Civil & Structural Design Considerations for Subterranean Integration with MRT Station

1. Introduction

Proposed integration of development with MRT station may be initiated by Private Developer to enhance the connectivity within the precinct. It may also be stipulated in Urban Redevelopment Authority (URA)'s Government Land Sales (GLS) agreements for developer to provide direct access from the proposed development to MRT stations.

This quick guide outlines the key design considerations related to civil and structural aspects when private development is integrated with MRT station at the subterranean level via Knock-Out Panel (KOP) provided. Due to its close proximity to MRT stations (i.e. within MRT 1st reserve), it is crucial that such integration work is carried out safely and without introducing risks to the Rapid Transit System (RTS) structure integrity and operation of MRT stations.

A case study would be used to illustrate the best practices to be taken to mitigate risks posed to the RTS structure integrity and safe operation of MRT stations during the following stages:

1. Piling
2. Excavation
3. Removal of Knock-out Panel

- Please refer to the *Code of Practice for Railway Protection (CPRP)* for detailed technical requirements for all works to be carried out within Railway Protection Zone and Railway Corridor.
- Please refer to *Guidebook for Carrying Out Modification Work to Rapid Transit System (RTS) Stations or Railway by Private Developer* for works involving modification of existing RTS structures, facilities and systems.
- Design approach illustrated in this quick guide is not applicable to LTA projects.

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2. CASE STUDY

2.1 Project Description

The project is located adjacent to an existing MRT station in a new mixed development with localised basement providing a direct connection to MRT station at concourse level.

2.2 Ground Conditions

The subject ground consists of Bukit Timah Geological Formation with subsurface soil made up of Bukit Timah residual soils with SPT N values increasing steadily with depth until N>100, followed by Bukit Timah granite rocks.

2.3 Secant Bored Pile (SBP)

Secant Bored Pile (SBP) walls have been proposed to facilitate the basement excavation work as illustrated in **Figure 1**. SBP is adopted due to space constraints and to ensure water tightness, with the net offset distance between the SBP wall and the existing MRT station box underpass about 300mm.

