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Tunnelling undercrossing existing live MRT tunnels ☆

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ABSTRACT

In conjunction with the government of Singapore's vision to have efficient and extensive Mass Rapid Transit (MRT) system across Singapore Island, more and more rail tunnels are planned to be constructed in close proximity to sensitive buildings and infrastructures in recent years. This being a particular challenge for major infrastructure works in the urban environment. In contract C937 of Downtown Line Stage 3 (DTL3), twin bored tunnels connect Fort Canning station to Bencoolen Station, under Fort Canning Hill, with the alignment overcrossing the existing North East Line (NEL) rail tunnel, undercrossing North South Line (NSL) and Circle Line (CCL) with clear distance of less than one bored tunnel diameter. This inevitably poses great challenges to tunnelling over and under existing live tunnels without disruption to daily operation of MRT. Further compounding the challenge is the ground condition comprising of Jurong Formation steeply variable sedimentary deposits transitioning into Fort Canning Boulder Bed a colluvial deposit of quartzite boulders in a stiff clay matrix. To successfully negotiate this challenge, requires all involved parties to make contributions in their areas of expertise and work as team together to ensure that the works progress smoothly and as planned. The designer provides an overall approach demonstrating that the work can be safely carried out and provides key parameters for the contractor who carries out the tunnelling with construction control, which in turn is supervised by the supervision engineers ensuring work is carried out safely. The client, who provides the vision in the first place, has overall responsibility for the work providing continuity and ensuring that the component parts of the job are co-ordinated and carried out successfully. In addition, different monitoring levels were also established to reduce the train speed if necessary and also bus bridging service as a contingency measure. This paper summarizes the approach to the tunnelling, key tunnelling parameters during undercrossing of existing live MRT tunnels, instrumentation monitoring as well as measured railway track and structure movements due to proximity tunnelling. It reflects upon the on crucial contributory factors that ensure success within the project and serves as a reference as to how engineering boundaries can be challenged underground.

1. Introduction

This paper focused primarily on the construction of C937 tunnels from Fort Canning Station to Bencoolen Station which are 790 m in length. The tunnels are bored in ground condition of Jurong Formation (SIII/SIV) and the Fort Canning Boulder Bed (FCBB).

The alignment of the tunnels starts off at a depth of 20 m and completed at Bencoolen Station at a depth of 45 m. The reason for this depth of 45 m is that it has to undercross North South Line (NSL) and Circle Line (CCL) at Bras Basah Road before reaching Bencoolen Station at B6 level.

Along this alignment, the 2 Tunnel Boring Machines (TBM) would have to underpass several critical structures, namely North-East Line tunnels, Fort Canning Cultural Centre, the Fort Canning Road Tunnel, the National Museum Singapore, the North-South Line tunnels and the Circle Line tunnels.

Being in the heart of the city centre, the team has to work with site constraints of a small shaft for 2 TBM operations (Bukit Panjang Bound and Expo Bound).

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The remaining portions of the paper shall elaborate the various technical challenges and stakeholder engagement.

1.1. Public relations and technical challenges

To ensure that the technical challenges are timely managed, stakeholders are proactively engaged. By keeping the stakeholders informed of the status of works and safety measures in place, stakeholders are assured that the impact, if any, is brought down to acceptable minimum.

This collaboration with the stakeholders is extremely important in maintaining a vigilant posture during the critical period of undercrossing. During the intense visual inspections, the close coordination for security clearances to carry out such activity became extremely critical.

The following will elaborate how the respective stakeholders are engaged to ensure smooth completion of the Downtown Line 3 East tunnels.

1.2. Geological conditions of C937 East tunnels

East tunnel beneath Fort Canning Park from C937 Station Box connecting to C936 Station Box is mainly in an area of Jurong formation and Fort Canning Boulder Bed formation (FCBB). The Jurong Formation exists at Fort Canning Hill area below the Fort Canning Boulder Bed, with depths of between 10 m and 60 m below existing ground level. FCBB is interfaced with the underlying Jurong Formation with depths ranging from 0.5 m to 20 m from the ground surface as shown in Figs. 1 and 2 and Table 1.

Along the East tunnel alignment, Jurong Formation exists in various states from highly fractured rocks to slightly weathered rocks. The Jurong Formation of East tunnel can be described as reddish-brown and purple siltstone with layers of dark grey mudstones and greenish-grey sandstone layers. The rocks of the Jurong Formation exhibit a wide range of strength in the Fresh State, and have weathered in different ways.

