Contract No. NE/2016/01
Site Formation and Infrastructure Works for Development of Anderson Road Quarry Site

Award submission for
Temporary Works Excellence Award 2017

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CHUN WO – STEC – VASTEAM JOINT VENTURE

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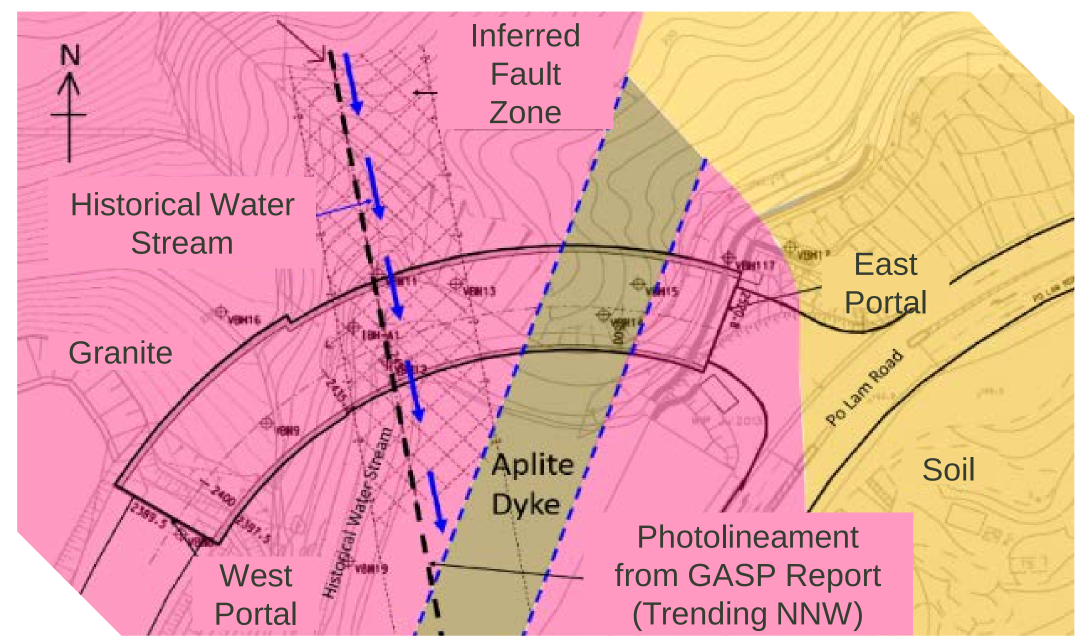
This Contract was awarded to Chun Wo – STEC – Vasteam Joint Venture on December 2016. It consists of approximately 3 kilometres of vehicular roads, a 130-metre underpass and the associated infrastructure at the existing 40 hectares of land platforms, footpath and cycle track. At completion, it will provide about 12 hectares of land for development of about 9400 private and subsidised housing flats for a planned population of 25 000.

The proposed underpass - the main route connecting Po Lam Road and the future housing development, is located at the southern end of the Anderson Road Quarry (ARQ) site. To successfully construct the proposed underpass alignment despite the existence of a potential weak zone, which was, historically, a natural stream with deep weathering profile, is a challenge. Safety in design and construction has been considered at planning stage to ensure workers are protected against any unnecessary exposure of potentially unsafe environment. To achieve this, we have taken the following considerations:

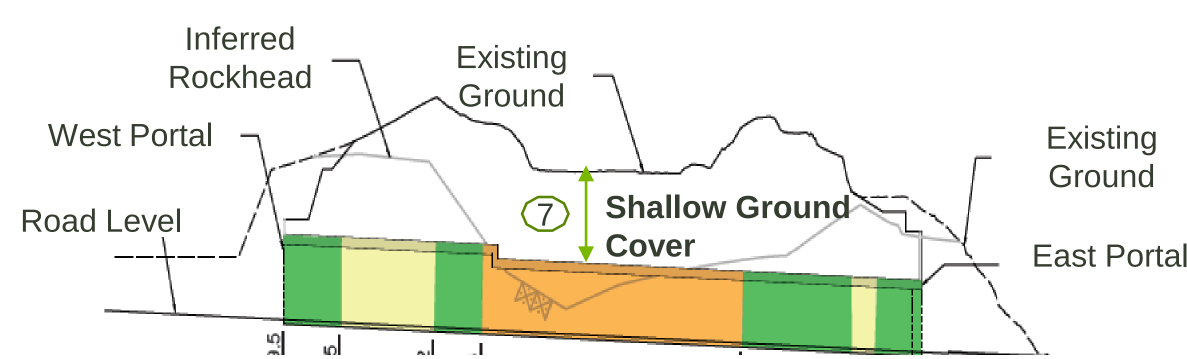
Safety Considerations at Planning / Construction Stage	Content Covered in
Identify and categorise risks/ constraints;	Page 2
Design and implement a robust system for interfaces between permanent and temporary works for ease of working at height;	Page 3
Selection of structural form, materials and adoption of prefabrication in order to minimise workers' exposure to unsupported ground;	Page 4 to 7
Implementation of Tunnel Information Management System (TIMS) for early detection of unfavorable ground movement;	Page 8
Implementation of advance 3D computer modelling and digitisation of urban ground condition as innovations in design and execution.	Page 9 to 10