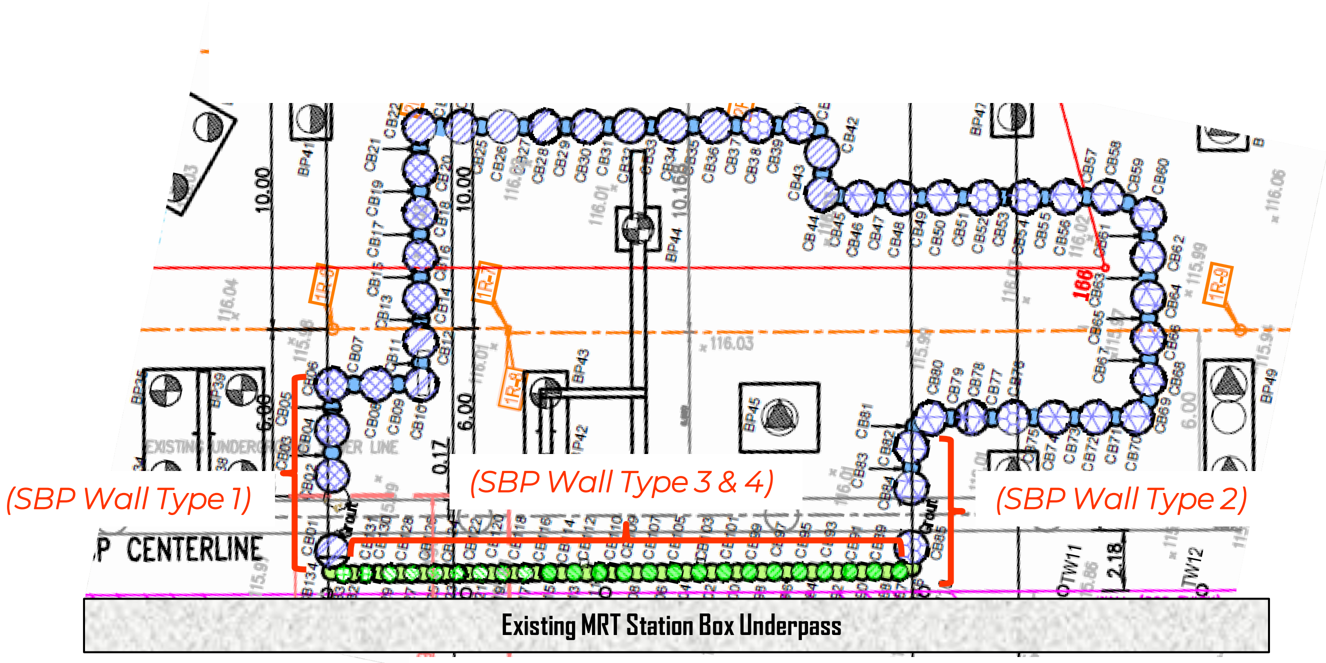


Figure 1 – Proposed SBP layout

For this case study, the SBP walls withstanding vertical load from super-structure in permanent condition have been designed with a minimum 1m socketing into the underlying weathered granite rocks, or a deeper SBP length of 25m, whichever is longer. For the other SBP wall sections with only nominal vertical load in the permanent condition, a SBP length of 24m was adopted. Hence, a total of 4 SBP wall types have been proposed along the basement perimeter of the development. Details are summarised in Table 1.

SBP WALL TYPE	PILE SIZE DIAMETER (MM)	PILE LENGTH (M)	MINIMUM SOCKETED LENGTH (M)
1	Ø1180/Ø880	25	1m into G-III
2	Ø1180/Ø880	24	NA
3	Ø600/Ø600	26	2m into G-III
4	Ø600/Ø600	24	NA

Table 1 – Proposed SBP Type

- Piling works within MRT 1st reserve is also subject to the approval of Certified Survey Plan (CSP). CSP shall be prepared and endorsed by registered land surveyor after conducting a physical geometric survey of the relevant sections of the MRT structures.
- The appointed QP shall submit engineering assessment report with endorsed calculations and design drawings for LTA's review and approval. This is in addition to any other design considerations the appointed QP may deem necessary.

2.4 Excavation

Top-down excavation has been proposed as it is more robust with the installed SBP wall around the basement perimeters. Detailed construction sequences are illustrated in Figure 2 below:

1. Construct 1180mm/600mm SBP wall to required toe level
2. Construct capping beam
3. Excavate to RL114.8m (2.7m from existing ground level) and construct 1st layer of RC waler and slabs
4. Excavate to RL111.10m (6.4m from existing ground level) and construct 2nd layer of RC waler and slabs
5. Excavate to RL108.70m (10.15m from existing ground level) and construct 3rd layer of RC waler and slabs
6. Excavate to RL104.30m with a cut slope 1V:1.5H to FEL (not shown)
7. Localised excavate to RL102.50m with a cut slope 1V:1.5H for detention tank and lift pit (not shown)

