawangan kejuruteraan yang dinyatakan di atas tertakluk kepada syarat-syarat yang dinyatakan di bawah.

Syarat-syarat:

LEMBAGA JURUTERA MALAYSIA

Perakuan pendaftaran ini akan habis tempoh pada 31 DISEMBER 2015

(DATO' Ir. Hj. ANNIES BIN MD. ARIFF)
Yang Dipertua

(Ir. HIZAMUL DIN BIN AB. RAHMAN)
Pendaftar

Tarikh dikeluarkan:
26 JANUARY 2015

** No. Resit 248232 ** MBB 350003 ** RM1,065.00 ** Tarikh bayaran:06-01-2015**
[RM50.00(Fee Pemprosesan) RM1,000.00(Fee Pendaftaran) RM15.00(Others)]
Pengesahan pendaftaran hendaklah disemak dilaman web www.bem.org.my

Content (3 Challenges)

1. **Tunnelling in close proximity to existing steel H-pile of Shophouse**

2. **Tunnelling under a cluster of 6 units of Shophouses**

3. **Overcoming of existing pile obstructions at demolished Shophouse**

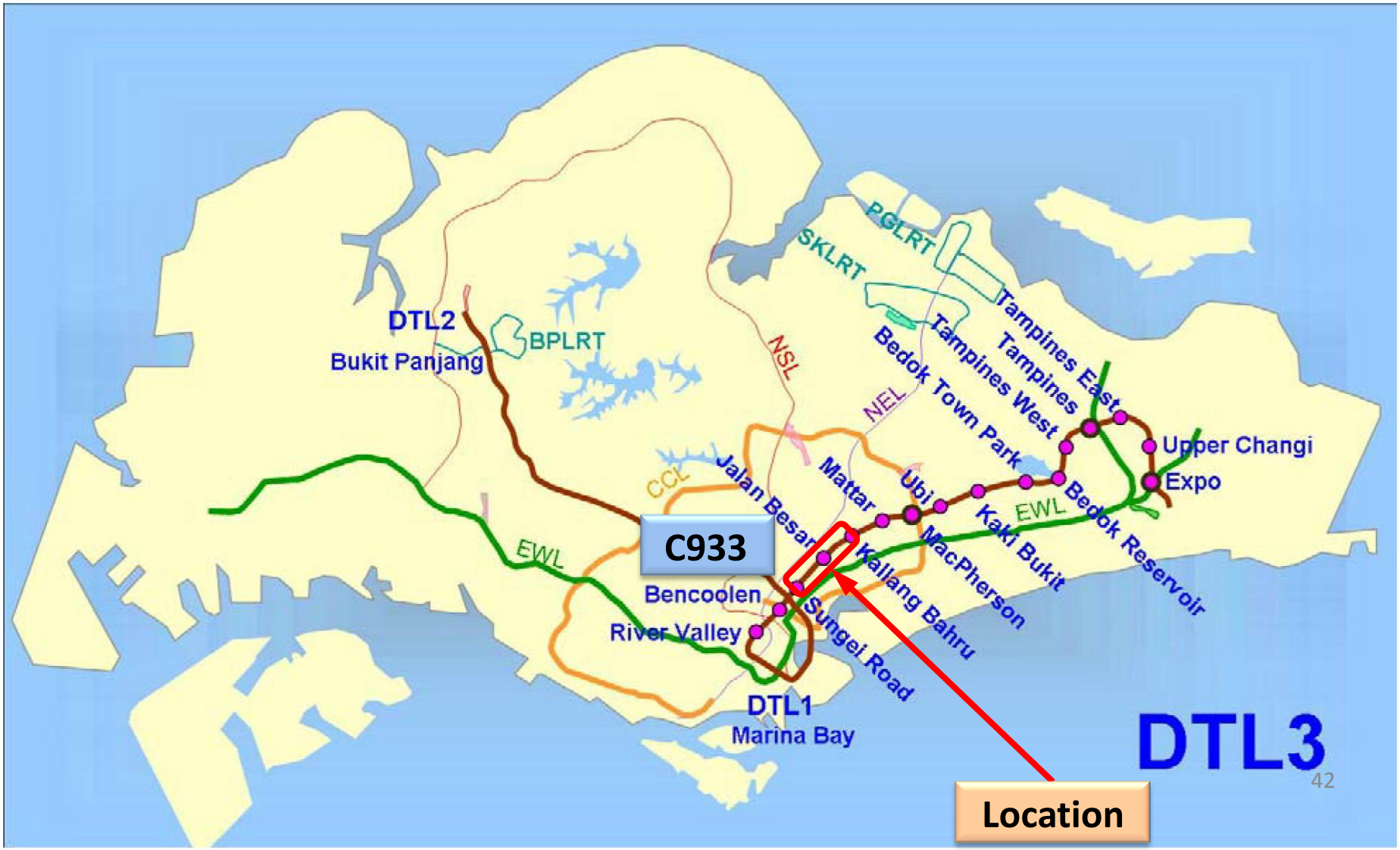
ONE SMART

Project Background

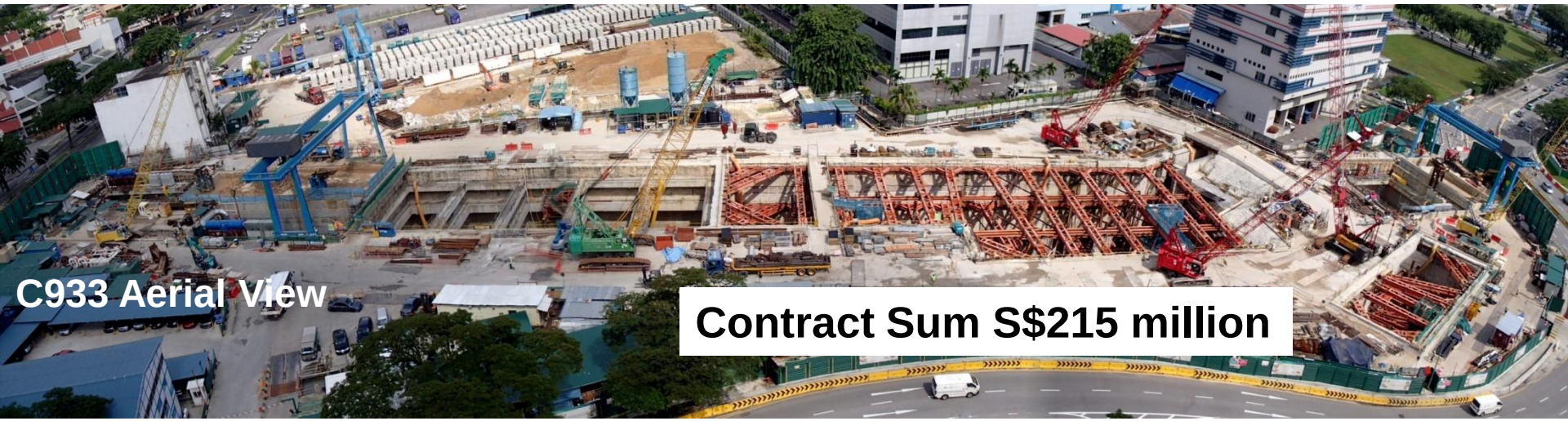
Bendemeer MRT Station (Downtown Line-3), Singapore

ONE SMART

Project Information - Location



Project 2 – C933 (Bendemeer Station DTL3)



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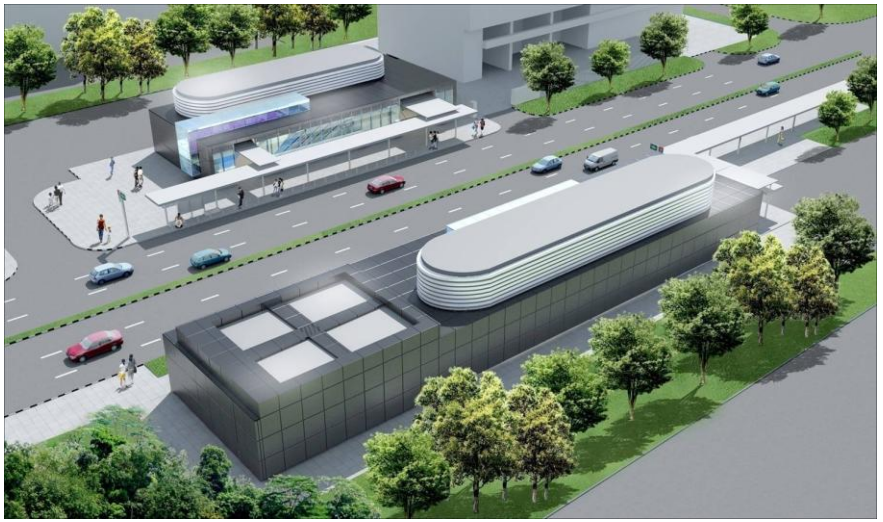
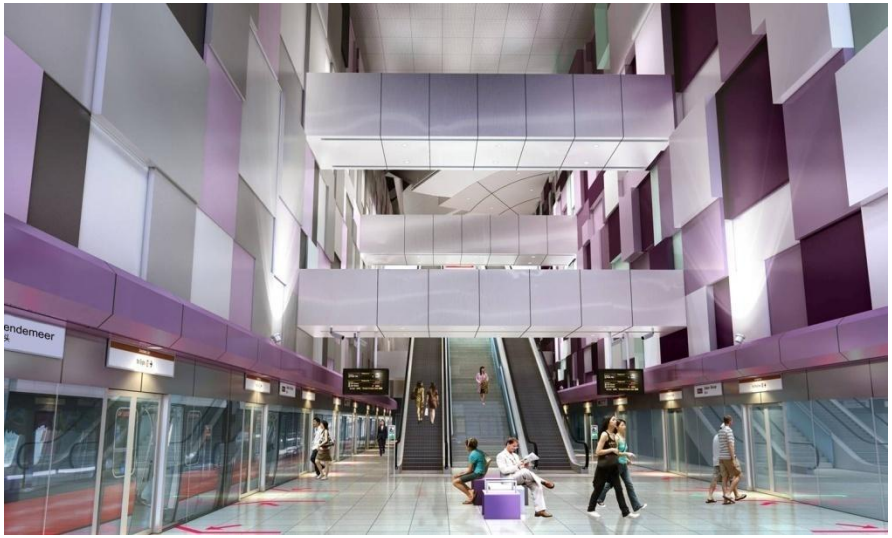
LTA C933 – Artist Impression



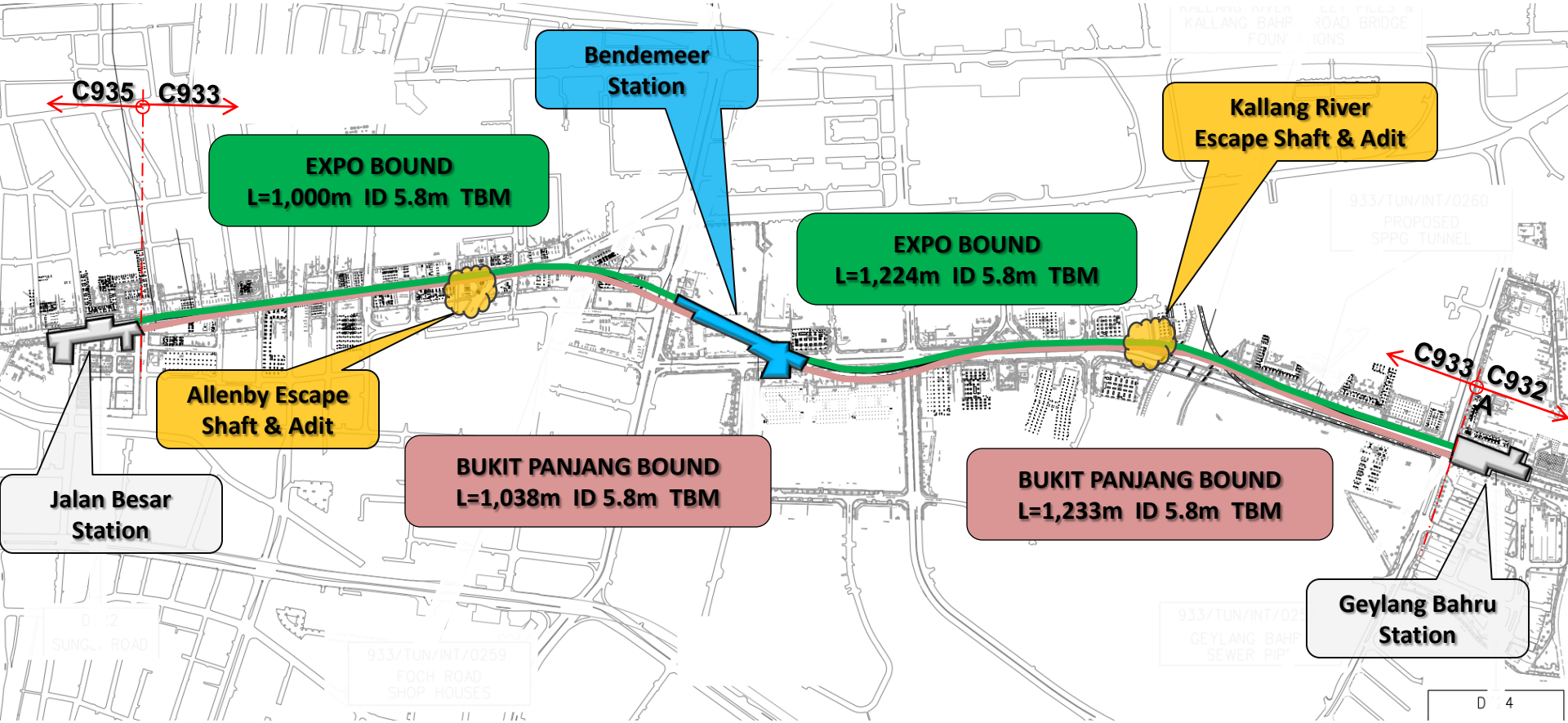


Platform

Concourse Ticketing

Contract Sum	SGD 215,240,000.00

Scope of Work : Overall



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45

Geological Profile/ Design Ground Volume Loss

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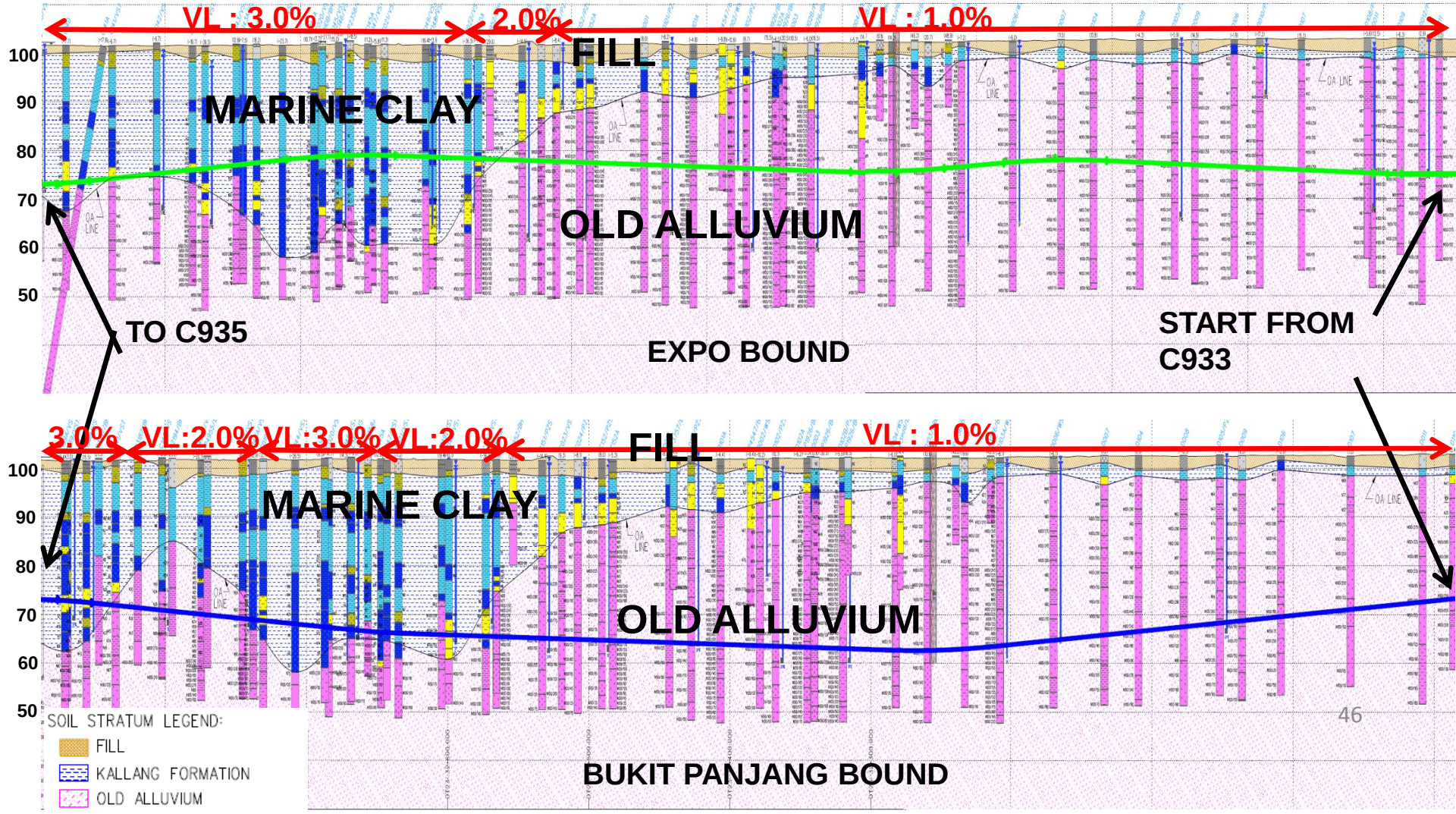
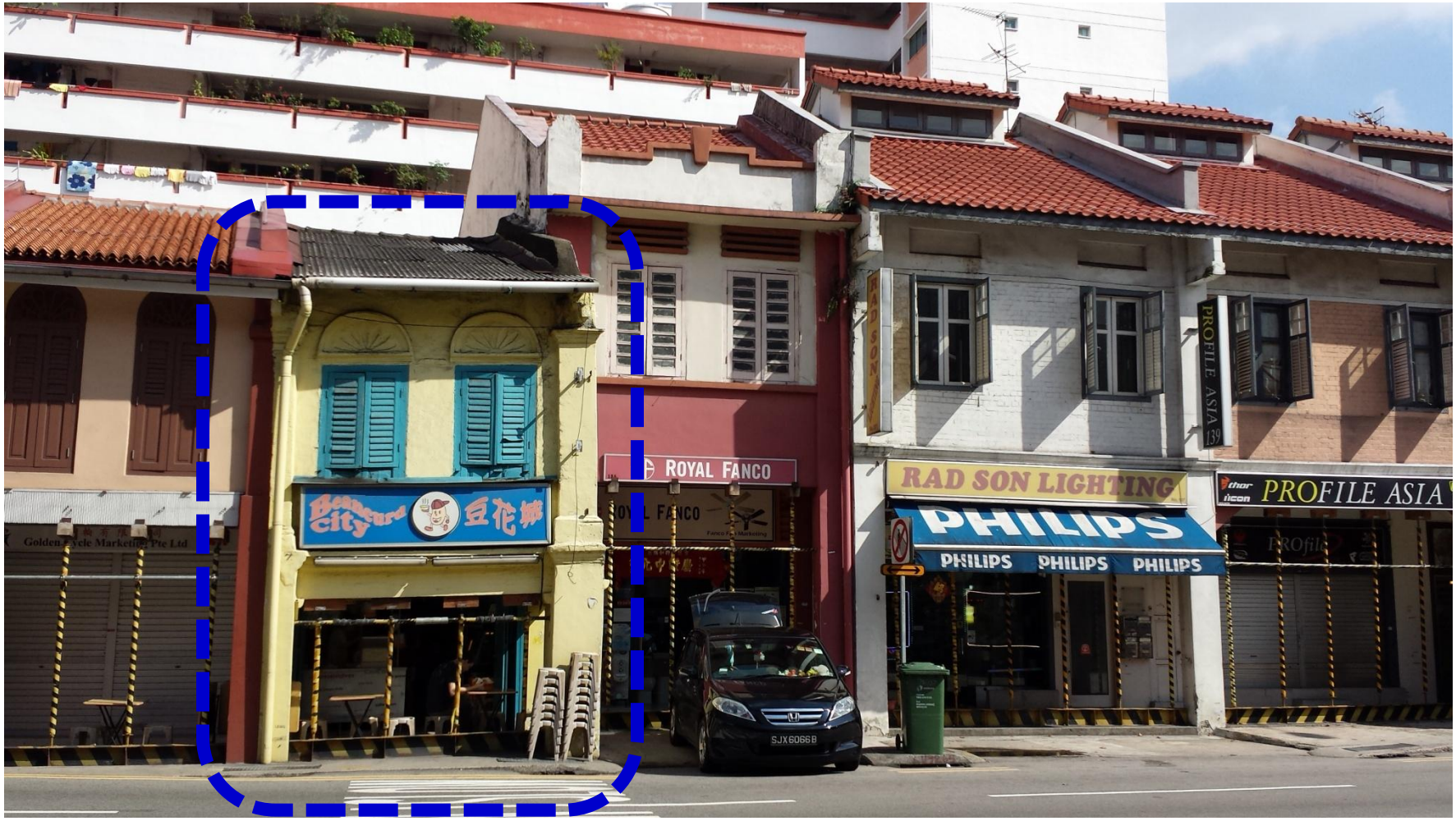