RECOGNITION OF CATEGORISED RISK

1. Historical Water Stream
2. Inferred Fault Zone
3. Aplite dyke
4. Photolineament from GASP report
5. Curvature in Alignment
6. Large Span of Underpass
7. Shallow Ground Cover
8. Congested Working Space
9. Confined Space



Indications of categorised risks



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ENHANCE WORK SAFETY INSIDE UNDERPASS & BETWEEN INTERFACE OF TEMPORARY AND PERMANENT WORKS

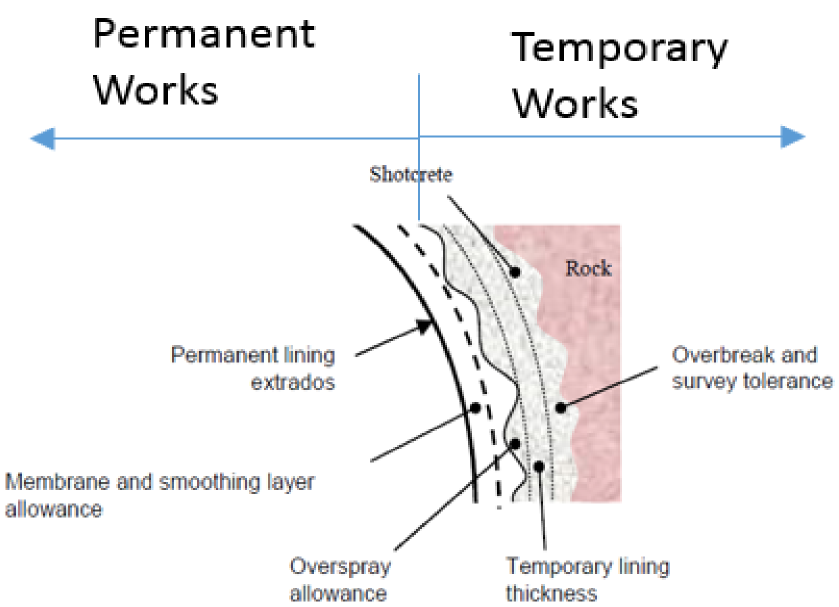
Self reacting moveable formwork "Shutter" is proposed to facilitate concrete pouring for permanent lining. Initial concrete pouring of kicker provides a stable base for formwork shutter.

BENEFIT OF USING SHUTTER

- Provide a safe and secured working platform for workers working at height
- Separate workers from moving machinery inside a confined tunnel during concrete-pouring
- Reduce the amount of workers inside the tunnel by eliminating erection and dismantle of wooden formwork and falsework
- Cleaner and tidier working environment
- Better control of identified risks

ACCIDENT AND HAZARD CONTROL

Separate working space between workers and vehicles, minimising accidents and hazards.



Section for the interface between temporary works and permanent works

Construction arrangement of permanent lining

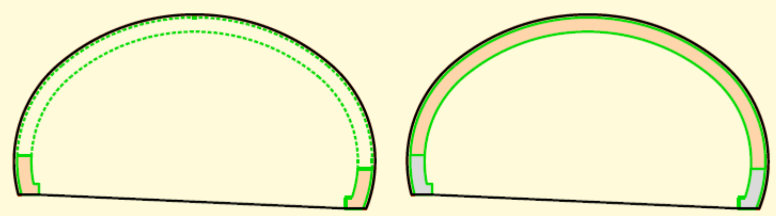
Photo for Kicker

Example of Type 1 & 2 Self Reacting Formwork

Example of Type 3 Self Reacting Formwork

Tunnel Lining Sequence (Type 1/2/3)

Tunnel Lining Sequence (Type 1/2/3)



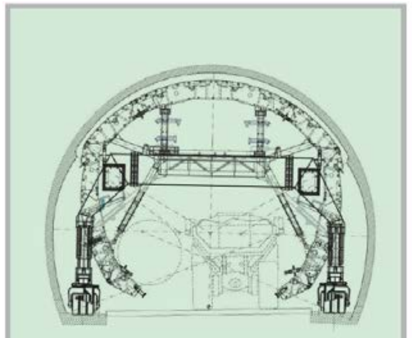
Blinding Layer + Kickers

1) Invert preparatory works, blinding layer (for rails only) and kicker pouring will commence approx. 100-130m from the working face. The blinding layer (for track laying only) will provide a level surface to tram the hydraulic formwork.