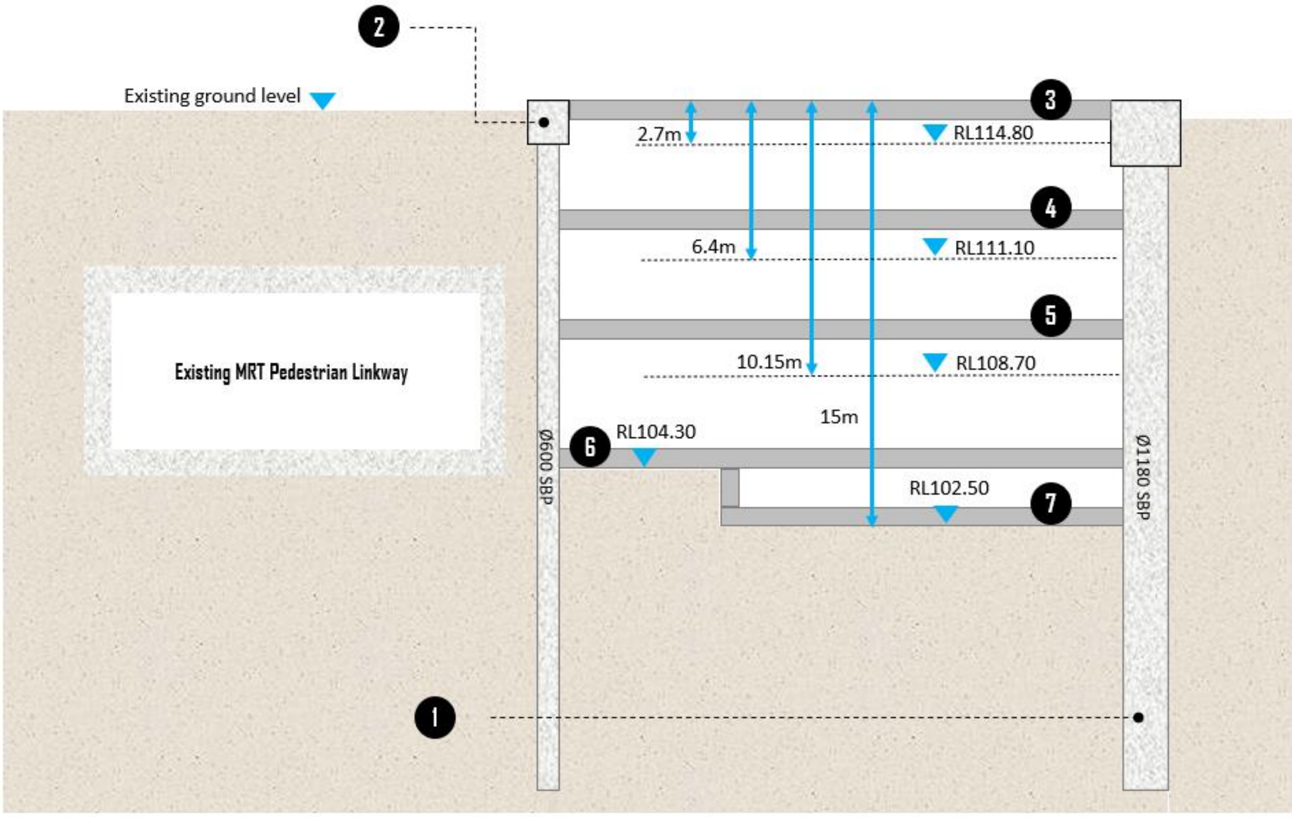


Figure 2 – Proposed Sequence of work

A geotechnical 3D FEM analysis has been carried out, following the EC7 concept. In addition, checks on Toe Stability and Base Heave were also carried out.

A total of 3 geotechnical 3D FEM analyses have been conducted in order to comply with EC7:

1. SLS without applying any partial factors to both loads and soil parameters;
2. ULS DA1-COM1 with partial load factor 1.35 for unfavorable permanent loads and 1.5 for unfavorable variable loads, coupled with partial factor of unity for soil parameters;
3. ULS DA1-COM2 with partial load factor 1.3 applying to unfavorable variable loads and partial factor of 1.25 for effective soil strength parameters and 1.4 for undrained shear strength.

The induced final max SBP wall movements for SBP Types are summarised in Table 2 at various construction stages. It can be seen that the induced Max SBP wall movement ranges from about 11mm to 40mm with a max wall deflection to Excavation Depth (H) ratio of about 0.32%H, which is within the allowable 0.5%H.

A detailed tabulation of the predicted accumulative MRT linkway movements at various basement construction stages is shown in Table 3.

Figure 3 shows the final induced MRT pedestrian linkway movement contour with a max value of about 2.6mm, which is mainly concentrated around the localised area adjacent to the development basement wall, while further away the induced linkway movement tends to diminish quickly.

Construction Sequence	SBP Wall Type 1	SBP Wall Type 2	SBP Wall Type 3	SBP Wall Type 4
3	0.6	0.8	1.2	1.2
4	3.7	5.1	7.3	7.3
5	9.1	11	26.1	26.1
6	20.7	31	39.3	39.3
Final Stage With Vertical Loads	20.9	31	39.5	39.5
MAX SBP Wall Deflection	20.9	31	39.5	39.5
Wall Deflection To Excavation Depth Ratio	0.17%H	0.25%H	0.32%H	0.32%H

Table 2 – SBP wall movement

Construction Sequence	Induced movement on MRT linkway (mm)
3	0.2
4	0.8
5	1.7
6	2.5
Final Stage With Vertical Loads	2.6
Max induced movement on MRT linkway	2.6