Conserved Shophouses late 19th & early 20th centuries



ONE SMART

Conserved Shophouses

ONE SMART

Conserved Shophouses

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Conserved Shophouses

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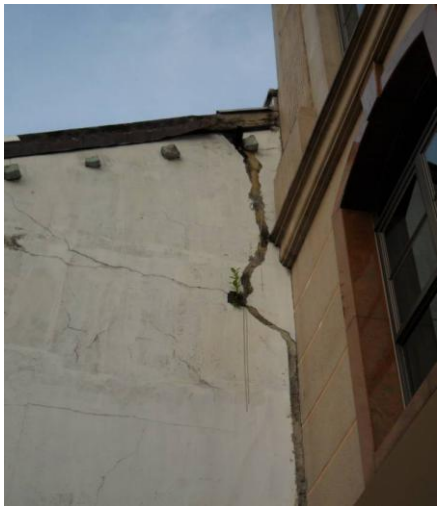
Conserved Shophouses



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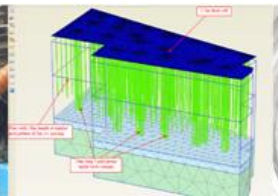
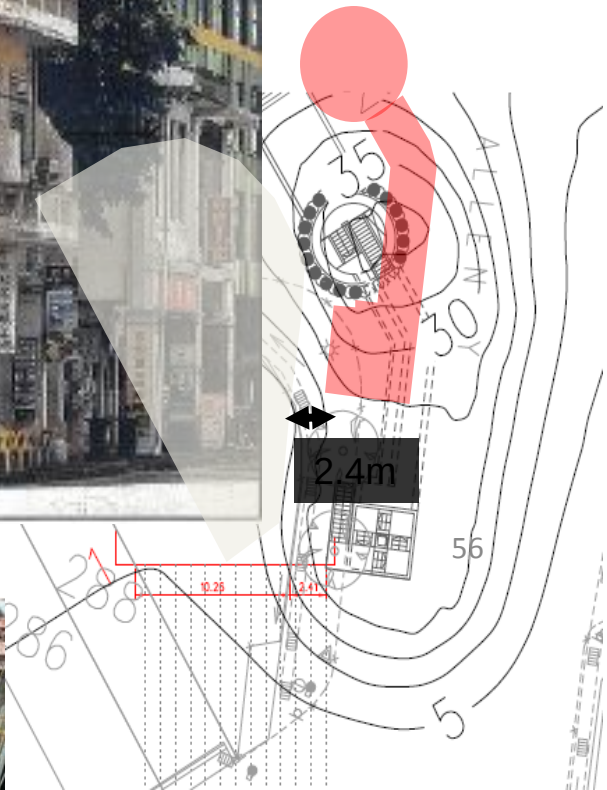
C933 – ALLENBY ROAD SHOPHOUSE DAMAGE ASSESSMENT





Potential Challenges

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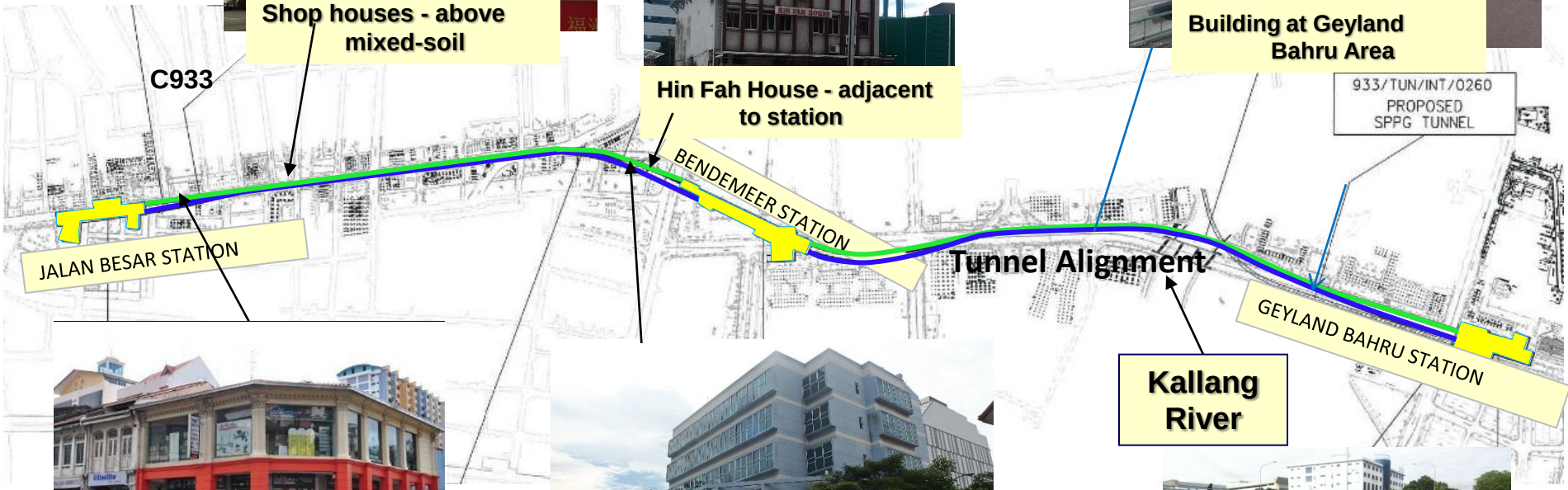
- Tunnel alignment passing through highly built-up areas

Shop houses - above mixed-soil

Hin Fah House - adjacent to station

Building at Geyland Bahru Area



Shop houses - above tunnel alignment

Hotel 81 - above tunnel alignment

C933 (Bendemeer Station DTL3)

Tunneling Works

- Bored Tunnel : 2.27km x 2 , 4 nos of TBM

C933 - Creativity/Innovation

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- Qualified Person (Supervision) for DTL3 C933

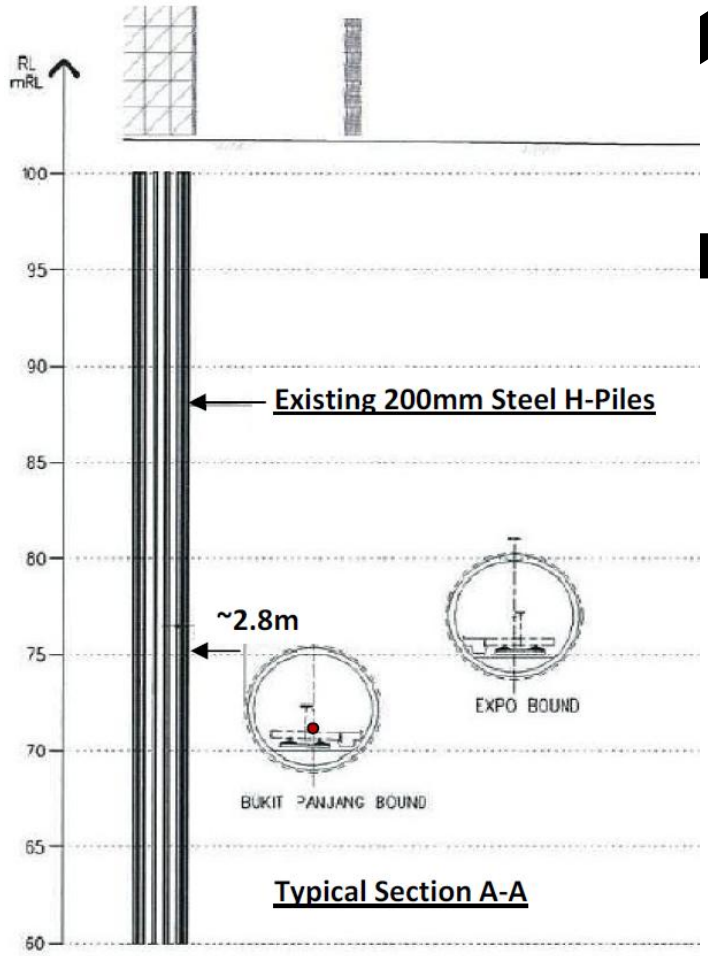
  Steel Fiber Reinforced Concrete (SFRC)Tunnel Segments, the project is a recipient of **Singapore Concrete Institute (SCI) Excellence Award** 2013

- **Increased speed of production**
- **Less labour needed**
- **Less land required for storage**
- **Steel fibre is multi-directional and evenly distributed**

John Poh, Kiang Hwee Tan, Graeme Laurence Peterson, Dazhi Wen

Challenge 1

- Tunnelling in close proximity to existing steel H-pile of Shophouse



1

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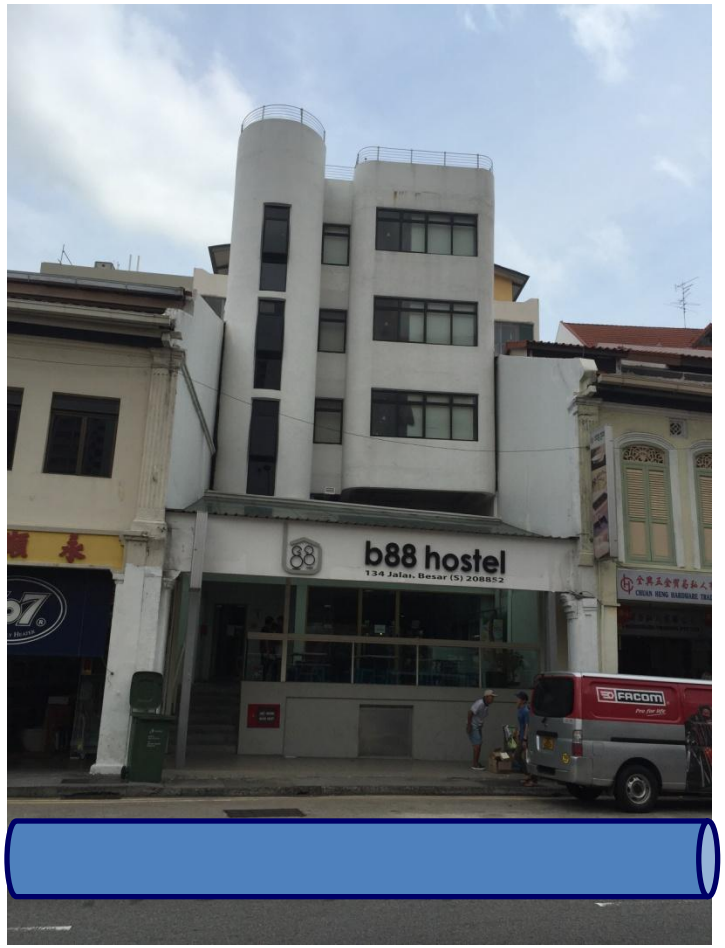
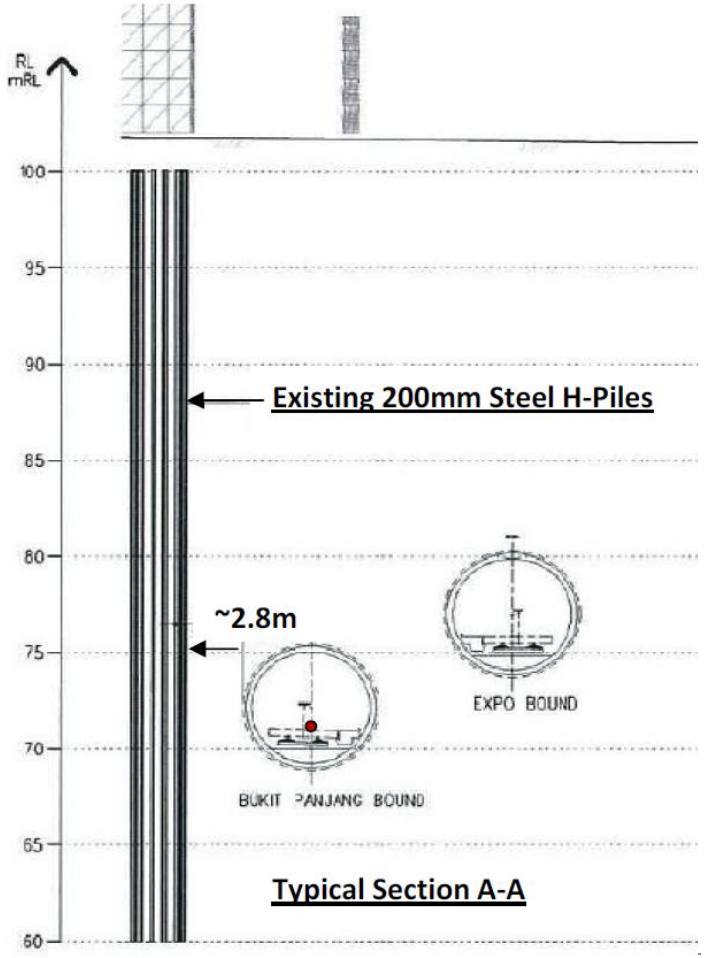
Tunnel-pile Interaction





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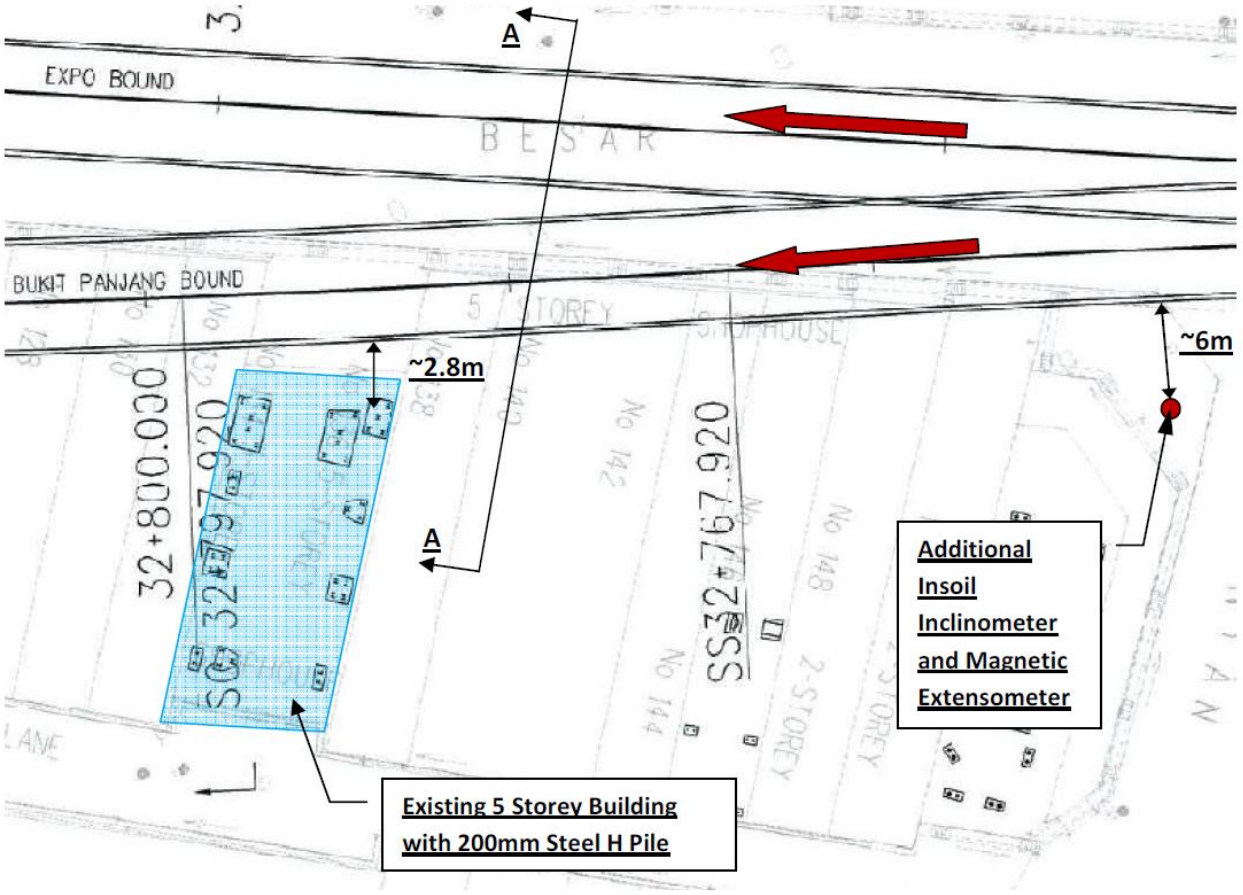
Plan of Building with existing Steel H-Pile in close proximity to Bored Tunnel