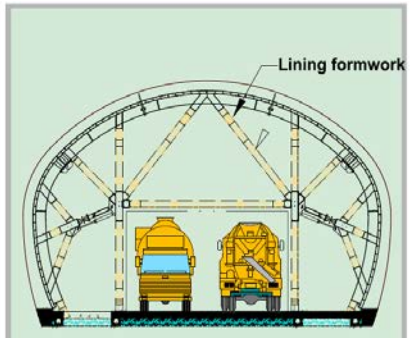
Crown (Waterproof and Concreting)

1) Waterproofing gantries will be used for safe and efficient installation of the membrane layer.
2) Multiple 5 m long trammable hydraulic shutters will be utilized to achieve 10m/WK programme rates for permanent concrete delivery pumps at the formwork will be used to fill the shutters from mobile agitator concrete truck. Lateral windows will be provided to ensure the concrete is evenly distributed in the form. For concrete compaction, electric/ compressed air external vibrators will be fixed to the formwork skin, at designated locations all across the formwork system.

General Construction Sequence for Permanent Lining



Indicative Arrangement for Type 1 and Type 2 Shutter with Self Reacting Formwork
Scale: N.T.S



Indicative Arrangement for Type 3 with Self Reacting Formwork
Scale: N.T.S

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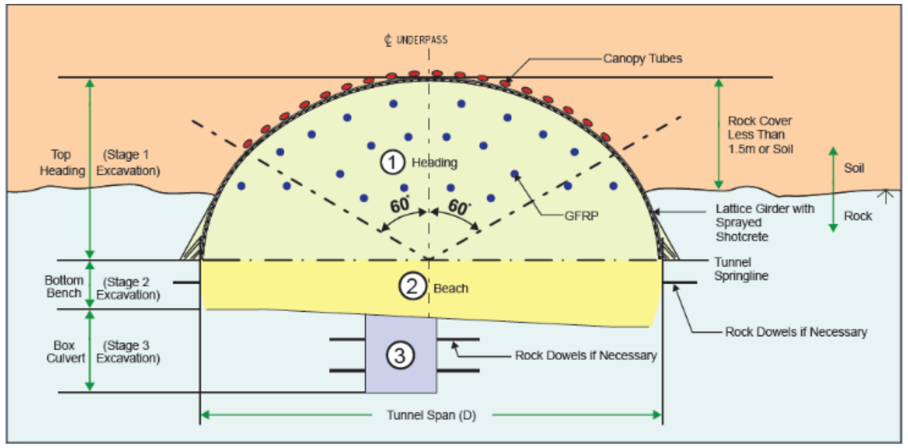
REDUCE RISKS EXPOSURE TO WORKERS

Full Face Excavation – Tradition method of tunnel excavation



Section for Full Face Excavation

Picture for Full Face Excavation

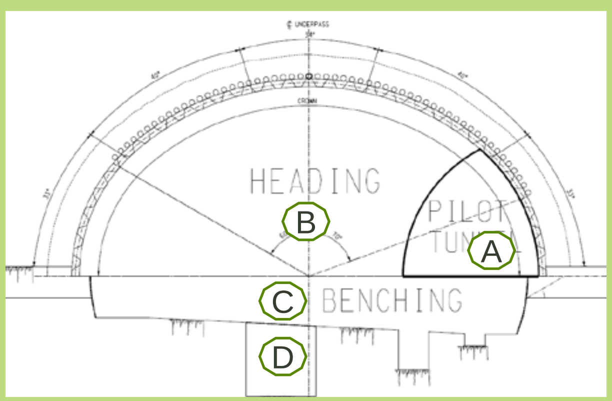
CHANGE OF FULL FACE EXCAVATION TO A SAFER METHOD OF CONSTRUCTION – MULTI-PHASE FACE EXCAVATION

Traditionally when large diameter tunnel is excavated in full face, it is susceptible to the following:

- Collapse of tunnel crown;
- Heavy temporary support;
- Tight working area with heavy machinery and workers working close to one another; and
- Excessive water ingress

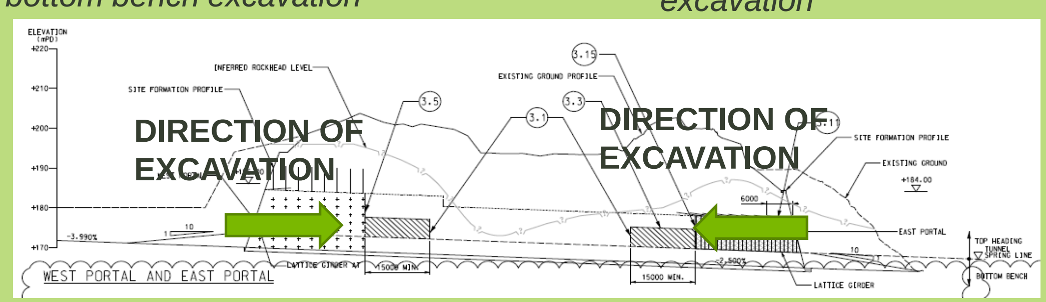
These could possibility increase the exposure of risks to workers inside the tunnel.