Table 3 – Predicted MRT linkway movement

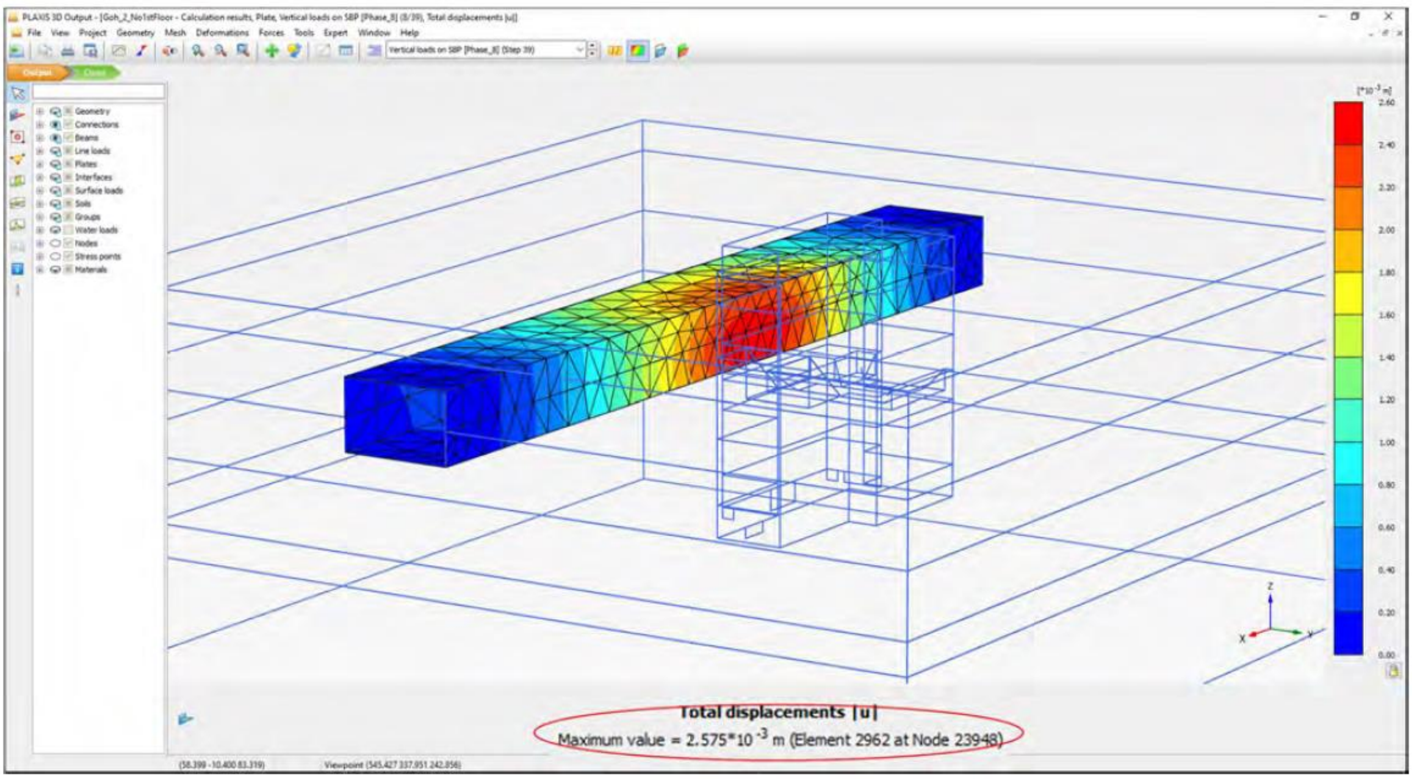


Figure 3 – Final induced movement of MRT pedestrian linkway with max value of 2.6mm

- It is important to ensure that the ground movements in the vicinity of the MRT structures are kept to a minimum and well below the allowable limit as stated in the CPRP.
- As the bulk excavation will be in close proximity to the MRT station, the deflection of the adjacent retaining wall contributed significantly to the movement of station structures. The geotechnical modelling for excavation works should ensure that the predicted wall deflection will be well controlled at each stage of construction.