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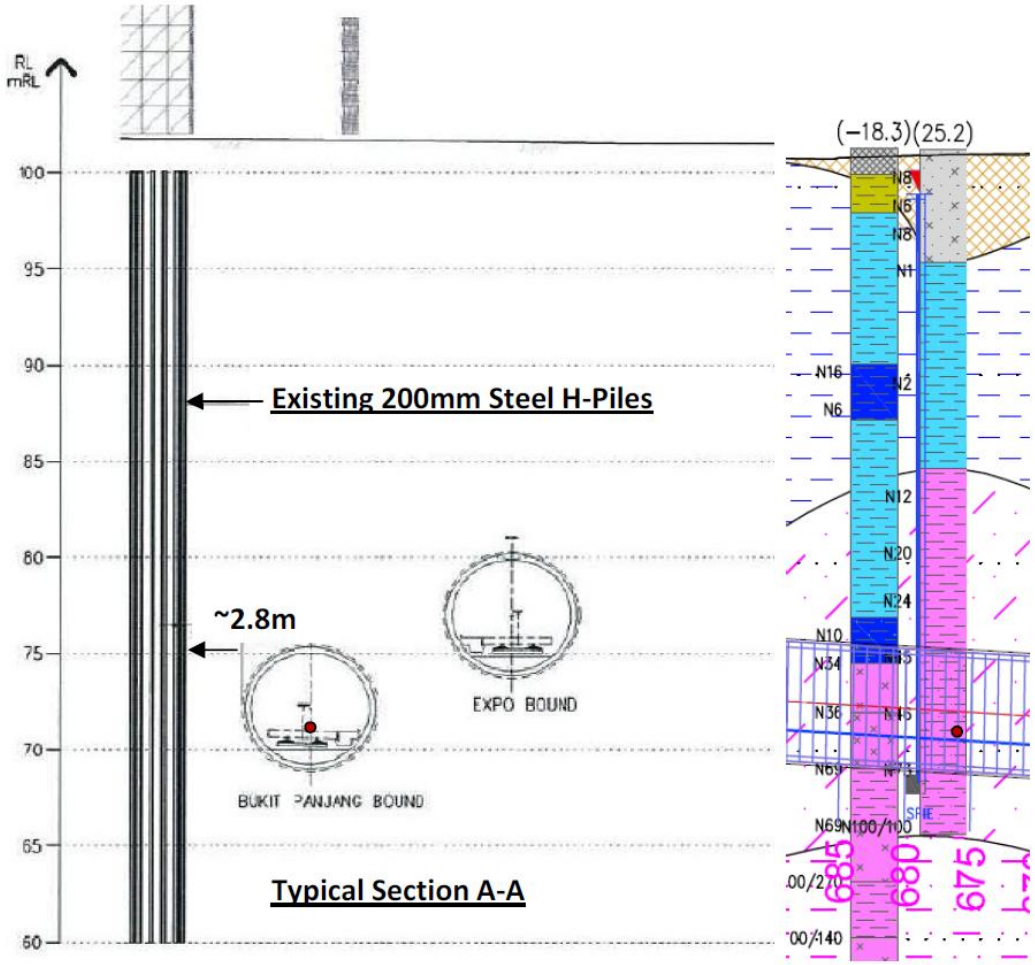
Typical Section of Building with existing H-Pile in close proximity to Bored Tunnel and Soil condition



The TBM face pressure was maintained at 48% higher than hydrostatic pressure during mining adjacent to the bored hole instruments.

The monitoring readings have shown minor horizontal and vertical soil movement of maximum 3mm after the TBM crossed the bored hole instrument location.

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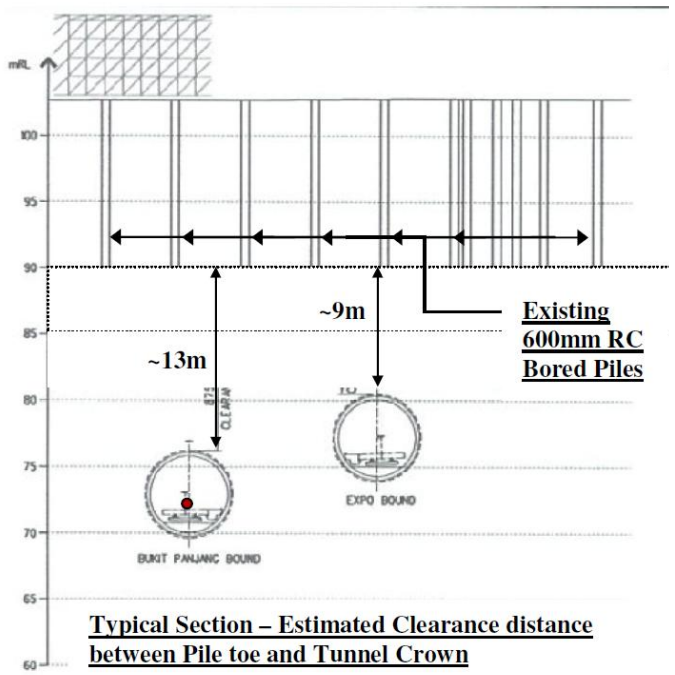
Challenge 2:

- Tunnelling under a cluster of 6 units of Shophouses



Typical Section – Estimated Clearance distance between Pile toe and Tunnel Crown

2

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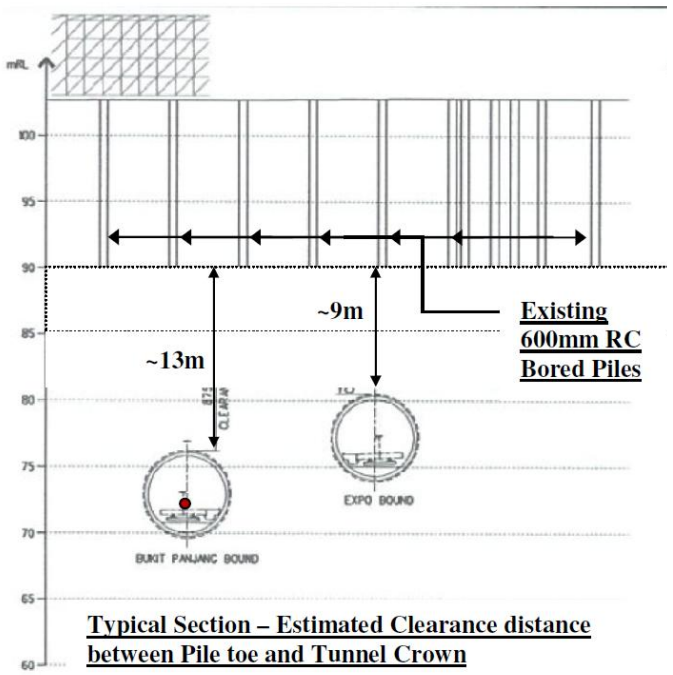
Challenge 2:

Case 1

- **Tunnelling under a cluster of 6 units of Shophouses which as-built pile depth information is <u>available</u>**



Typical Section – Estimated Clearance distance between Pile toe and Tunnel Crown

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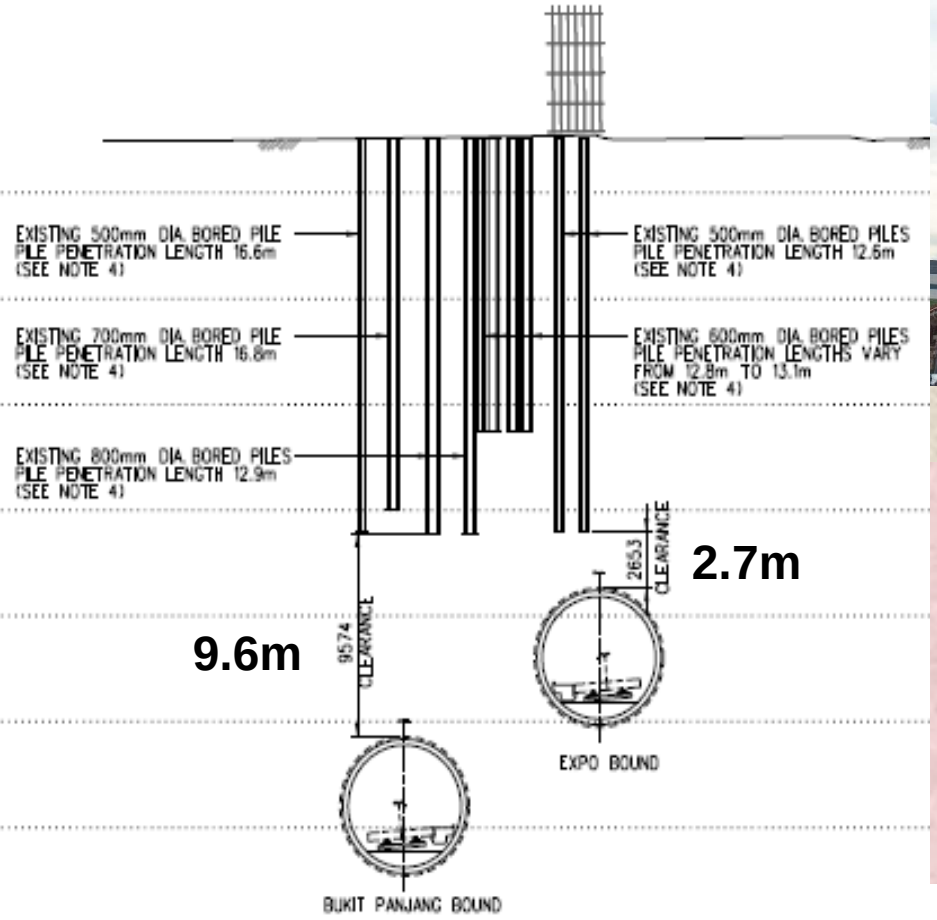
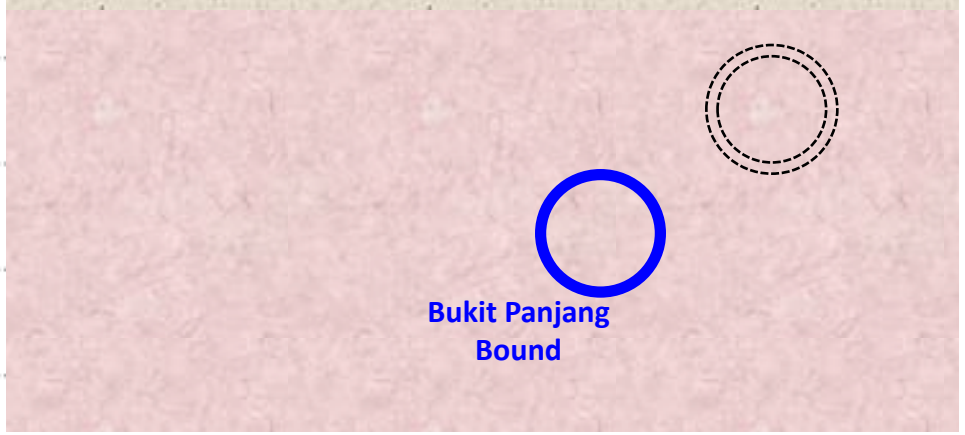
Hotel 81





View A

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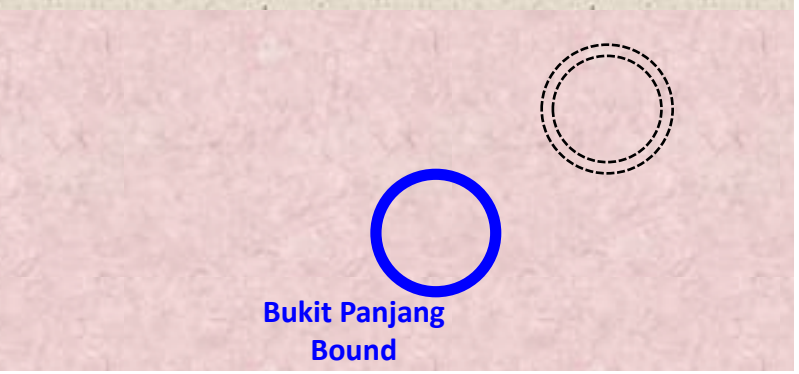
Tunnel-Pile Interaction (HOTEL 81)



Understanding of Soil Responses due to Tunnelling – 3D Numerical Analysis and Case Study of Bendemeer Station (DTL-3), Singapore

Ong, C. W.
Managing Director, ONE SMART Engineering Pte Ltd, Singapore & Malaysia
Thiri Su
PhD Student, National University of Singapore, Singapore
Yong, K. Y.
Professor, National University of Singapore, Singapore
Kulaindran Ariaratnam
Deputy Director, Land Transport Authority, Singapore

International Conference on Geotechnical Engineering
ISSMGE Technical Committee 207, St. Petersburg 2014

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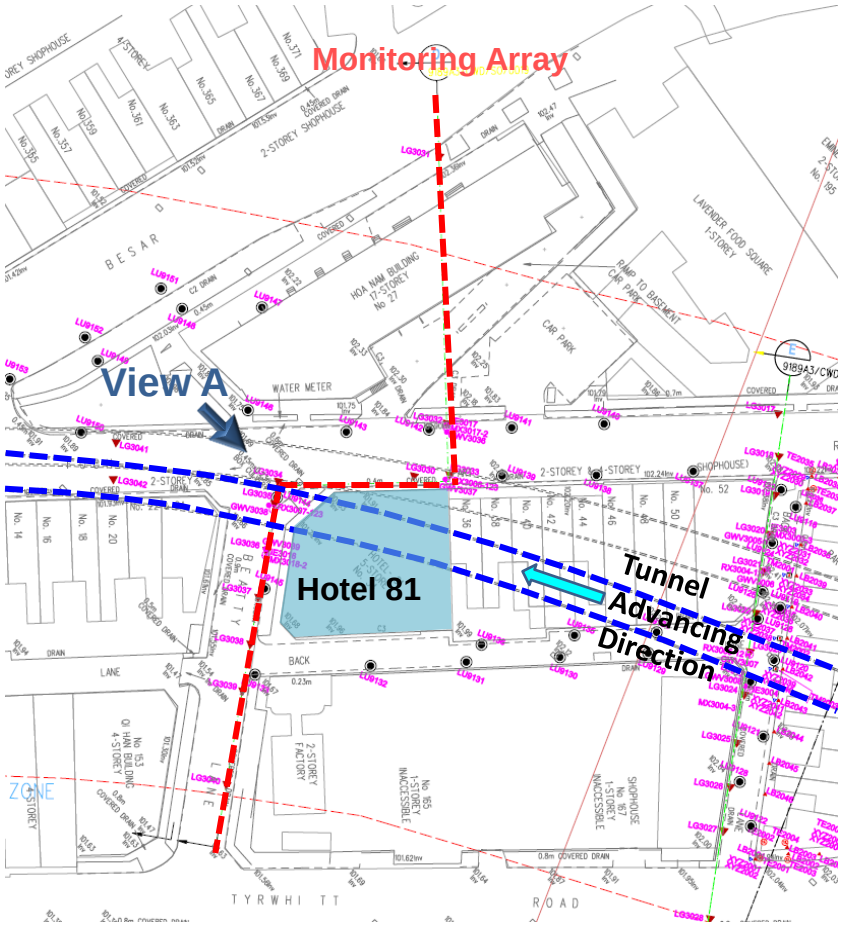
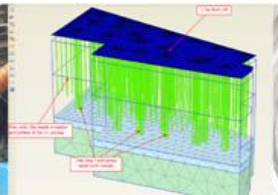
Ground Instrumentation Layout



Hotel 81

View A

Bukit Panjang Bound



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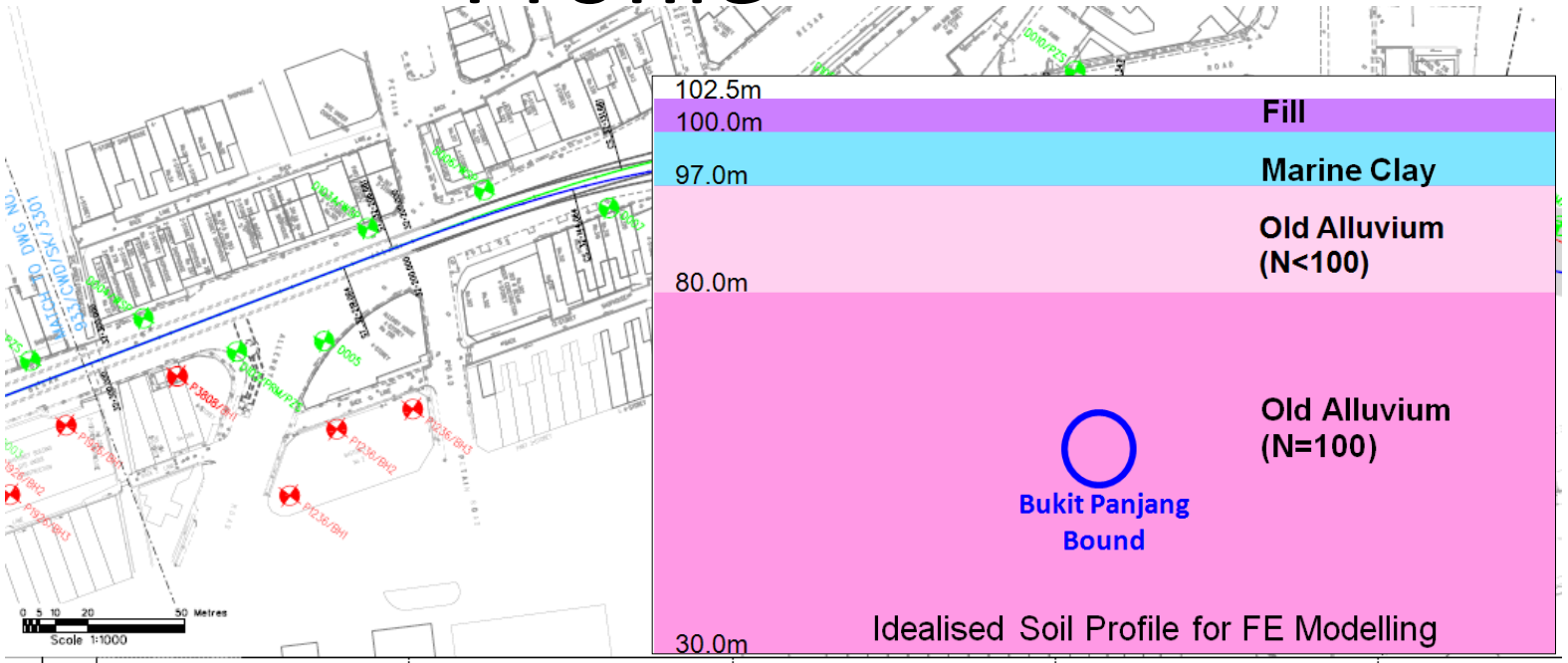
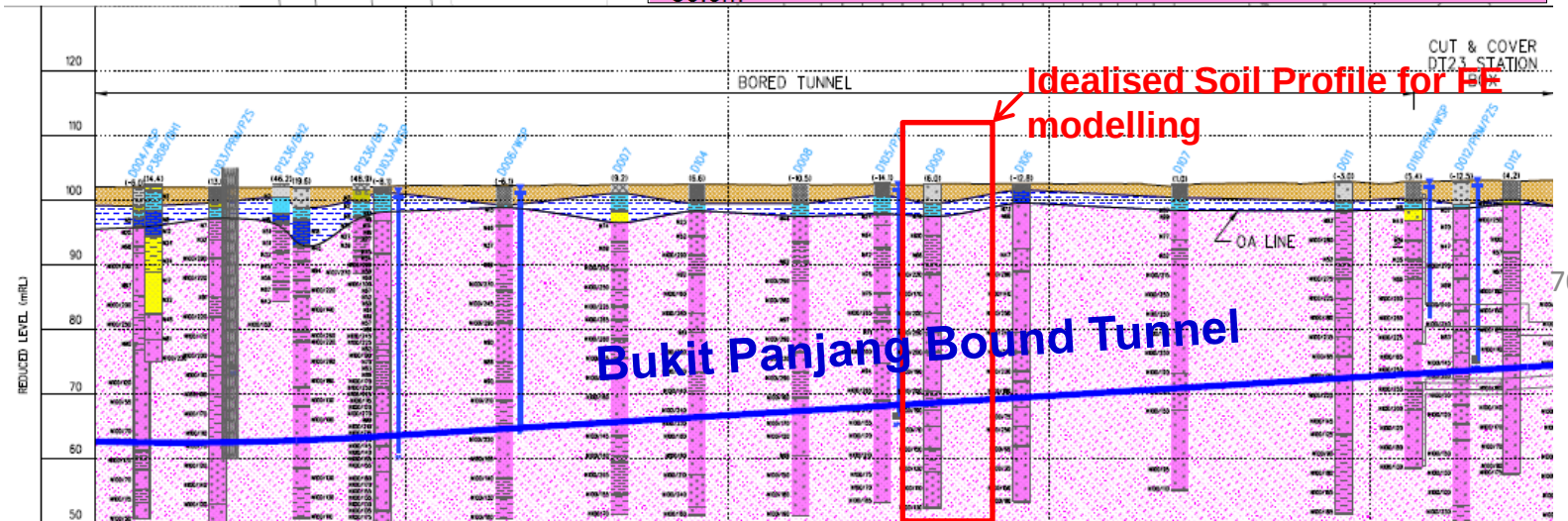
Borehole Layout Plan & Soil Profile