Multi-Phase of Face Excavation – Top heading excavation with pilot tunnel followed by remaining heading and bottom bench excavation



Section of Top heading with pilot tunnel and bottom bench excavation

Picture for Top heading with pilot tunnel and bottom bench excavation



Longitudinal Section

Picture for Full Span Heading Excavation

The adoption of multi-stage face excavation (Stage A, B, C & D) allows a relatively smaller diameter pilot tunnel to advance along the alignment for certain length before excavation of the remaining top heading and bottom bench. This technique of excavation has the following advantages:

- Early notification of the forward ground condition through probing ahead;
- Reduce the chances of tunnel crown and side walls collapse with smaller opening;
- Lighter temporary support for pilot tunnel making it easier to maneuver and install inside the confined space;
- Allow forward grouting for water ingress control;
- Reduce the time the workers required to stay underground;
- Improve ventilation of a confined space by early connection between portal via pilot tunnel.

MODULARISATION AND PREFABRICATION OF LATTICE GIRDER

Lattice Girder

Location:
Adopt in Temporary Support Type B and Type C

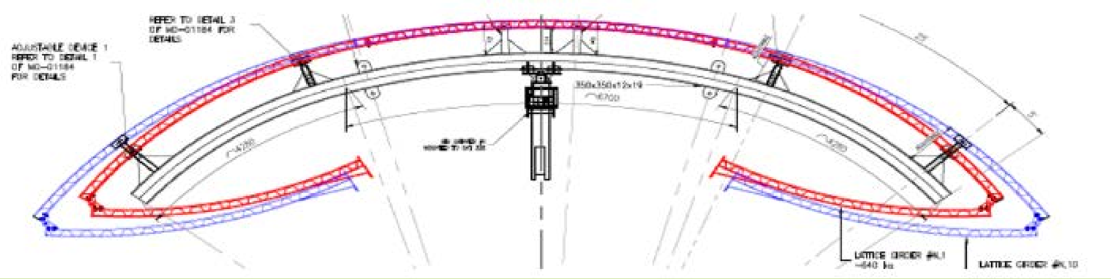
Application:
Temporary support for insufficient rock cover zone and weak zone

Advantages:
- Easy to transport and establish
- Lighter than steel ribs

Picture of prefabricated Lattice Girder

Steel lattice girder has been chosen as the main temporary support for the underpass excavation due to its light weight nature and flexibility. In order to streamline the installation process of steel lattice girders in a tight confined space, following considerations have been implemented:

- Steel lattice girder will be prefabricated and modularised off-site to avoid in-situ steel fixing and welding on site.
- The prefabricated lattice girder can be easily maneuver by a small excavator around site for the ease of manual handling,
- Bolt and nuts have been designed for the connection between different segments of lattice girders to avoid hot works at height.



Typical Arrangement for the installation of lattice girder

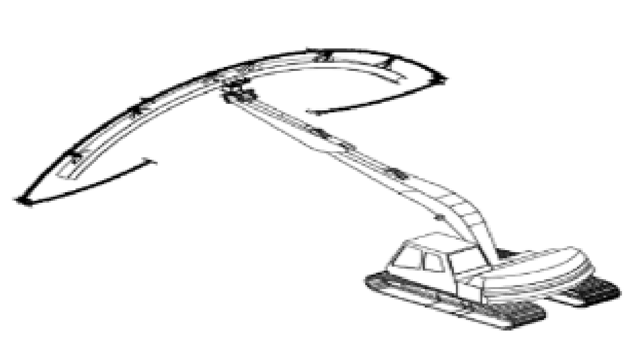


Illustration of easy installation by small excavator

ADVANTAGES OF SPILE BARS OVER CANOPY TUBES

Spile Bars

Location:
Adopt in Temporary Support Type B (Refer to Drawing 4a(i) - 9)

Application:
Temporary crown support for insufficient rock cover

Advantages:
- Easy to be transported and installed
- Save materials for temporary crown support

Illustration of spile bars installation

Canopy tubes have been widely used for forepoling in underground tunnel construction. Due to the curvature of the underpass alignment, canopy tubes are not appropriate to cater for the steep curvature and will lead to excessive overbreaking of tunnel profile, increasing the risks of rock collapse.