2.5 Removal of Knock-out Panel (KOP)

The knock-out panel is located at the north-west side of MRT Station Concourse at gridline 14/15 as shown in **Figure 4 & 5.**

Generally, the design of the strengthened strips around the knock-out panel only considered the permanent stage as presented in the station permanent works design calculation. The strips at the roof slab above the knock-out panels are designed to transfer the vertical load to the supporting walls at both sides. The strips are strengthened and designed for ULS bending moments and shear forces while the side walls are designed for the increased vertical loads. Similarly, the base strip below the KOP is designed to resist the vertical uplift force due to the build up of water pressure.

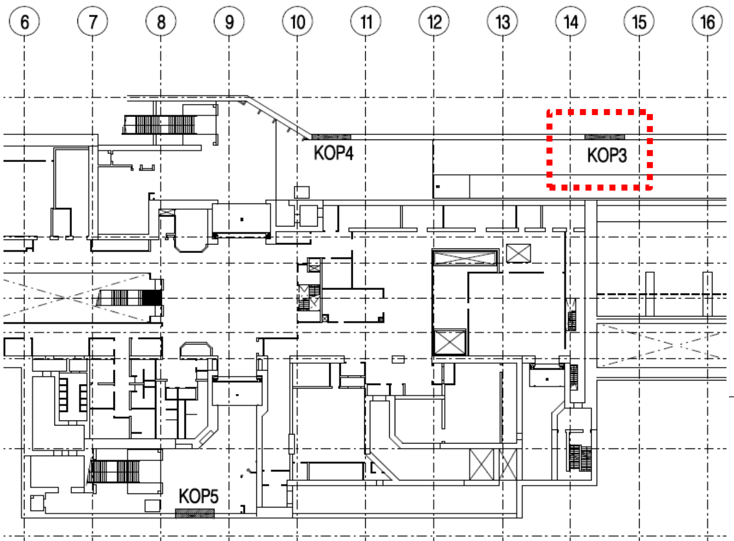


Figure 4 – Part print of the KOP layout plan at concourse level

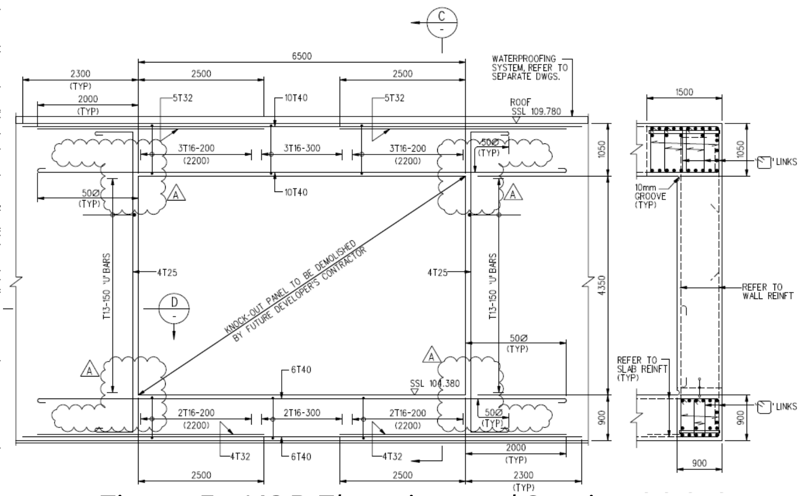


Figure 5 – KOP Elevation and Section

- Where provision for KOP is made on the wall of existing MRT stations, KOP needs to be removed and reinforcements cut to achieve the required opening for future connection between the proposed development and MRT station.
- The appointed qualified person is required to perform structure stability/capacity check after the knock-out panels are removed and propose any structural strengthening measures (during construction and permanent stage) where applicable.

Prior to the removal of KOP, the gap between the proposed SBP wall and existing MRT station box underpass wall are filled with TAM grouting (refer to Figure 6 & 7) as an additional control measure to prevent water ingress. Permanent structure of the proposed development will need to be constructed and achieve the design strength. The proposed development is designed as an independent structure which does not impose any additional load to the existing MRT station pedestrian linkway structure and foundation.