Fort Canning Boulder Bed (FCBB) is a colluvial deposit comprising strong to very strong sandstone and quartzite boulders and cobbles within a very stiff soil/clay matrix. The matrix is generally described as a hard sandy clayey silt or sandy silty clay. The colour of the matrix where encountered is typically mottled, with the characteristic deep red colour in addition to red and white, yellow, brown and red and white and occasionally purple. The cobbles and boulders in the FCBB are typically moderately strong to strong light grey, yellow and brown fine to coarse grained sandstone.

Figs. 3 and 4 show actual ground condition of Jurong formation and FCBB which was observed during cutterhead intervention of East Tunnel.

The groundwater level along the tunnel alignment fluctuates from 1.0 m to 30.0 m due to mountainous terrain at the Fort Canning Hill area.

Based on geology and ground condition, TBM operation for East tunnel was carried out in closed mode with the face pressure of 2 bar in Jurong Formation and 1.5 bar in FCBB.

1.3. Cutterhead intervention before crossing NEL, NSL and CCL tunnels

Along the East tunnel alignment, there are three existing MRT lines, North-East Line (NEL), North-South Line (NSL) and Circle Line (CCL). East tunnel is located approximately 1.3 m above NEL Tunnel, 8.7 m below NSL Tunnel and 3.3 m below CCL tunnel.

In order to cross these three MRT lines without any major problem, Cutterhead intervention (CHI) was carried out to check TBM machines and replace any wear or tear cutting tools before crossing NEL, NSL and CCL tunnels. The location for CHI was chosen at least 20 m away from existing MRT lines to limit any settlement impact.

As shown in Figs. 1 and 2, NEL tunnels are in an area of Jurong formation and NSL/CCL tunnels are in an area of FCBB. Based on geological condition and previous TBM operation data, optimum

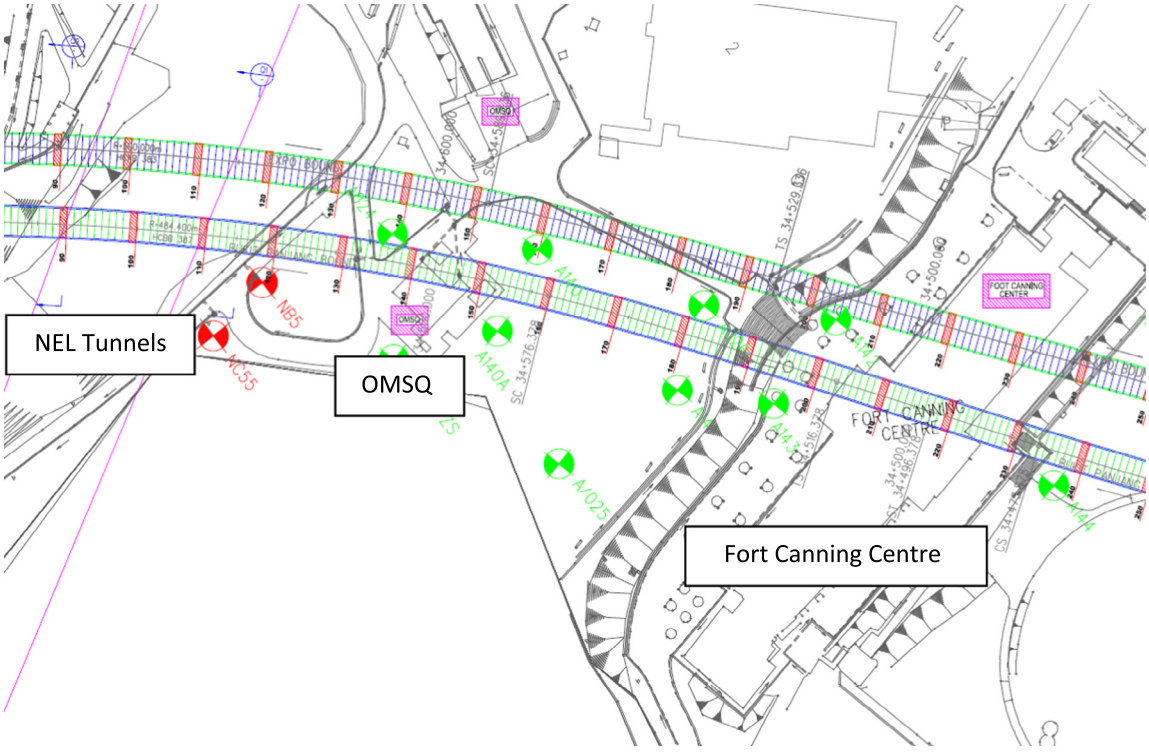

Fig. 1. Overall layout of East tunnels.

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