With the use of spile bars as the alternative reinforcement materials for temporary support, it could overcome the risks associated to canopy tubes as listed below:

- Spile bars are relatively short (approx. 6m) and it can be designed to cater for the steep tunnel curvature without excessive overbreaking of the tunnel profile;
- It is easy to handle and maneuver reducing the risk of muscle straining from manual handling;
- Installation procedures are simple and it is suitable for general workers to follow;
- Spile bars system is practice-proven

Illustration of complete row of spile bars

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GLASS FIBRE REINFORCED POLYMER (GFRP) FOR TEMPORARY FACE STABILISATION

Glass Fibre Reinforced Polymer - GFRP

Location:
Adopt in Temporary Support Type C (Refer to Drawing 4a(i) - 9)

Application:
Temporary face support at soil portion during tunnel excavation

Advantages:
- Strengthen the excavated face
- Ensure the excavated face stability at soil portion

Example of Glass Fibre Reinforcement Polymer (GFRP)

Normally, steel bar are the most commonly used material to temporarily stabilise the exposed face during tunnel excavation.

However, as these are only temporary measures and will be removed once it is confirmed for further advancement, the steel bar has the following disadvantages:

- Prolonged period for bar cutting increase the risks of workers staying inside the confined space area;
- Workers are required to work at height for manual bar cutting;
- Possibility of face collapse during bar removal.

In order to resolve the possible risks associated with steel bar, Glass Fibre Reinforcement Polymer (GFRP) is proposed as the material for temporary stabilisation measures of the exposed rock face. GFRP has the following advantages:

- Enhance efficiency of tunnel excavation and reduce the time required for workers to be in confined space area;
- Eliminate manual cutting at height and it can be easily remove by an excavation;
- Eliminate hot works inside underpass for potential steel bar cutting;
- Eliminate the need to stand in front of the exposed rock face during removal of temporary stabilization measures.
- GFRP is approx. ¼ of the weight of the steel bar with greater tensile capacity than steel, it greatly improve site logistic and handling of these material on and off site.

IMPLEMENTATION OF TUNNEL INFORMATION MANAGEMENT SYSTEM (TIMS)

What is **Tunnel Information Management System (TIMS)**?

It aims to provide an integrated approach to construction monitoring built around TIMS.

TIMS can be classified into three main groups:

TUNNEL DATA GATHERING AND PROCESSING SYSTEM
Construction information can be added, amended and modified by using PDA. Monthly statistical data can be viewed on PDA.

TUNNEL GEOLOGICAL DATA PROCESSING SYSTEM
This provide geologists the functions to record the geological information on site, in office and process ongoing data.

TUNNEL MONITORING AND DATA PROCESSING SYSTEM
It allows the drawing of deflection-time graph, safety analysis, analysis of axis deformation trends and output of report and monitoring of real time rock deflection situation. These functions help to study the rock stability in tunnel.

An effective data storage system

1. To review the construction progress immediately
2. To monitor the quality and workmanship
3. To confirm the assumptions made previously in the design stage
4. To review the construction progress and cost as fast as possible
5. To provide a full set of well recorded information for the use of the future construction
6. A convenient and all-in-one data base

What are the PROS?

- It is a system built to record process in a manner so the planning and design process could be done in a systematic way. The system comprises the functions of collection, management, analysis and storage of information and data.
- It stores construction information and allowed them to be access efficiently, such as the excavation labour rate, statistic on materials use, manpower, plant working information and etc. These figures can be accessed easily by construction team members and decision makers so to stay aware of site condition.
- The geological structure of tunnel is traditionally drawn by hand by geologist to record the acquired information. This way of geological structure recording has resulted in dated recorded and would cause inefficient communication of the geological information between users. The software helps to improve this situation.
- It builds an all-in-one database
- It reduces storage space (in comparison to the traditional data storage.)
- It ensures the site operation team and supervisors share the same understanding of the rock information, and is a key element to improve communication, co-ordination and understanding of the up-to-date working information between supervisors and the site operation team.
- It is a safe, secured and effective way for the data storage.

IMPLEMENTATION OF 3D PLAXIS MODELLING FOR BETTER ESTIMATION OF THE GROUND REACTION

- Minimise construction risks where complex construction sequence will be used and allow the designer and contractor to capture critical stage of temporary work;
- Necessary space for installation of temporary works can be accurately estimated, enhancing workers safety during installation;
- Better understanding of soil behavior between the interface of different geology, temporary works can be accurately design to ensure the workers are not exposed to unsafe working environment;
- Reduce the geological risk through holistic and comprehensive study in 3D PLAXIS;
- Verify and Improve design and construction assumption via 3D PLAXIS modelling.
- Recognise the site constraints – 3D PLAXIS establishes a full study and input all the data from desk study, site reconnaissance, and ground investigation, thus getting better understanding of site constraints.