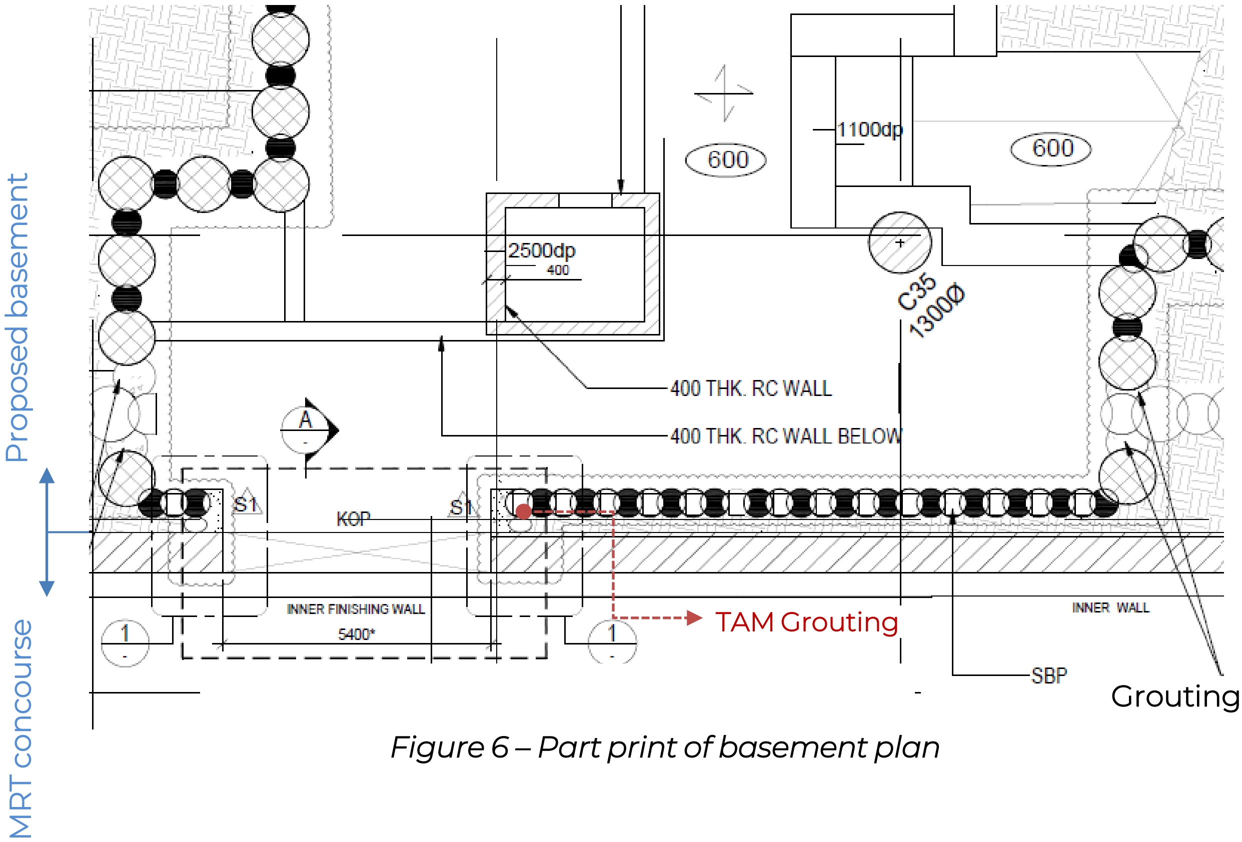


Figure 6 – Part print of basement plan

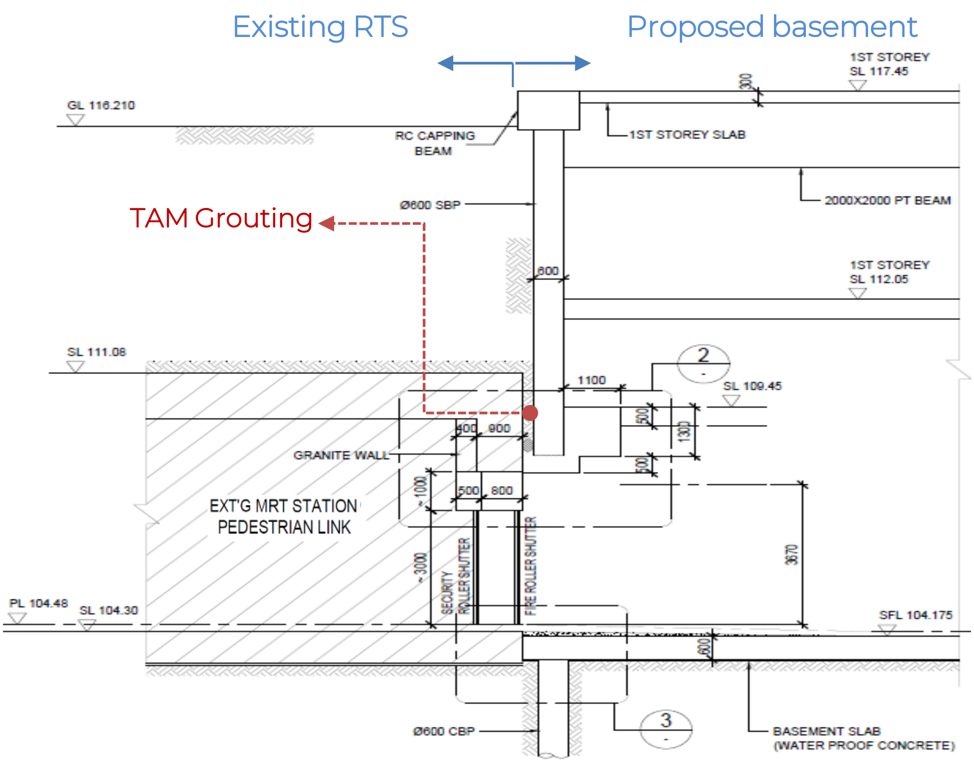