Instrumentation and Monitoring

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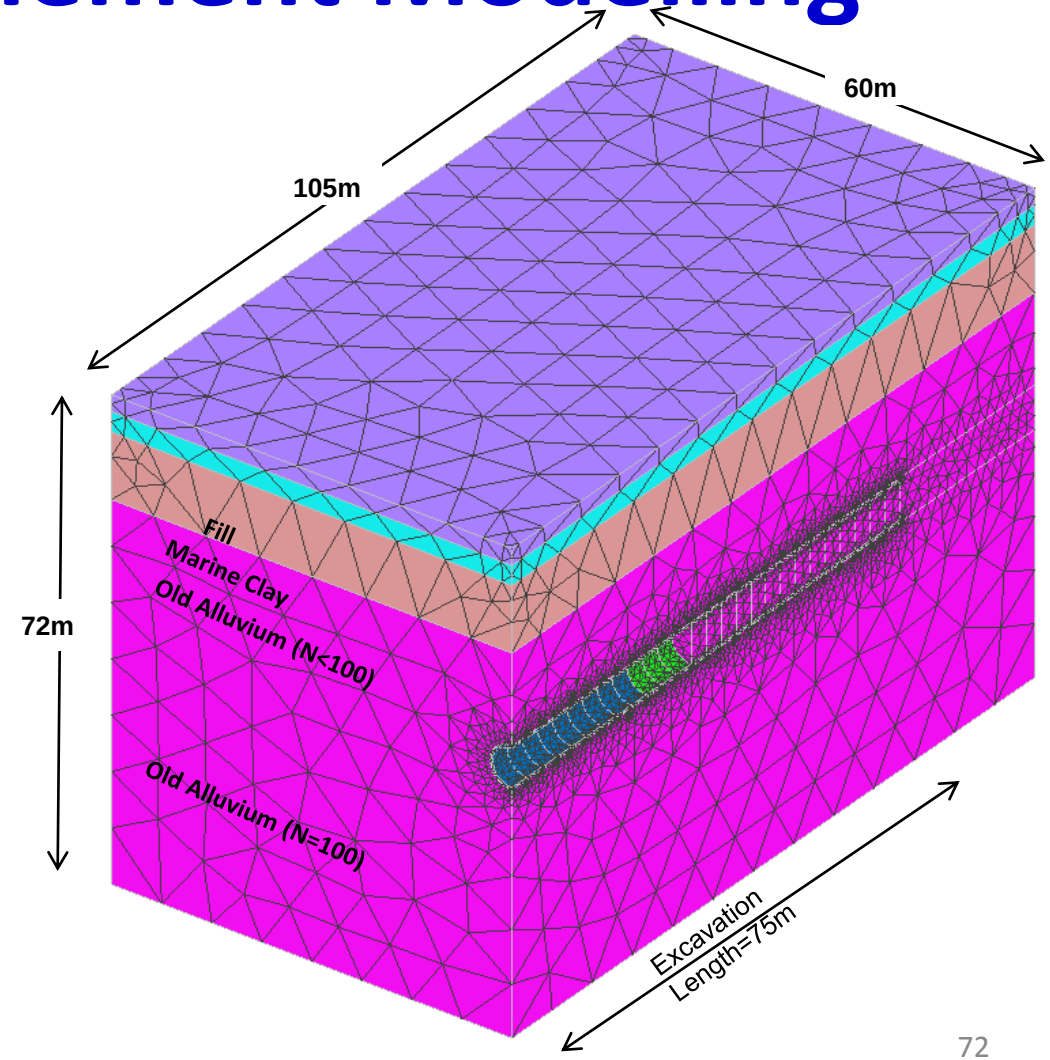
3-D Finite Element Modelling

- Tunnel Geometries
  - 6.6m tunnel diameter
  - 32.5m tunnel depth
  - H/D=5
- Stage-by-stage tunnel advancement
- Mohr-Coulomb soil model
- Coupled Consolidation Analysis



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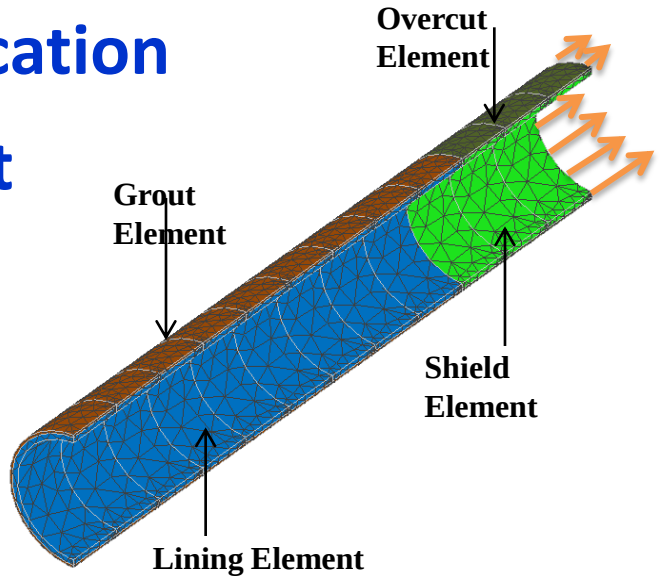
Analysis Assumptions and Simulations

- **3-D FE analysis using GeoFEA software**
- **Full tunnel construction process are considered as follow;**
  - **Face Pressure Application**
  - **Shield Advancement**
  - **Overcutting**
  - **Tail Void Closure**
  - **Lining Installation**



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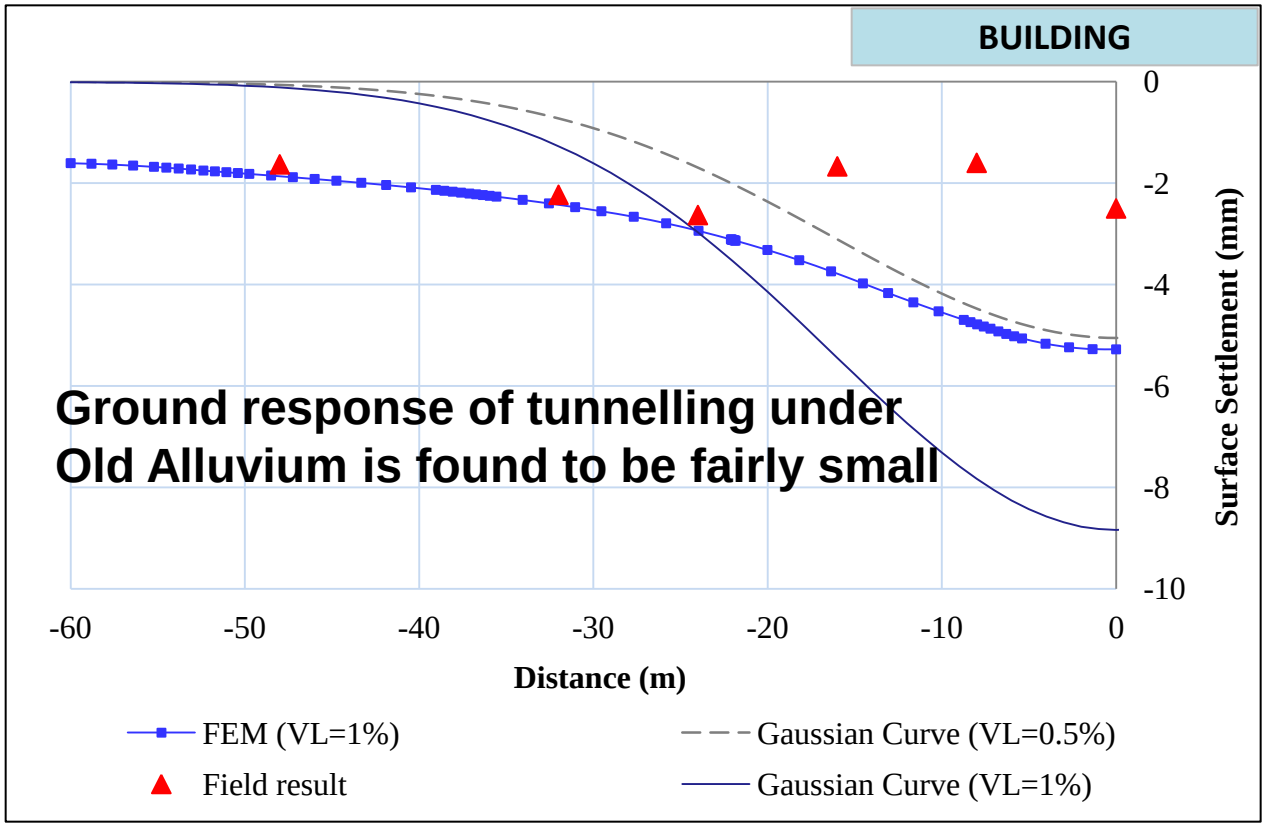
Results and Discussion

- Surface Settlement (Transverse)



- Final settlement trough no longer follows Gaussian curve
- Possible Factors
  - Stiffening effect of the presence of existing building (Hotel 81)
  - Settlement markers installed on road pavement

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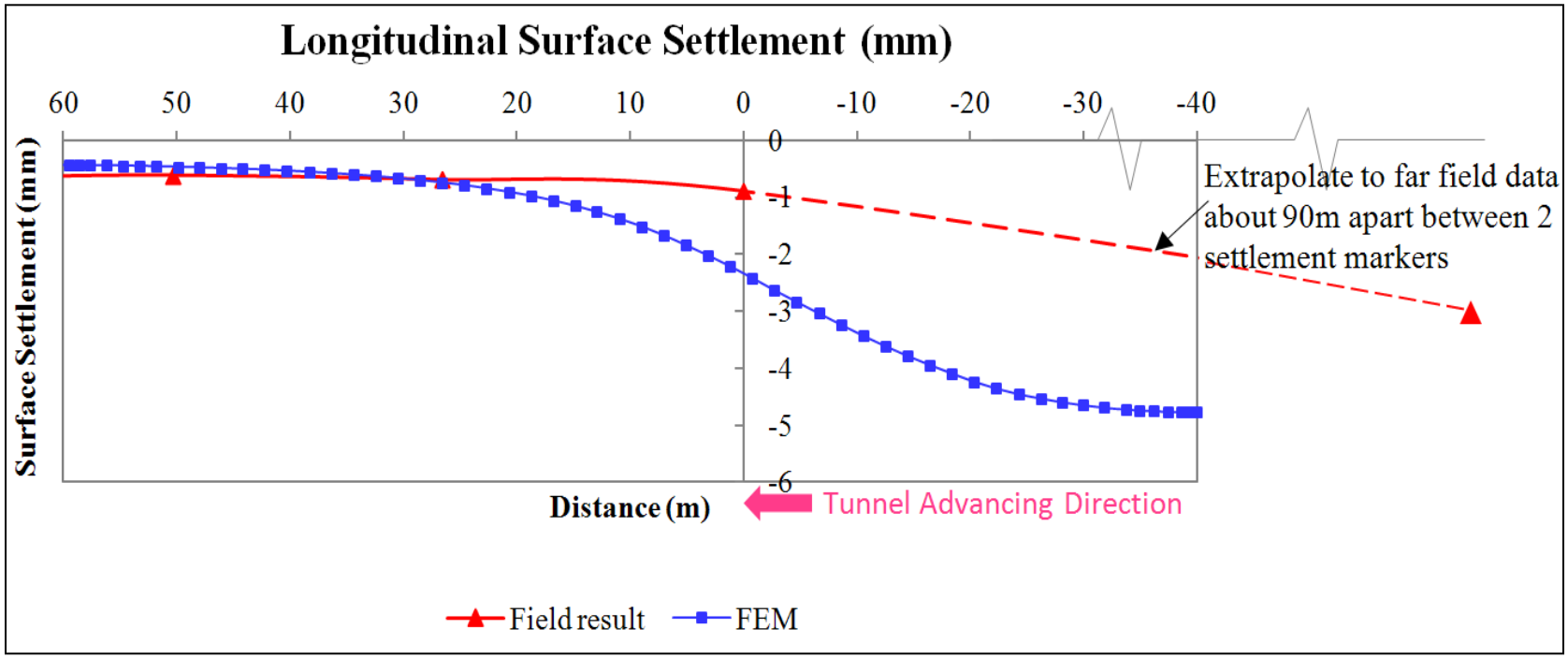
Results and Discussion

- Surface Settlement (Longitudinal)



- Both field and FE results show similar trend
- Maximum transverse settlement (at 5D) = 2 x longitudinal settlement at tunnel face
- Cumulative probability curve [New and O'Reilly (1991)]

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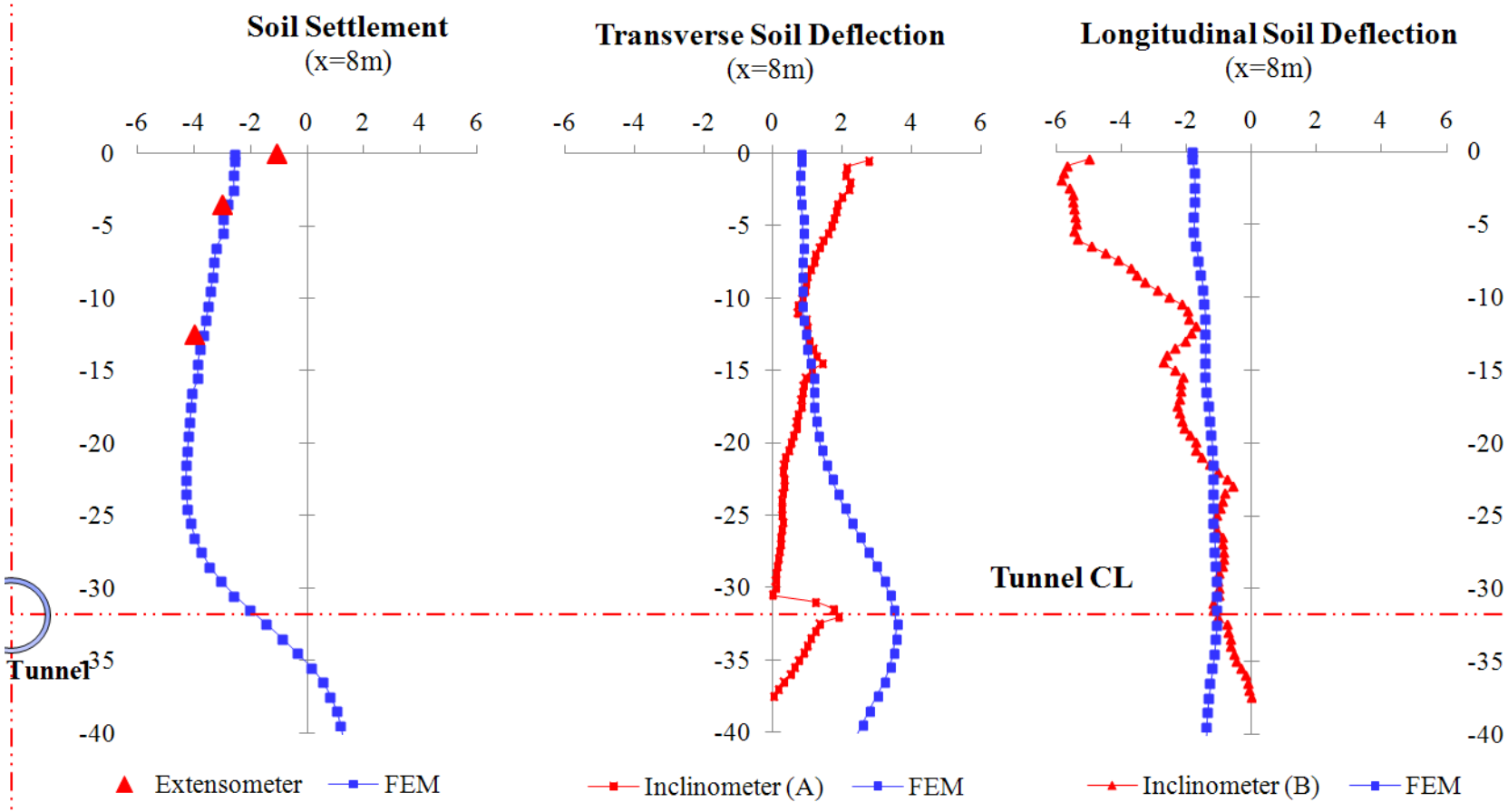
❑ Soil Displacement versus Depth



- ❑ FEM predictions are comparable with the actual field data
- ❑ Longitudinal deflection cannot capture the correct behaviour up to 10m depth.