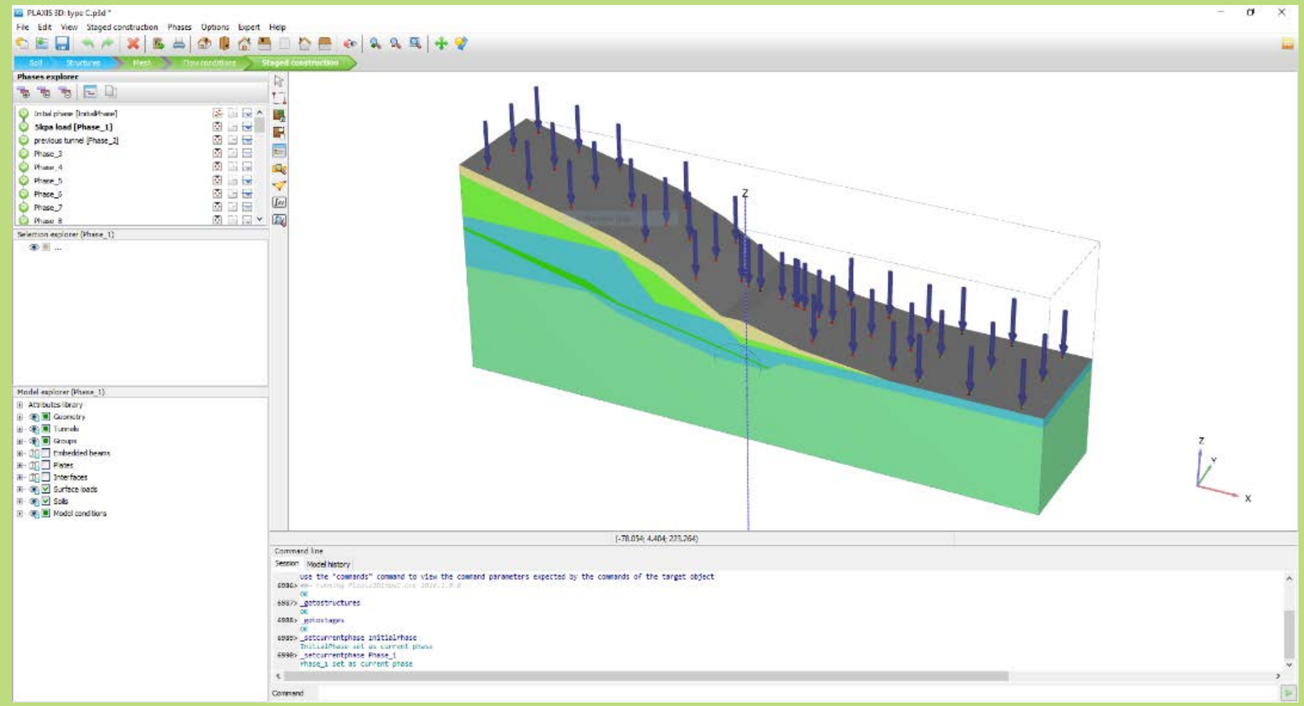
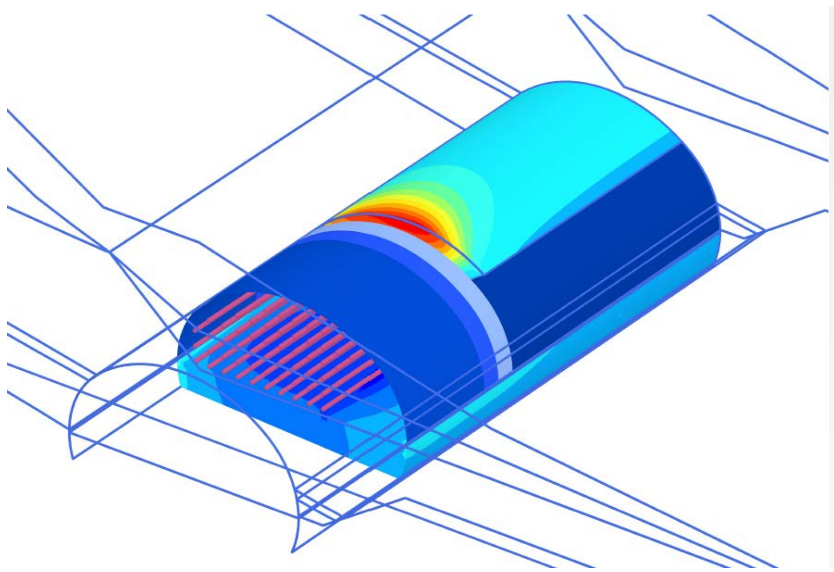