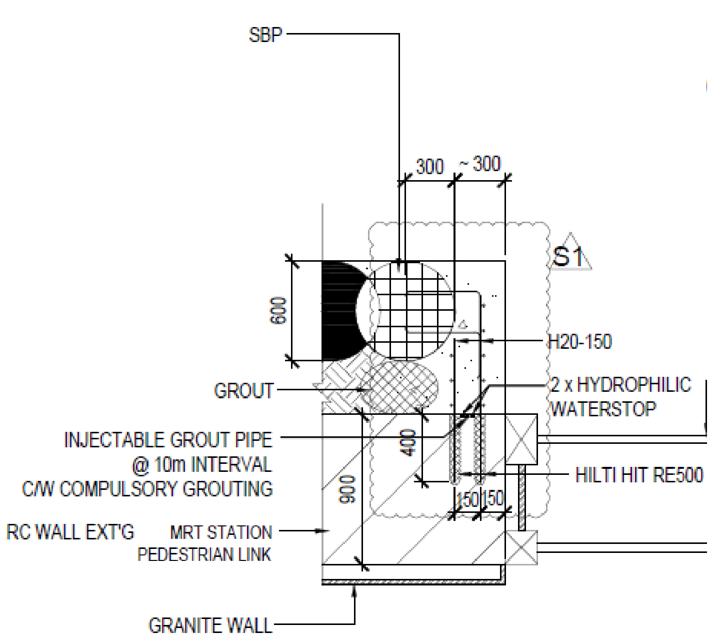
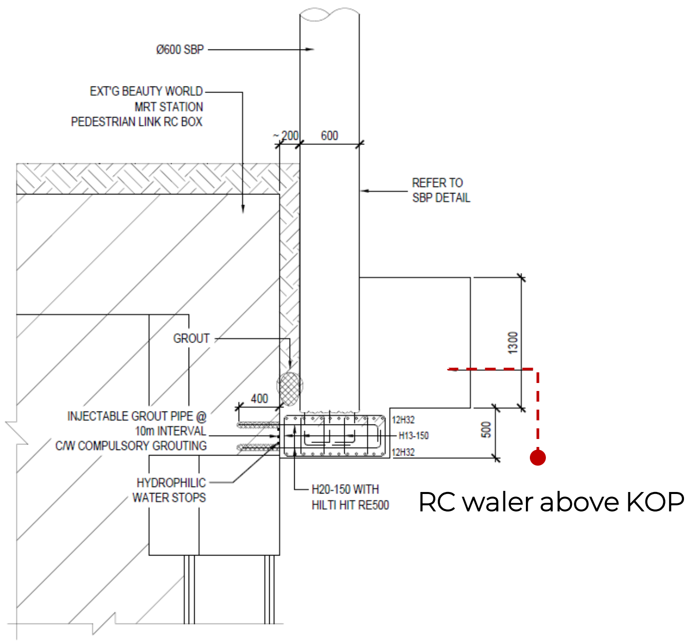