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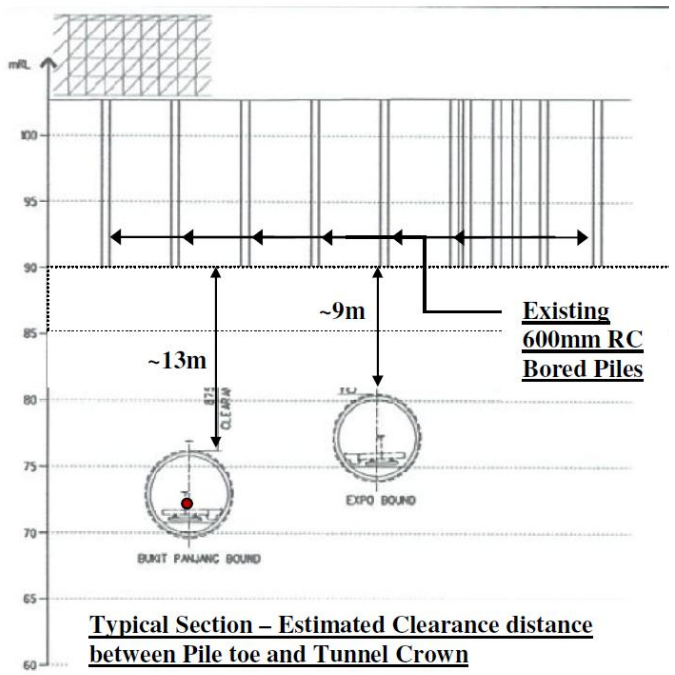
Challenge 2:

Case 2

2

- **Tunnelling under a cluster of 6 units of Shophouses which as-built pile depth information is <u>unavailable</u>**



Typical Section – Estimated Clearance distance between Pile toe and Tunnel Crown

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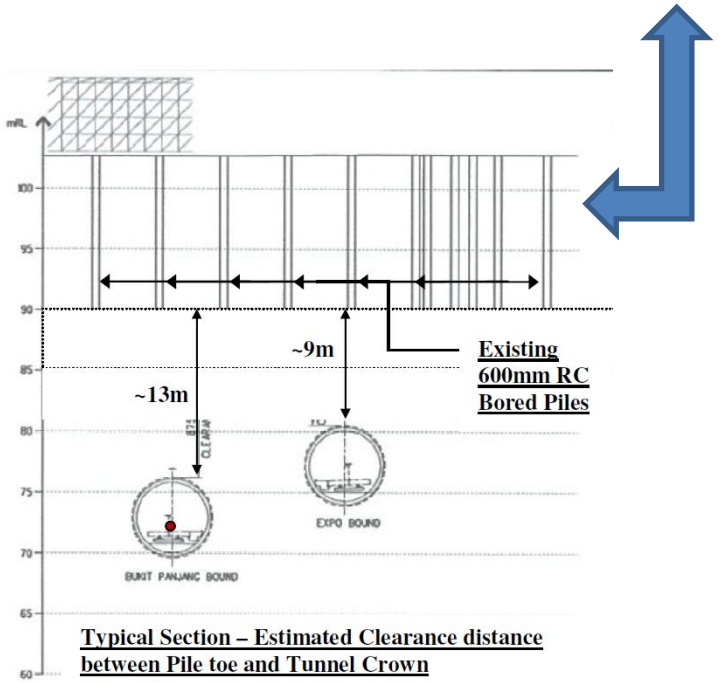
As-built pile depth information is <u>unavailable</u>



Typical Section – Estimated Clearance distance between Pile toe and Tunnel Crown

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As-built pile depth information is <u>unavailable</u>

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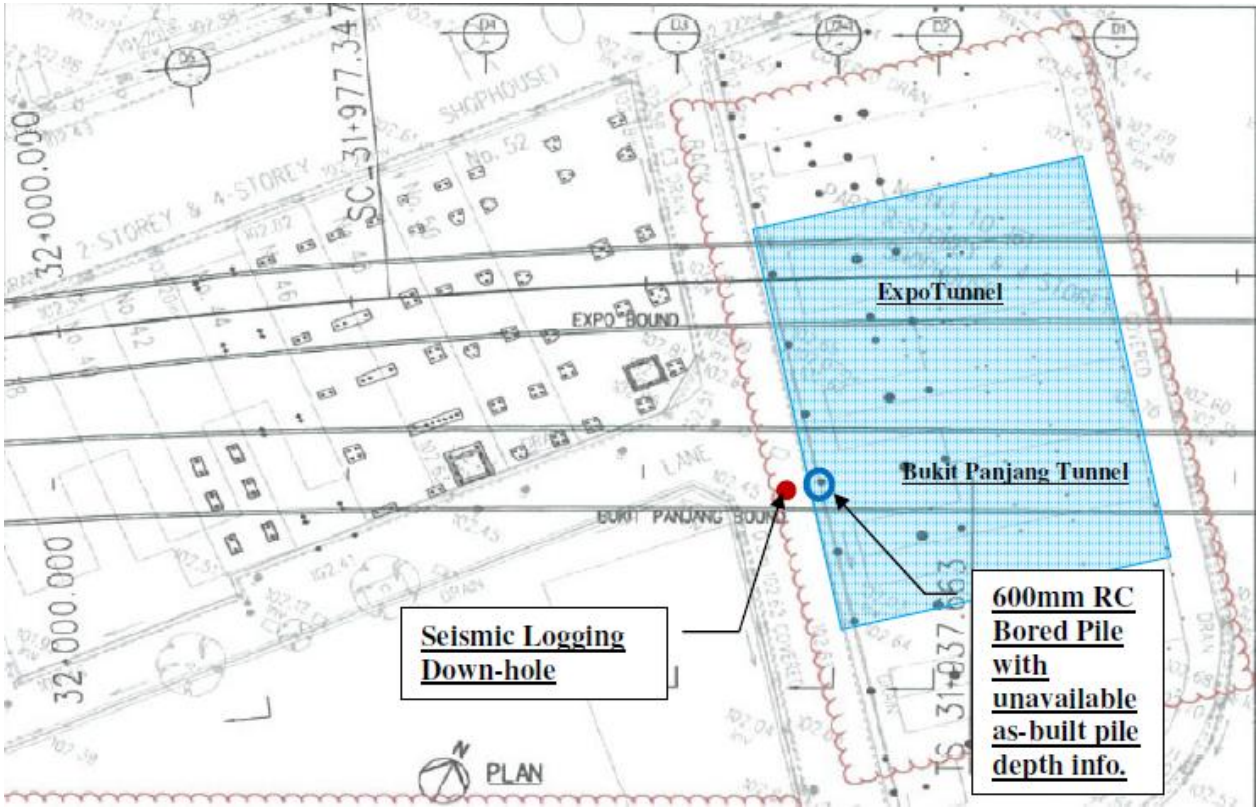
Advance detection of Potential Obstruction to Bored Tunnelling Works



1)To detect any potential obstruction to TBMs due to existing Bored Pile foundation with unavailable as-built pile depth information.

2)Seismic Logging was carried out to determine the length of the 600mm diameter Borepile and therefore the clearance from TBM crown to Bored pile toe

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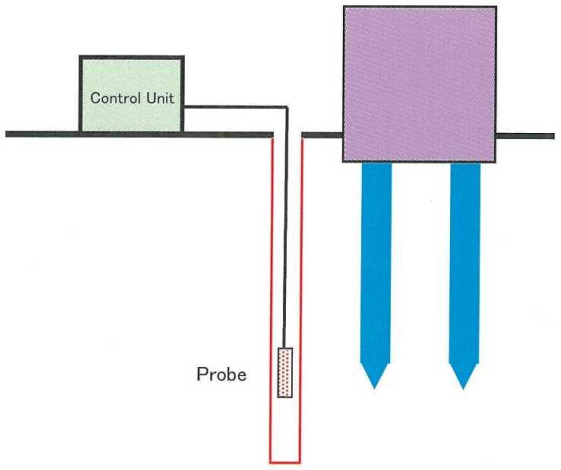
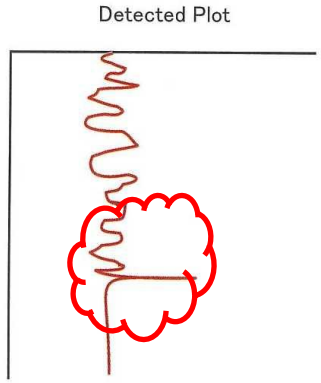
Pile Length Investigation : Magnetic Logging

The Magnetic Logging detect the metal nearby the probe. By detecting rebars used in the pile, the measurement of pile length is possible.



MEASUREMENT SET UP

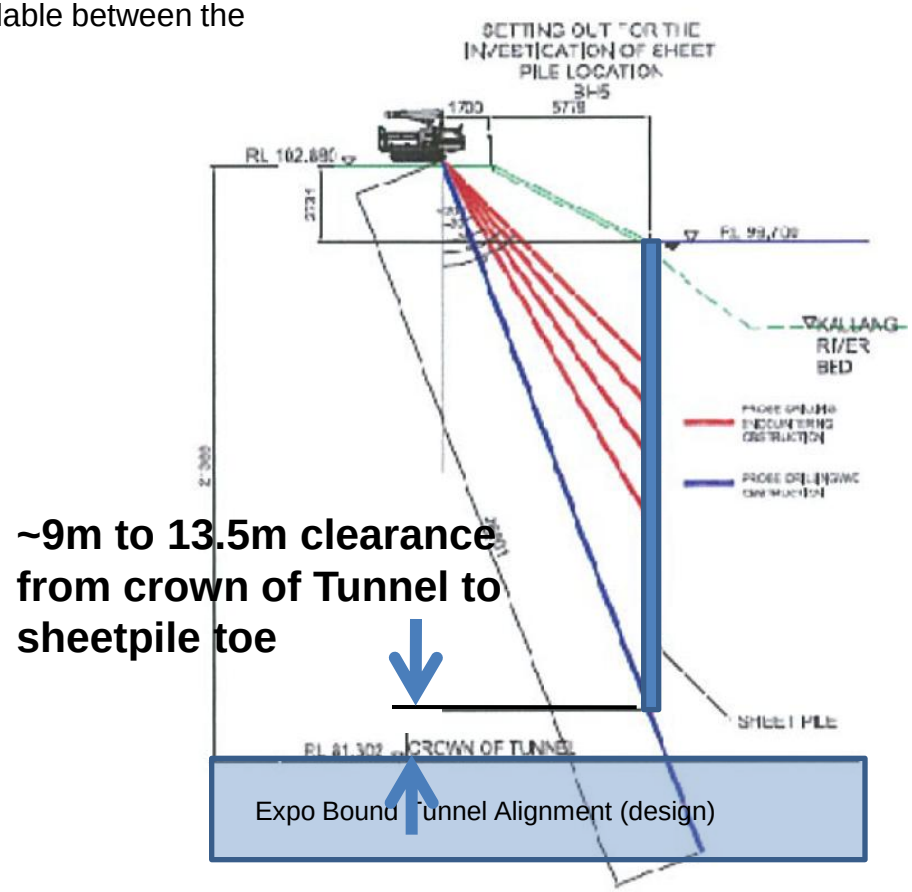


EXAMPLE DATA

Photos of Magnetic Logging Apparatus

Advance detection of Potential Obstruction to Bored Tunnelling Works

Physical Probing results shows that 9 to 13.5m clearance distance is available between the Tunnel to the pile toe.



~9m to 13.5m clearance from crown of Tunnel to sheetpile toe

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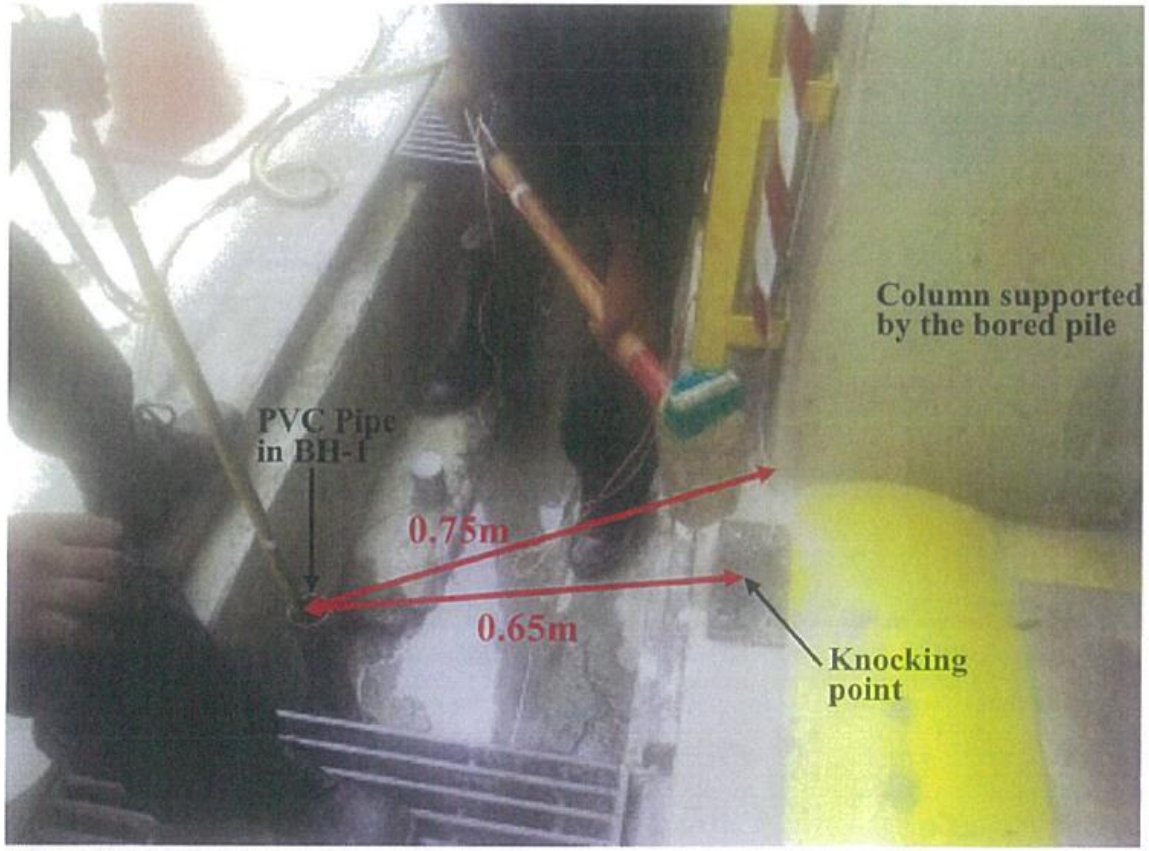
Advance detection of Potential Obstruction to Bored Tunnelling Works



Seismic Logging conducted to estimate length of Boreplies

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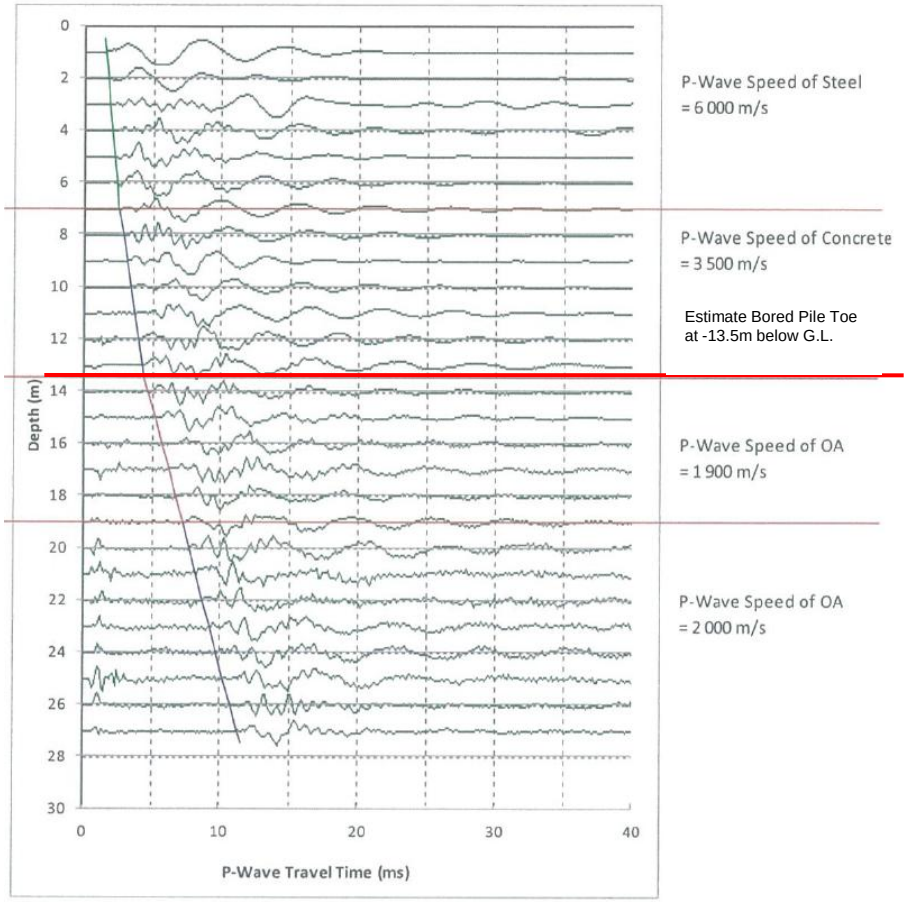
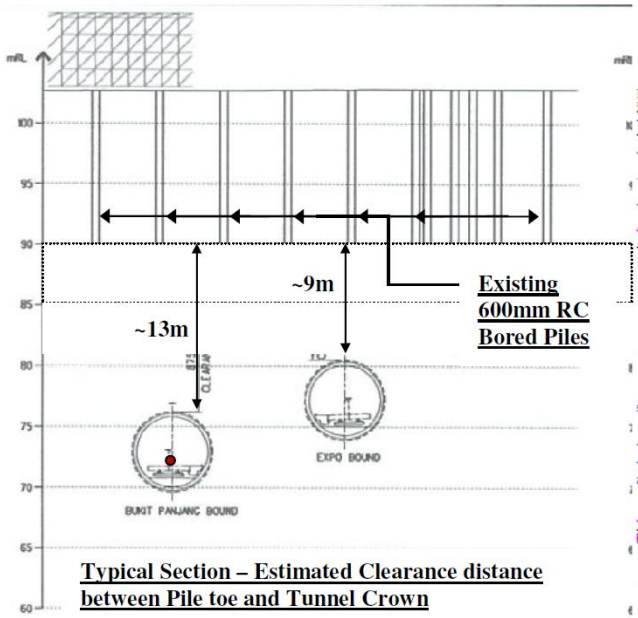
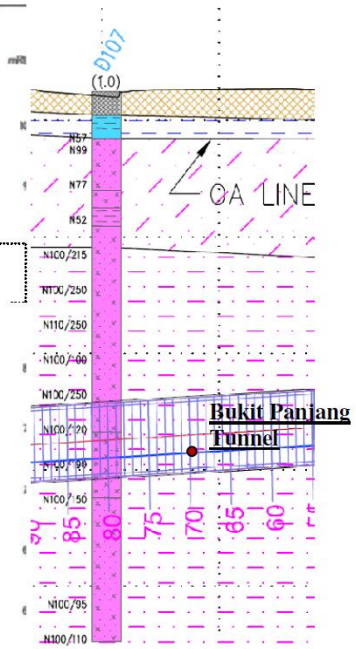
Advance detection of Potential Obstruction to Bored Tunnelling Works