Illustration of PLAXIS 3D modelling

PLAXIS 3D graphical output of deflection



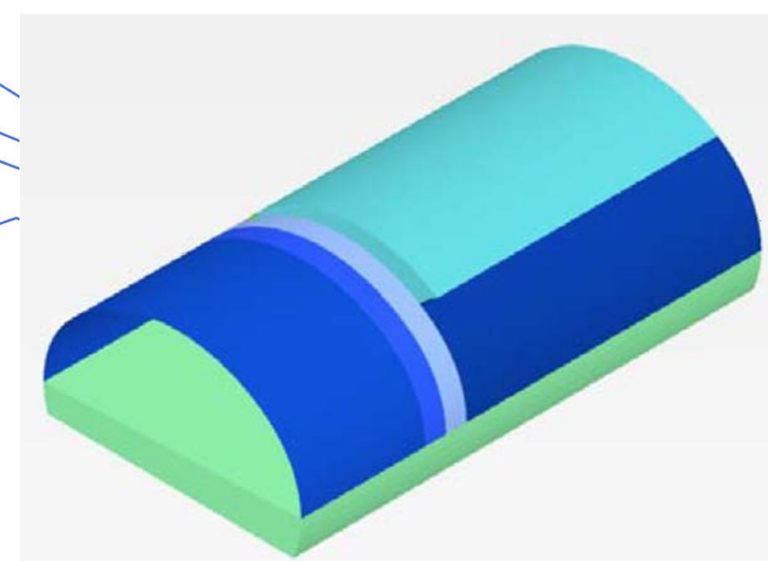


Illustration of PLAXIS 3D tunnel profile

INNOVATIONS IN DESIGN - DIGITIZED THE GROUND CONDITION

In order to enhance the awareness of possible encounter geology to the contractor and its workers, a 3D visualization of the surrounding ground has been established.

The 3D model provide us with a better understanding of the risk of geological profile to the inferred fault zone, Aplite Dyke , photolineament and historical water stream which are categorised as potential risks to the project.

The other advantages of digitised ground condition are as follows:

- Recognise the impacts from other construction activities in planning stage and minimise the interface problem prior to excavation;
- Minimising human error through interpretation by visualising the weak zone;
- Overseeing and easy monitoring of the construction changes through a user-friendly tool