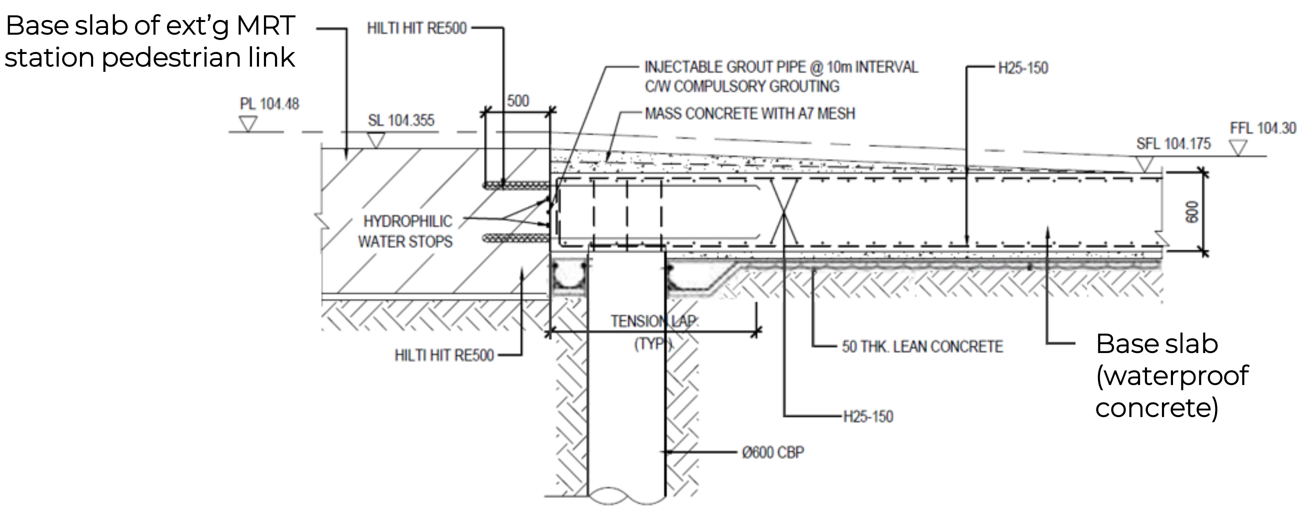
Figure 7 – Part print of basement section



DETAIL 1
SCALE - 1:40



DETAIL 2
SCALE - 1:40



DETAIL 3
SCALE - 1:40

- The waterproofing at KOP interface shall meet the criteria in LTA M&W Specification Chapter 14.

- The grout tubes at KOP shall be injected before removal of the KOP regardless of any leakages observed. Such details shall be clearly indicated in the proposal to LTA for review and approval.

- Fire separation and flood protection of MRT station during the construction and permanent stage shall be included in the proposal for LTA's review and approval.

- Removal of parts of the RTS structures shall take account the following safety considerations :
  - Minimise the vibration induced on the station structure (not exceeding 15mm/sec peak particle velocity).
  - Minimise the generation of dust and noise disturbance or inconvenience to the commuters during train operation hours.
  - Maintain the flood protection level of the stations

3. CONCLUSION

The case study aims to provide a quick understanding of the key civil and structural considerations for subterranean integration with MRT station. By ensuring that the proposals address these considerations from the start, the industry can look forward to smoother and faster approvals for their MRT integration works.

Please note that this quick guide does not supersede the Rapid Transit Systems (Development and Building Works in Railway Protection Zone) Regulations and the Rapid Transit Systems (Railway Protection, Restricted Activities) Regulations. If there is any conflict, the prevailing regulations will take precedence.

We welcome any suggestion or feedback on the quick guide for improvement of future editions.

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