Seismic Logging conducted to estimate length of Boreplies

Seismic Logging results shows that the Toe of Bore Pile is approx. 13.5m b.g.l and therefore a ~9 m and 13m clearance distance is available between the Pile Toe and Expo Bound Tunnel and Bukit Panjang Bound Tunnel respectively

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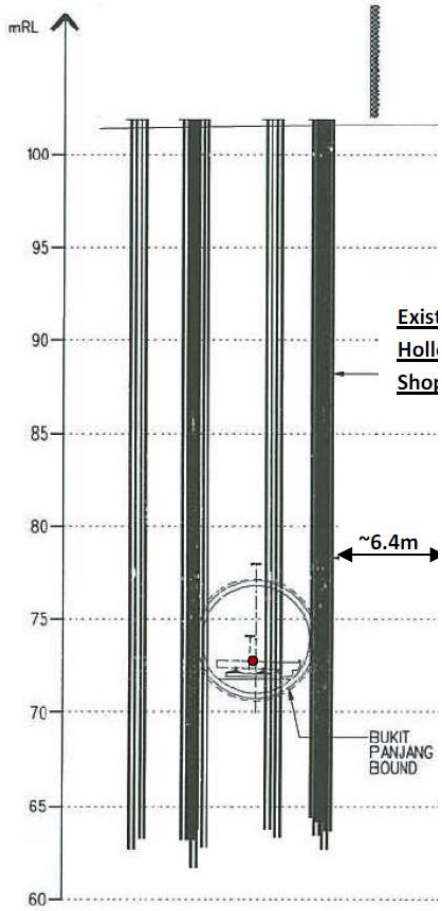
Challenge 3:

- **Overcoming of existing pile obstructions at demolished Shophouse**



3

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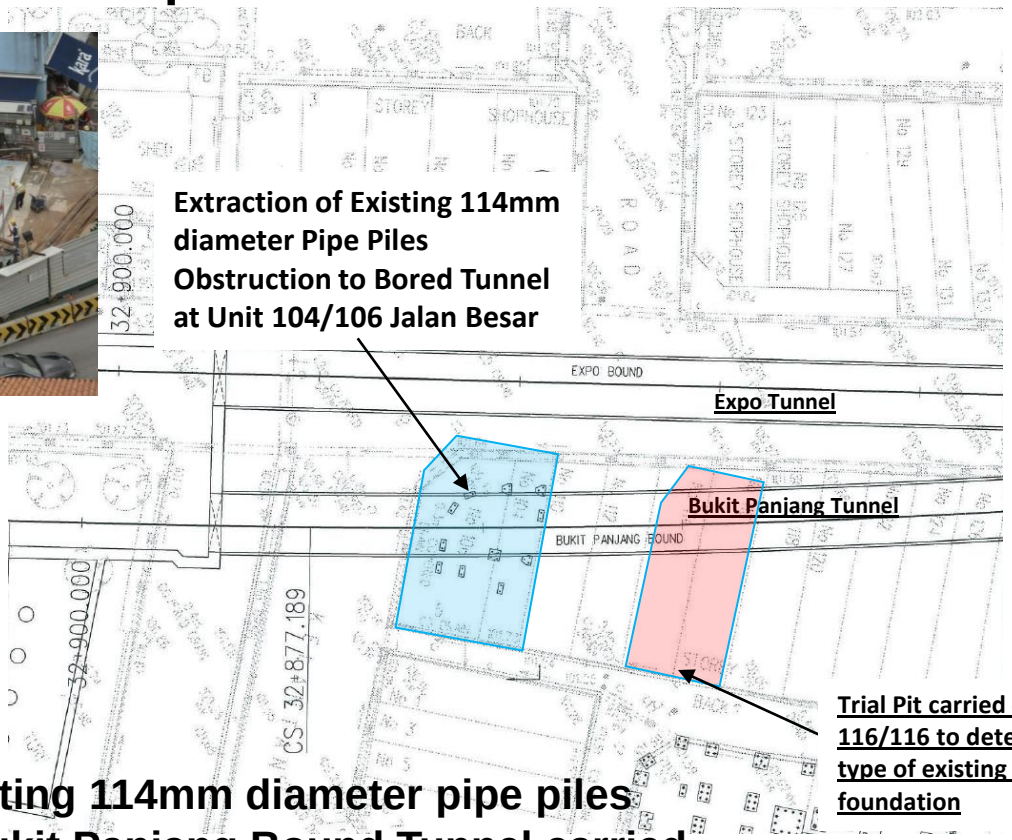
Advance verification of existing building foundation and removal of Pipe Piles obstruction to TBM



1) Extraction of existing 114mm diameter pipe piles obstruction to Bukit Panjang Bound Tunnel carried out at Unit 104/106 Jalan Besar
2) Trial Pit carried out at Unit 116/116 to determine type of existing building foundation

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Advance verification of existing building foundation and removal of Pipe Piles obstruction to TBM

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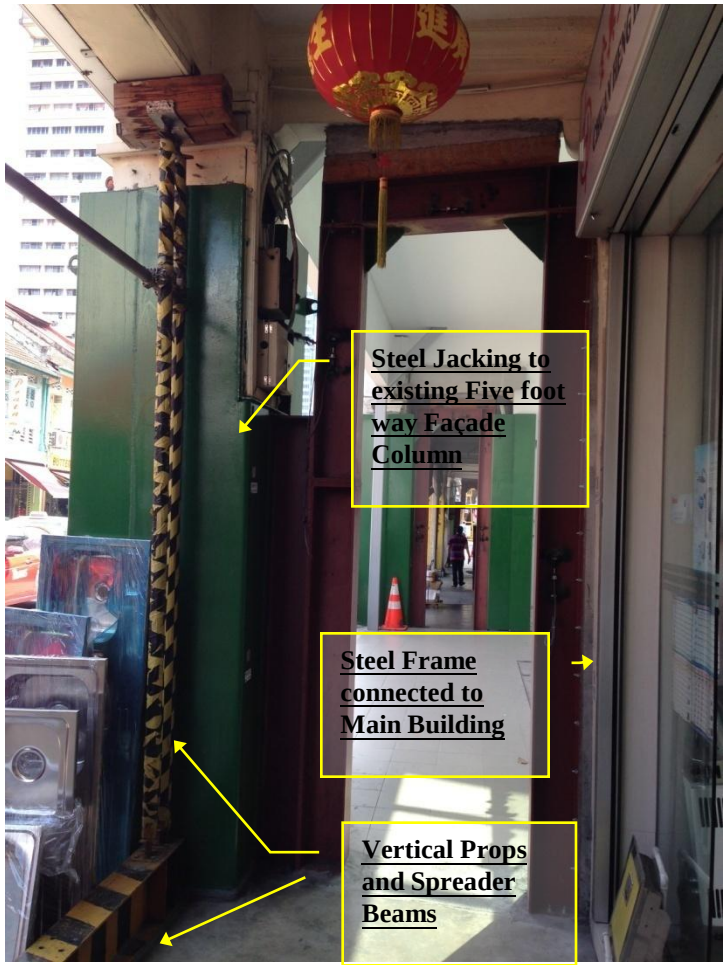
Building Protection Measures



Steel Jacking and Steel Frame to connect existing Five-footway Column to the Main Building where the TBM undercrossed

Building settlement registered a range of 11mm to 24mm

Vertical Prop installed along the 5-footway façade of Shophouses

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Building Protection Measures

ONE SMART

Extraction of Existing Steel Pipe Pile

ONE SMART

Extracted Steel Pipe Piles

ONE SMART

Advance verification of existing building foundation and removal of Pipe Piles obstruction to TBM

Existing Pile extraction using temporary external steel casting and wash boring at Unit 104/106 Jalan Besar

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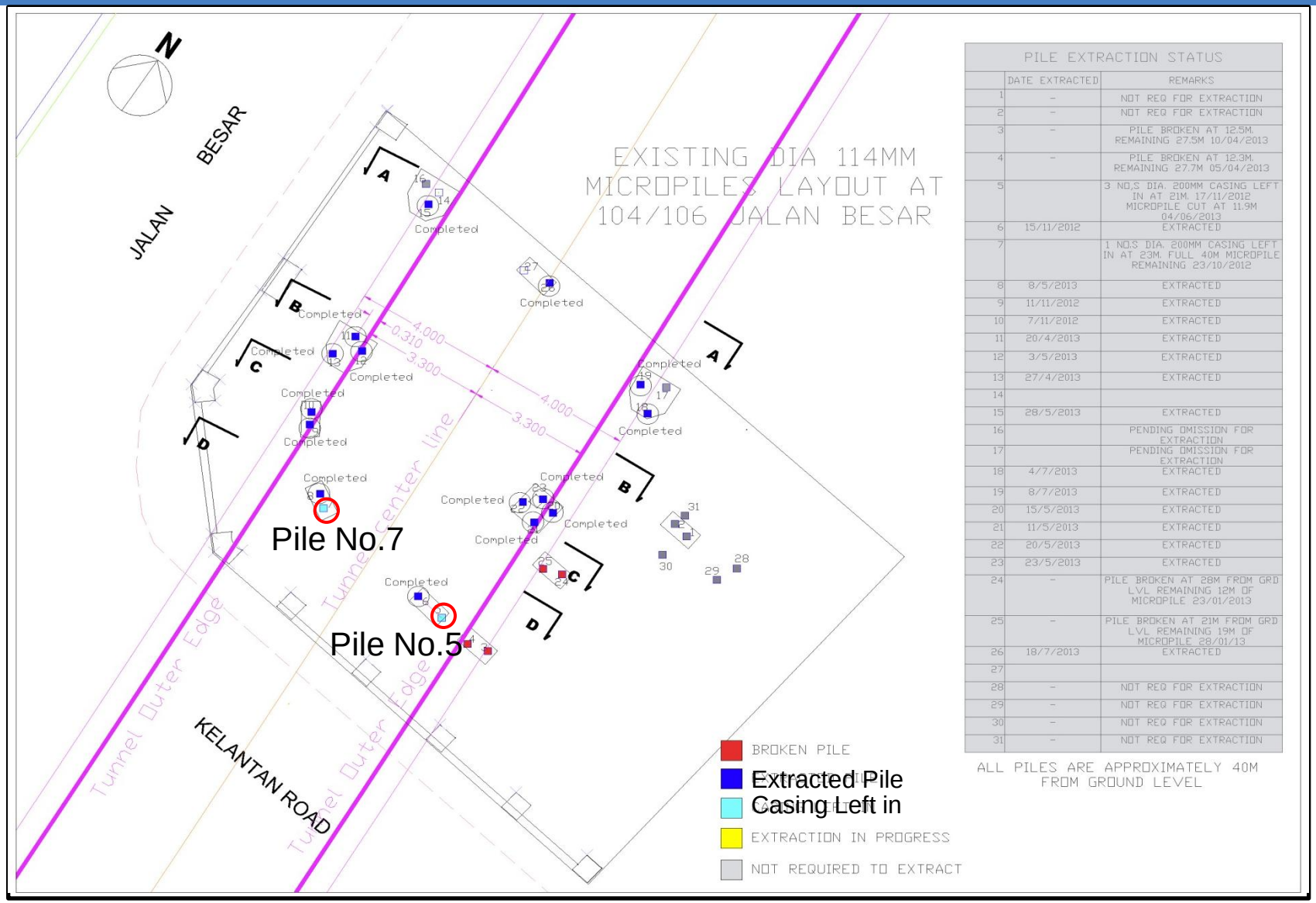
Unit 104 / 106 Jalan Besar – Layout Plan and Status of Pile Extraction

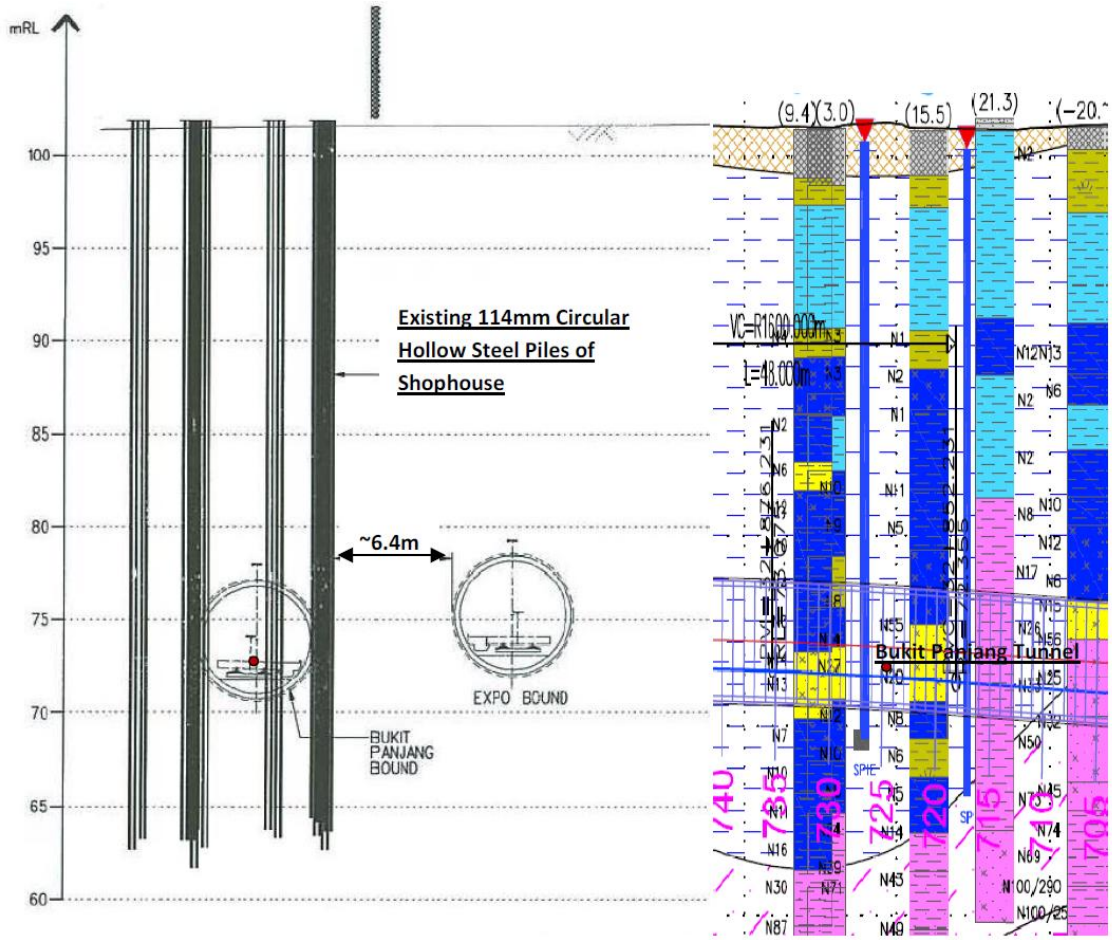


PILE EXTRACTION STATUS

	DATE EXTRACTED	REMARKS
1	-	NOT REQ FOR EXTRACTION
2	-	NOT REQ FOR EXTRACTION
3	-	PILE BROKEN AT 12.5M. REMAINING 27.5M 10/04/2013
4	-	PILE BROKEN AT 12.3M. REMAINING 27.7M 05/04/2013
5		3 NO.S DIA. 200MM CASING LEFT IN AT 21M. 17/11/2012 MICROPILE CUT AT 11.9M 04/06/2013
6	15/11/2012	EXTRACTED
7		1 NO.S DIA. 200MM CASING LEFT IN AT 23M. FULL 40M MICROPILE REMAINING 23/10/2012
8	8/5/2013	EXTRACTED
9	11/11/2012	EXTRACTED
10	7/11/2012	EXTRACTED
11	20/4/2013	EXTRACTED
12	3/5/2013	EXTRACTED
13	27/4/2013	EXTRACTED
14		
15	28/5/2013	EXTRACTED
16		PENDING OMISSION FOR EXTRACTION
17		PENDING OMISSION FOR EXTRACTION
18	4/7/2013	EXTRACTED
19	8/7/2013	EXTRACTED
20	15/5/2013	EXTRACTED
21	11/5/2013	EXTRACTED
22	20/5/2013	EXTRACTED
23	23/5/2013	EXTRACTED
24	-	PILE BROKEN AT 28M FROM GRD LVL REMAINING 12M OF MICROPILE 23/01/2013
25	-	PILE BROKEN AT 21M FROM GRD LVL REMAINING 19M OF MICROPILE 28/01/13
26	18/7/2013	EXTRACTED
27		
28	-	NOT REQ FOR EXTRACTION
29	-	NOT REQ FOR EXTRACTION
30	-	NOT REQ FOR EXTRACTION
31	-	NOT REQ FOR EXTRACTION

ALL PILES ARE APPROXIMATELY 40M FROM GROUND LEVEL

Typical Elevation view of existing Steel Pipe Piles, tunnel position and Soil Condition