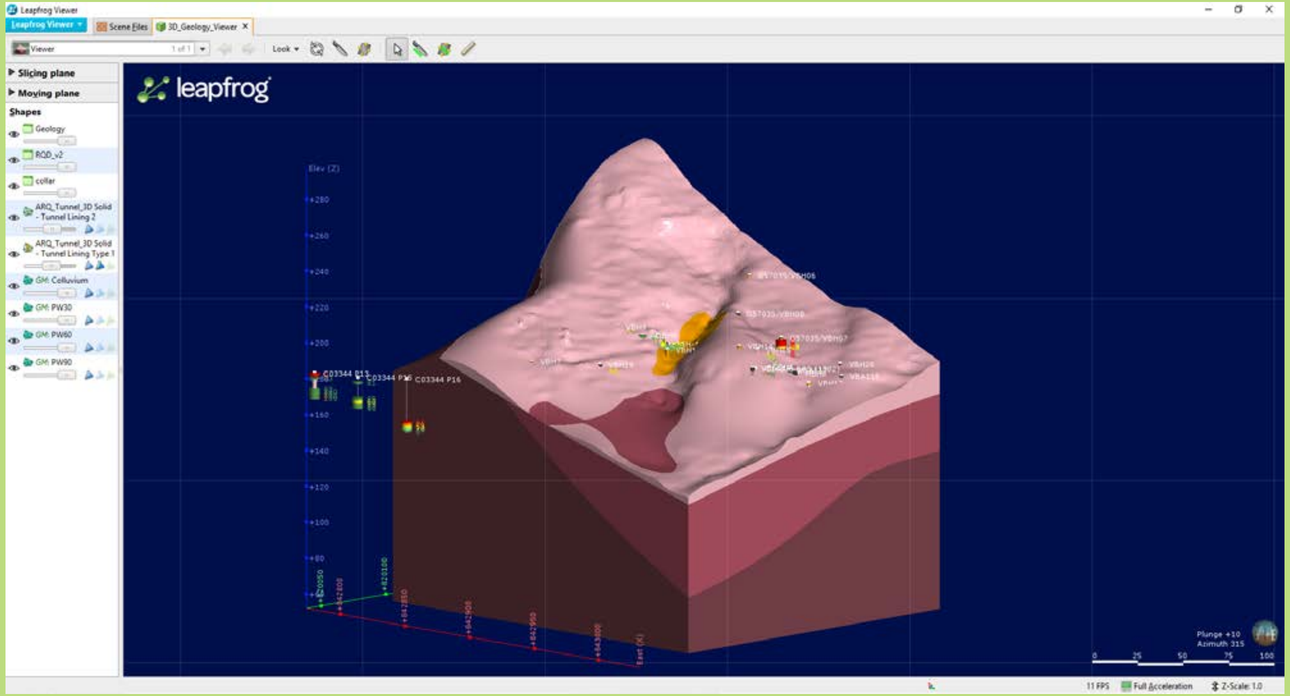
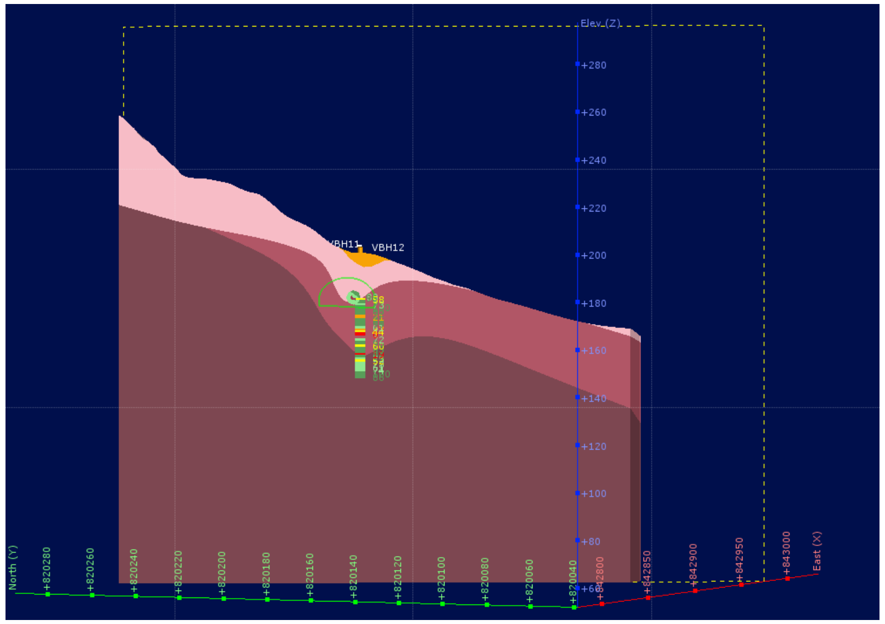
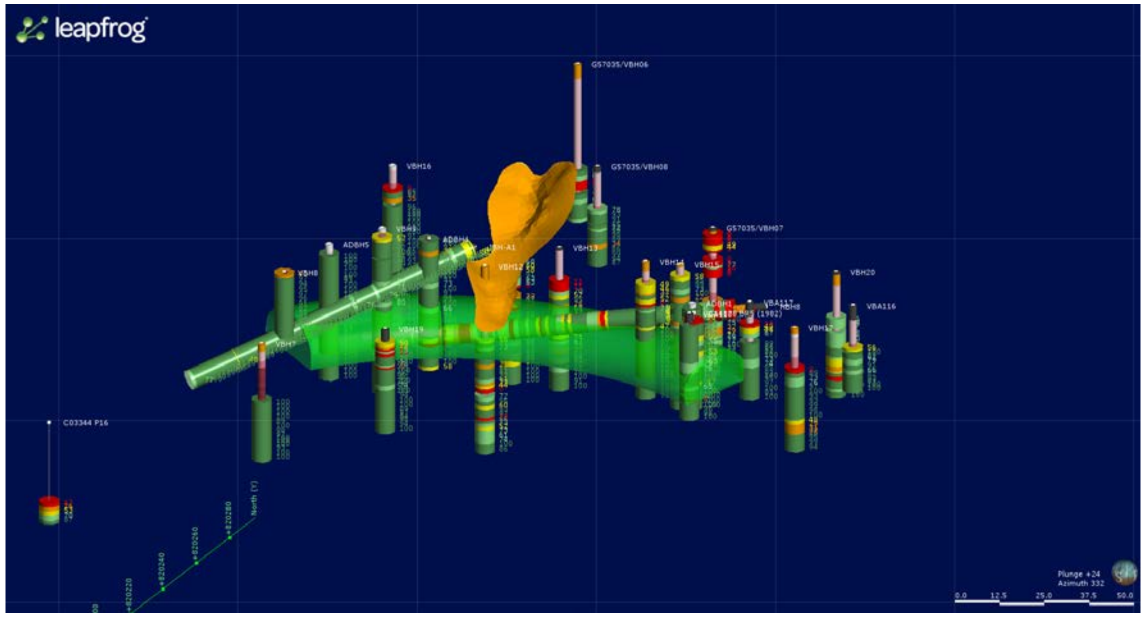


Illustration of Leapfrog 3D model



Automated geological section generated from Leapfrog model



Leapfrog model input borehole information

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