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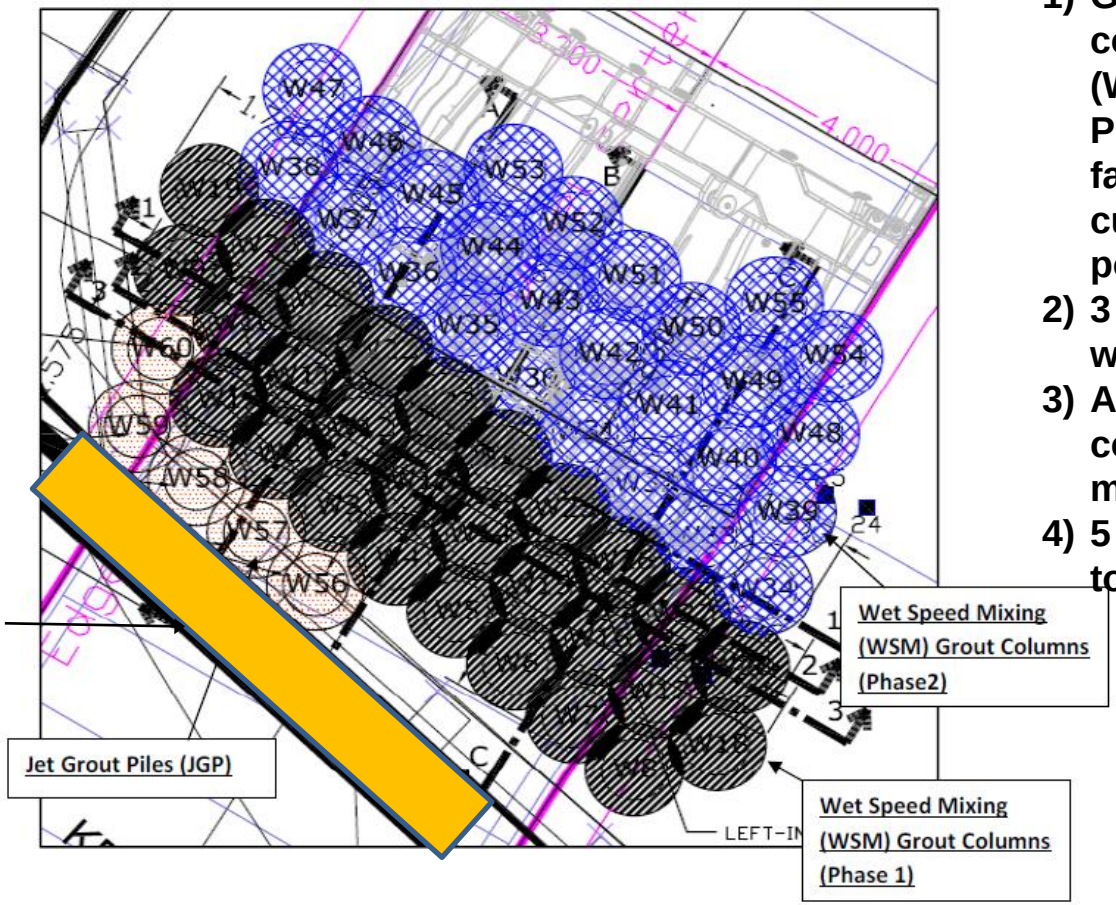
Ground Improvement block to facilitate CHI for Change of Cuttertools & removal of potential obstruction



1) Ground Improvement Block comprising of Wet Speed Mixing (WSM) Grout Pile and Jet Grout Pile (JGP) were installed to facilitate CHI for change of cuttertool & removal of potential obstruction
2) 3 rows of WSM Grout column was originally proposed
3) After review, the WSM Grout columns was extended to cover more of the TBM shield body
4) 5 nos of JGP were installed near to the existing Utilities corridor

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Installation of Wet Speed Mixing (WSM) Grout Columns in Progress

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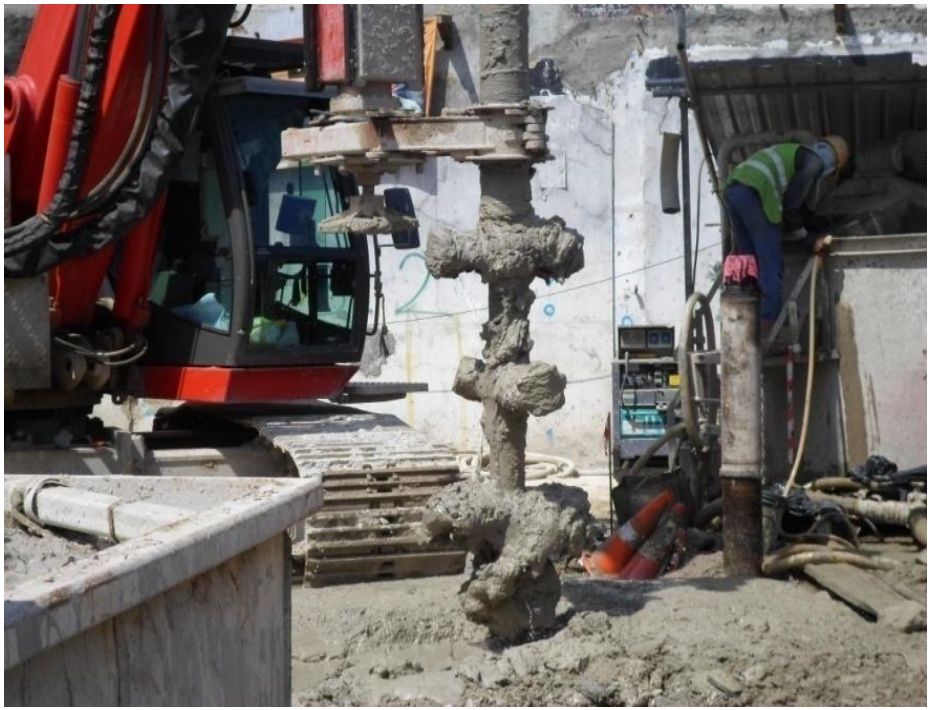
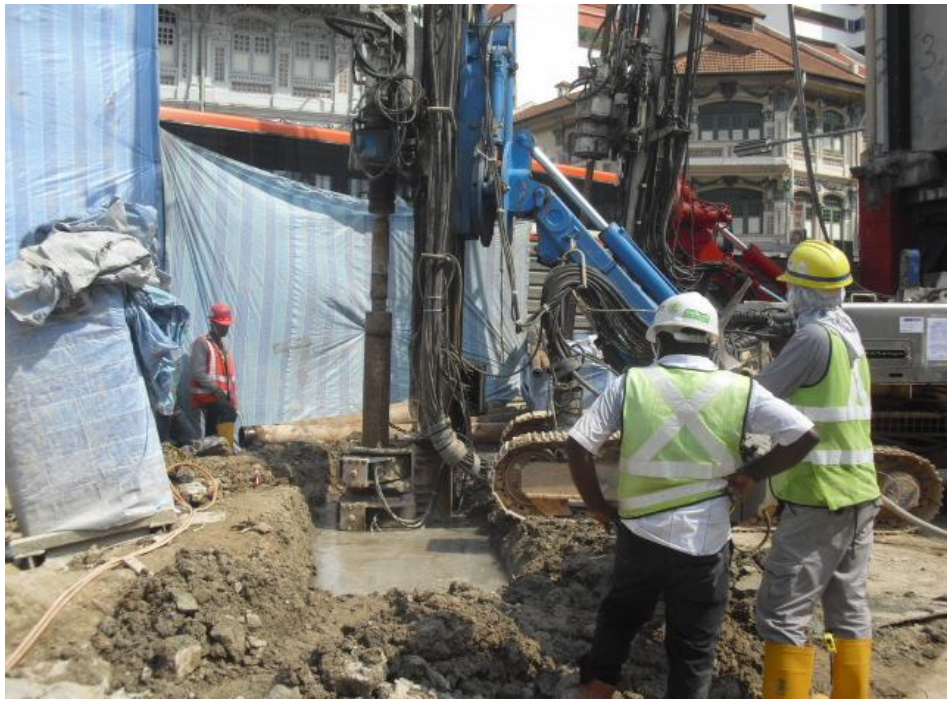
Ground Improvement block to facilitate CHI for cuttertool change & potential obstruction removal



Installation of WSM in progress



Installation of JGP in progress

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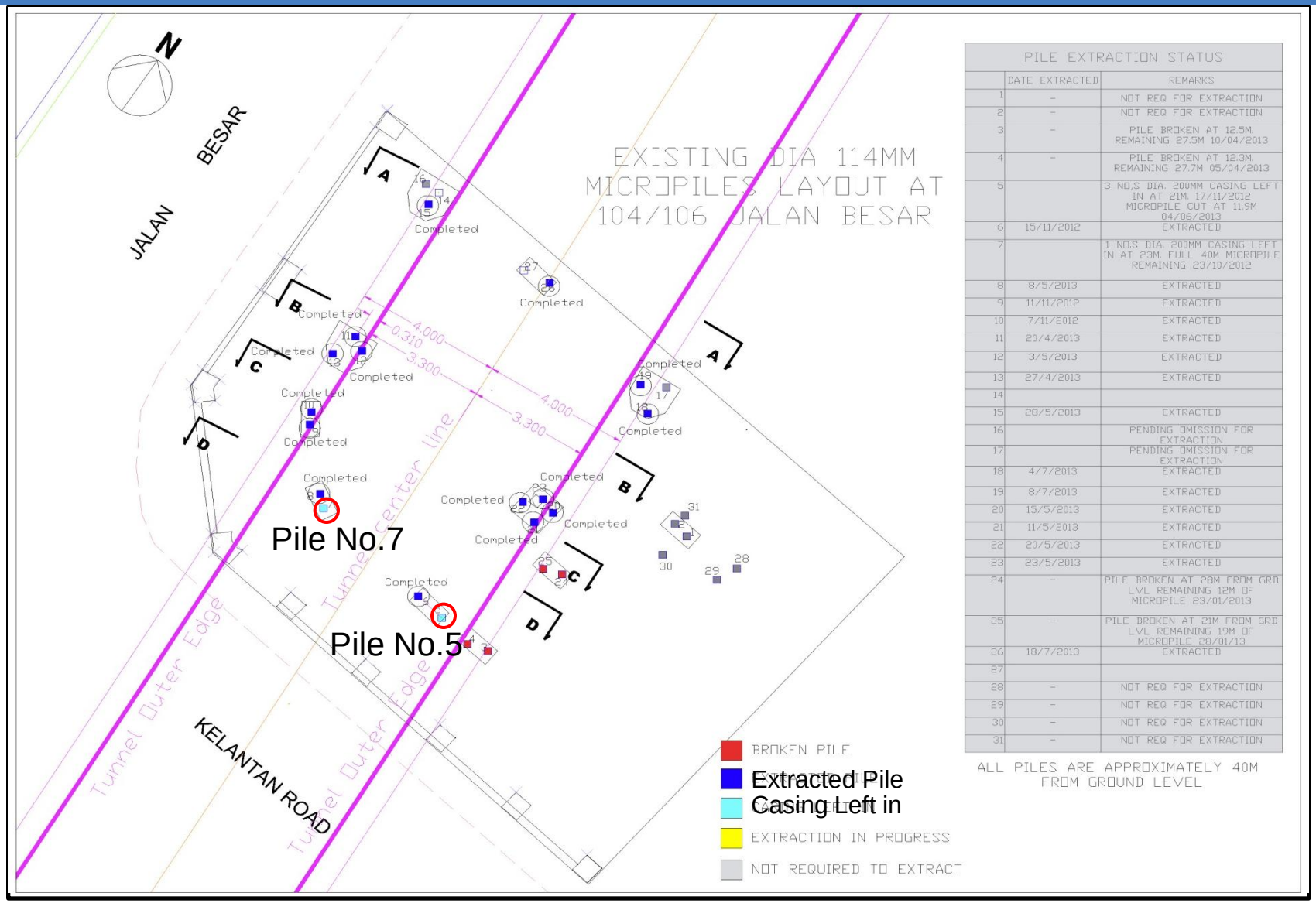
Unit 104 / 106 Jalan Besar – Layout Plan and Status of Pile Extraction

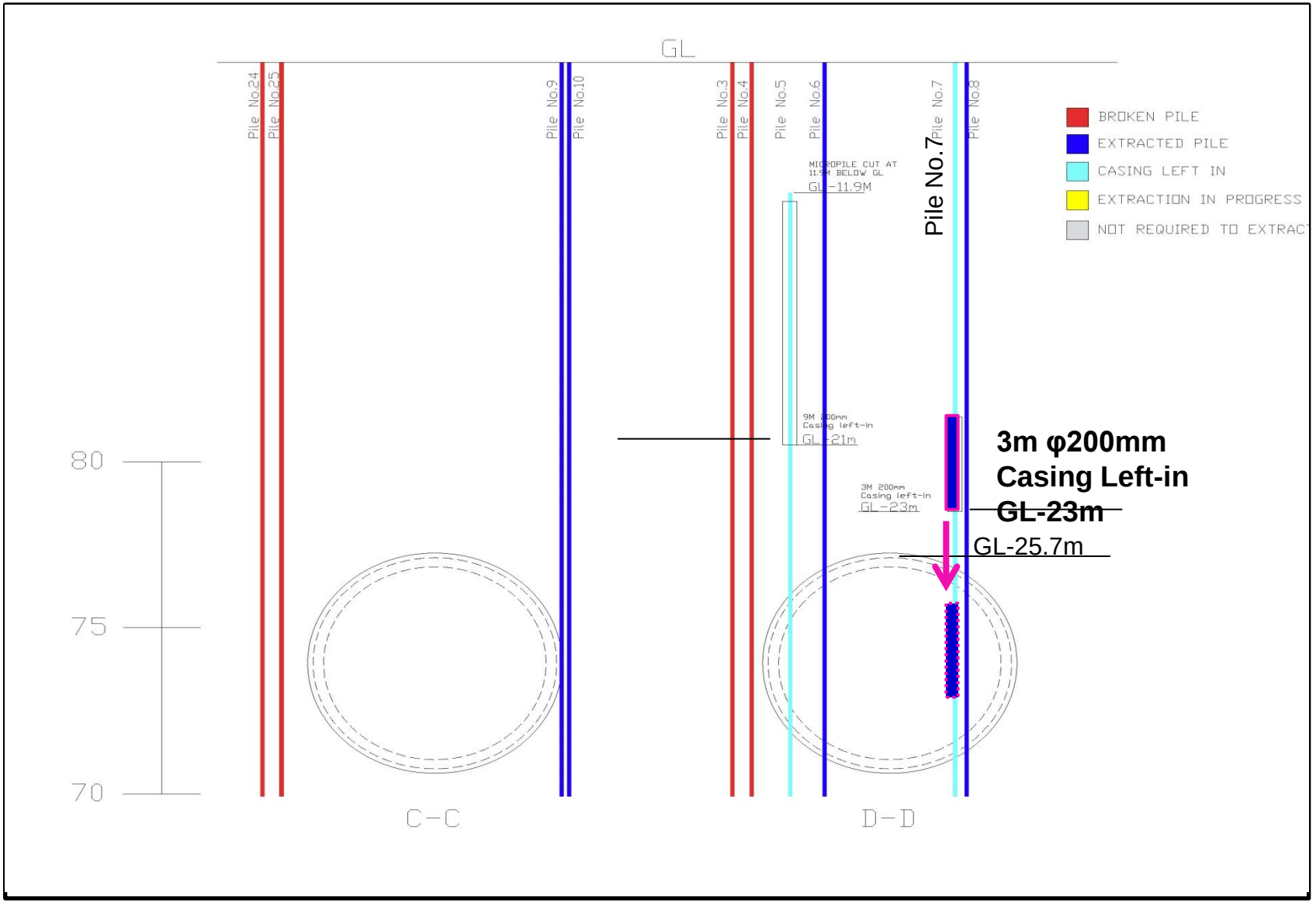


PILE EXTRACTION STATUS

	DATE EXTRACTED	REMARKS
1	-	NOT REQ FOR EXTRACTION
2	-	NOT REQ FOR EXTRACTION
3	-	PILE BROKEN AT 12.5M. REMAINING 27.5M 10/04/2013
4	-	PILE BROKEN AT 12.3M. REMAINING 27.7M 05/04/2013
5		3 NO.S DIA. 200MM CASING LEFT IN AT 21M. 17/11/2012 MICROPILE CUT AT 11.9M 04/06/2013
6	15/11/2012	EXTRACTED
7		1 NO.S DIA. 200MM CASING LEFT IN AT 23M. FULL 40M MICROPILE REMAINING 23/10/2012
8	8/5/2013	EXTRACTED
9	11/11/2012	EXTRACTED
10	7/11/2012	EXTRACTED
11	20/4/2013	EXTRACTED
12	3/5/2013	EXTRACTED
13	27/4/2013	EXTRACTED
14		
15	28/5/2013	EXTRACTED
16		PENDING OMISSION FOR EXTRACTION
17		PENDING OMISSION FOR EXTRACTION
18	4/7/2013	EXTRACTED
19	8/7/2013	EXTRACTED
20	15/5/2013	EXTRACTED
21	11/5/2013	EXTRACTED
22	20/5/2013	EXTRACTED
23	23/5/2013	EXTRACTED
24	-	PILE BROKEN AT 28M FROM GRD LVL REMAINING 12M OF MICROPILE 23/01/2013
25	-	PILE BROKEN AT 21M FROM GRD LVL REMAINING 19M OF MICROPILE 28/01/13
26	18/7/2013	EXTRACTED
27		
28	-	NOT REQ FOR EXTRACTION
29	-	NOT REQ FOR EXTRACTION
30	-	NOT REQ FOR EXTRACTION
31	-	NOT REQ FOR EXTRACTION

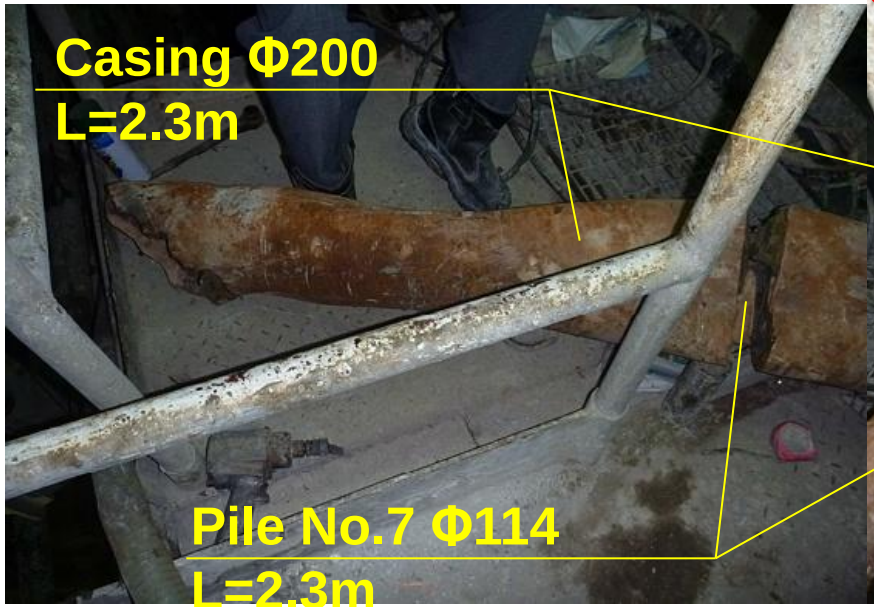
ALL PILES ARE APPROXIMATELY 40M FROM GROUND LEVEL

Unit 104 / 106 Jalan Besar – Section View for Status of Pile Extraction



Existing Pile No. 7 Detection

Removed from the front of cutter wheel



Existing Pile No. 7 Detection

Existing Pile No. 7 Detection

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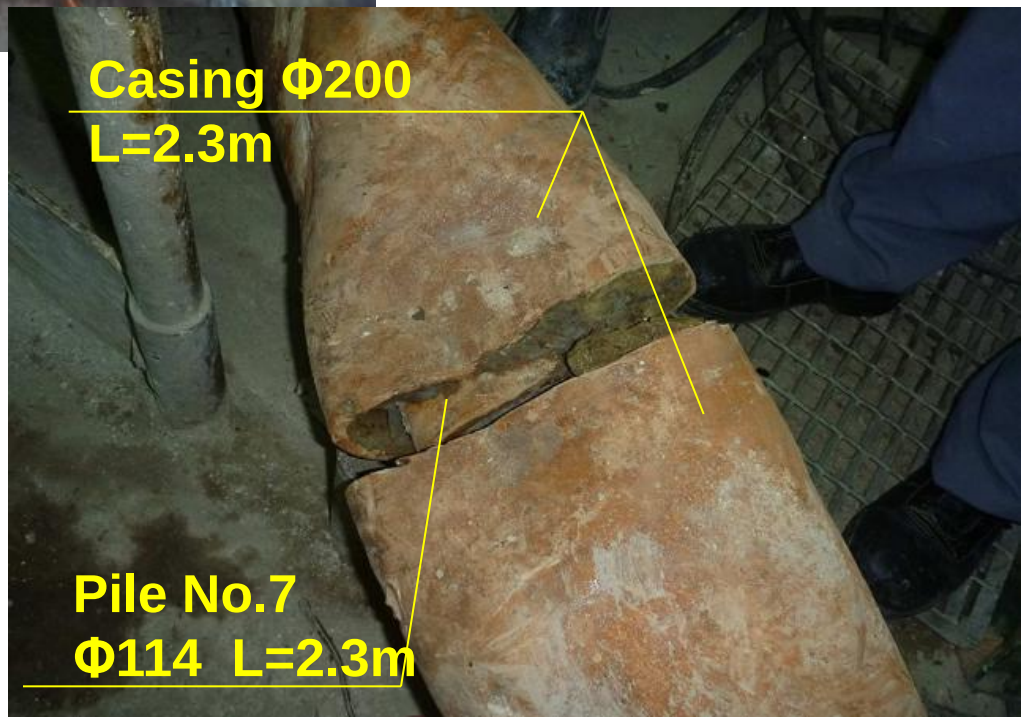
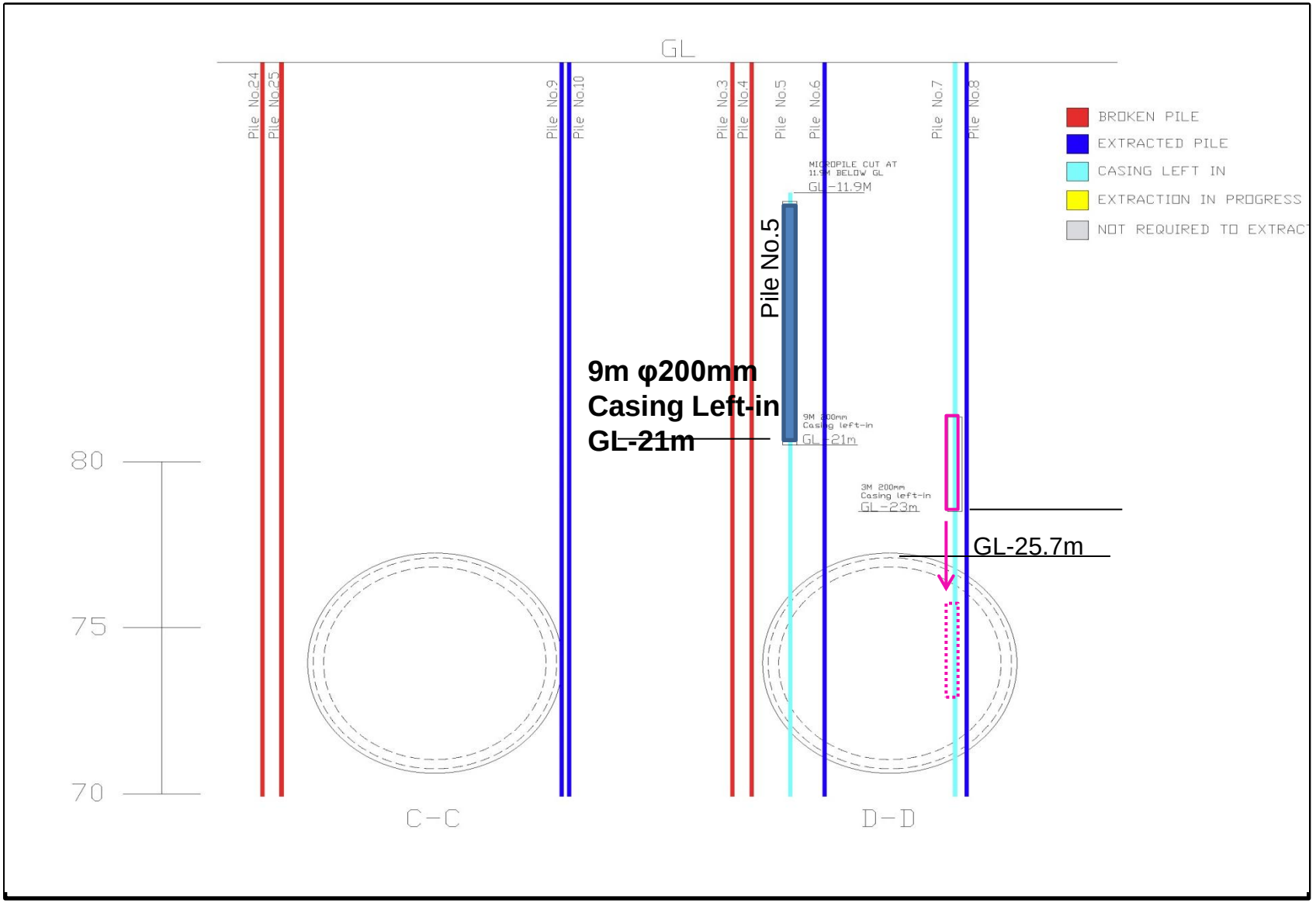
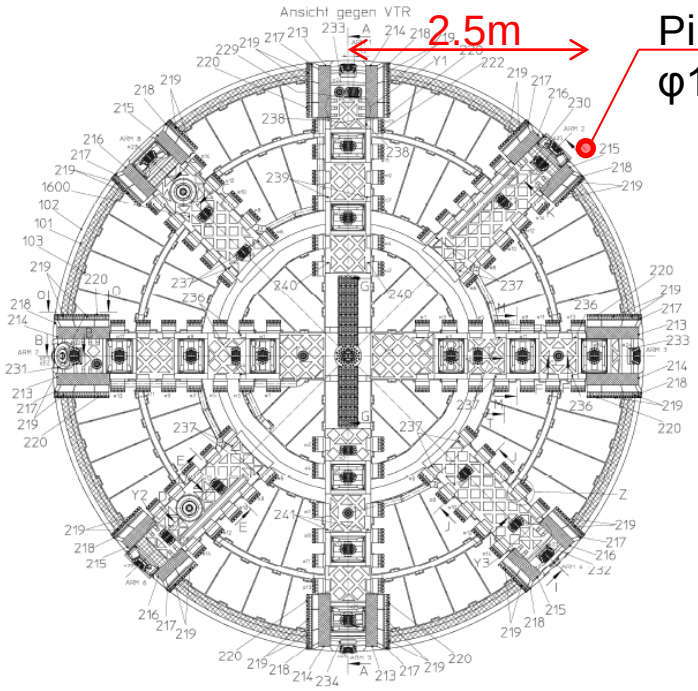
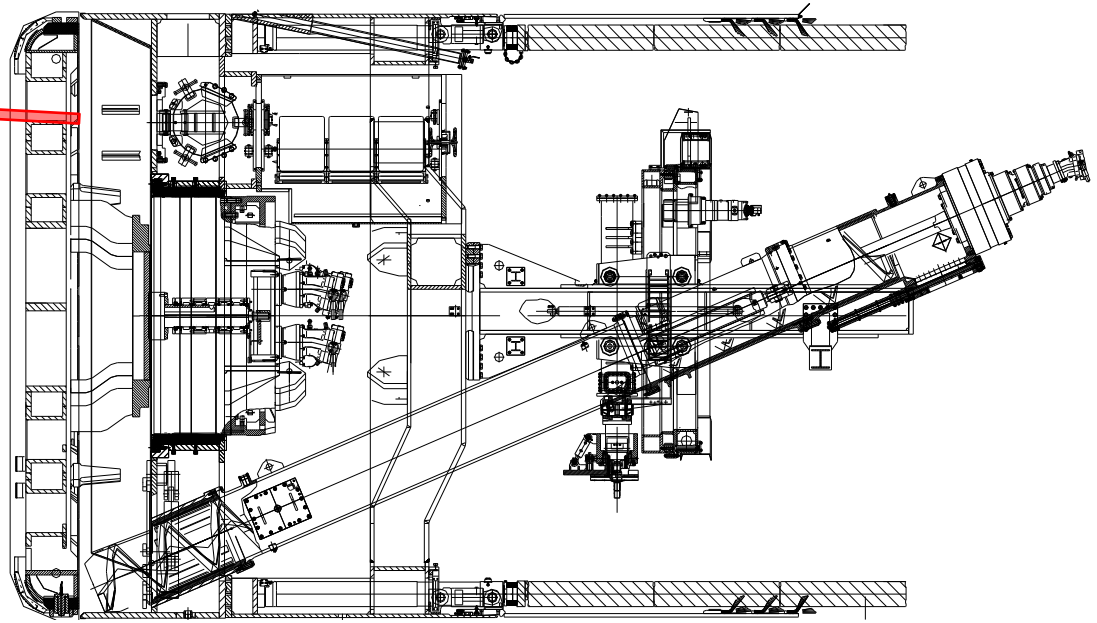


Unit 104 / 106 Jalan Besar – Section View for Status of Pile Extraction



Existing Pile No. 5 Detection





Existing Pile No. 5 Detection

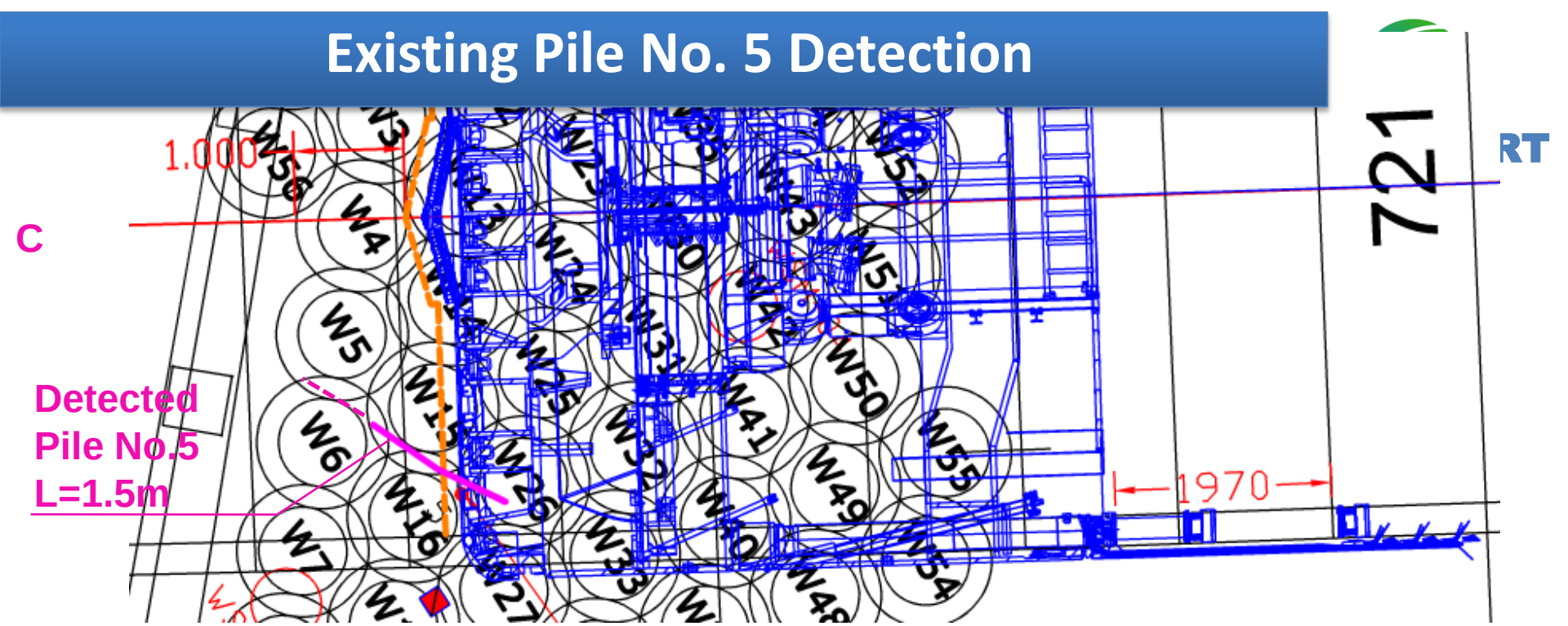
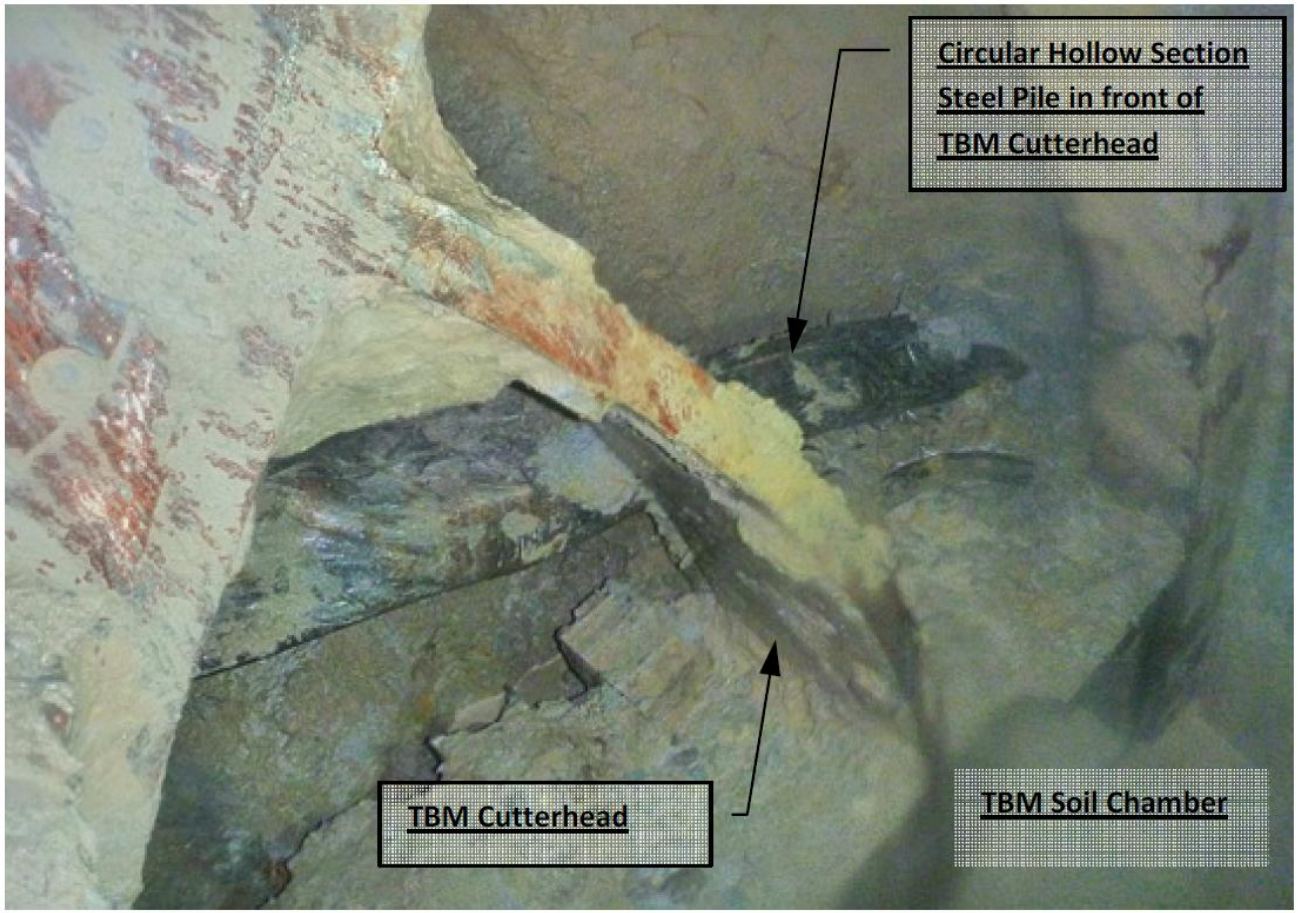


Photo of Existing Steel Pile found during TBM Cutterhead Intervention



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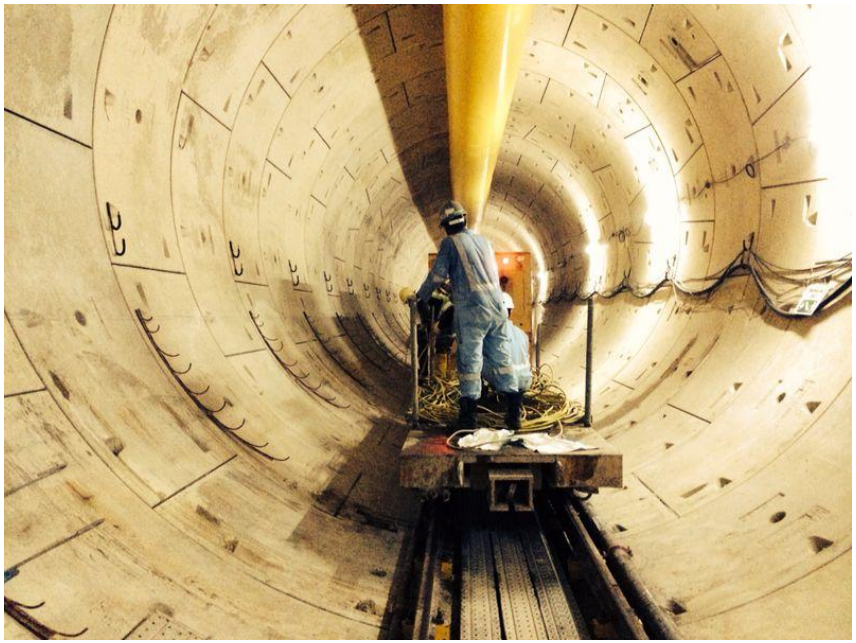

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A section of the completed SFRC Tunnel

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....you will see the light at the end of the tunnel

Needs:

- Good design
- Good material selection
- Good moulds
- Correct casting & curing
- Careful handling
- Careful tunnelling
- Good build
- Good grouting

Everything has to be right!

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