The Design and Philosophy of the Tunneling Survey for the Klang Valley Underground Mass Rapid Transit Project

David Leng Hua CHANG, Malaysia

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ABSTRACT

The Government of Malaysia under the Greater Kuala Lumpur / Klang Valley National Key Economic Area as detailed in the Economic Transformation Programme of Malaysia, planned to provide an integrated and sustainable transport system for the Klang Valley. The MRT Sungai Buloh - Kajang Line has a portion of underground line which formed part of the Klang Valley Mass Rapid Transit Project. With approximately 9.5km of bored tunnel, and with as many as 6 concurrent tunnel boring machines, and with stringent accuracy requirements, the underground tunnelling survey is, by any standard, a very challenging surveying project. Great care has to be taken in the design of the surface and underground networks and monumentation. This paper seek to present the philosophy and designs of the control network, field and office procedures for the precise transfer operations and extensive horizontal and vertical control into the underground facilities, and the control traverse scheme employed in the tunnels.

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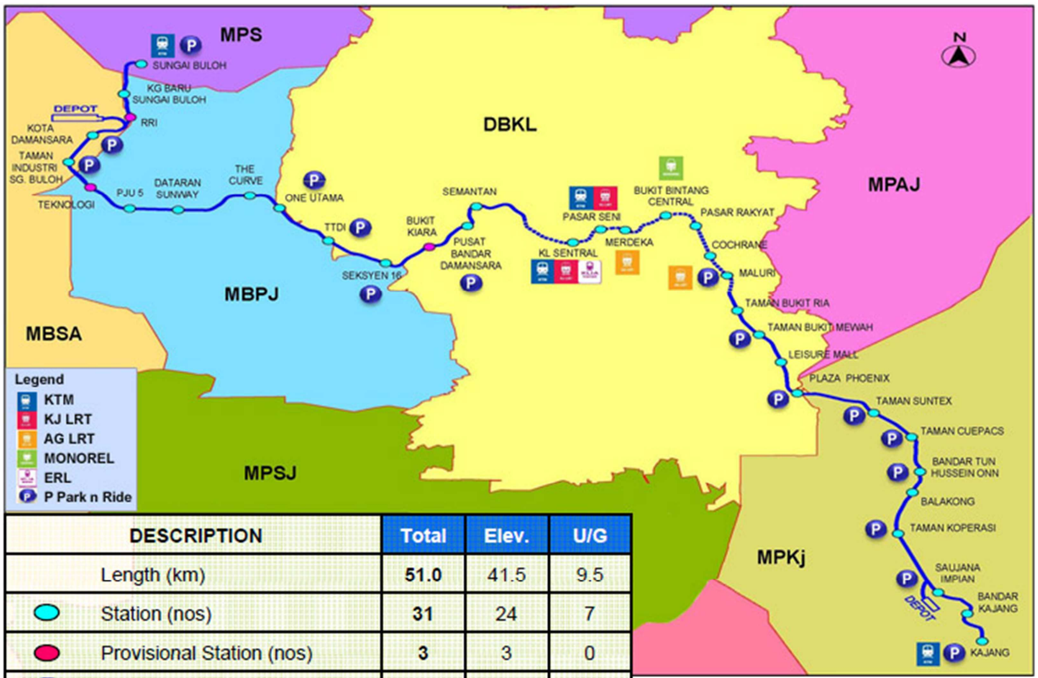
1. INTRODUCTION

1.1 The Greater Kuala Lumpur/Klang Valley (GKL/KV) National Key Economic Area (NKEA) is one of the 12 NKEAs under the Economic Transformation Programme of Malaysia. The goal of this NKEA is to transform Greater Kuala Lumpur/Klang Valley into the top-20 most liveable metropolis globally and top-20 in terms of economic growth. Greater KL/KV extends beyond the boundaries of Kuala Lumpur.

1.2 On 8 July 2011, the Malaysian Prime Minister launched the first MRT line (**Figure 1**) that will run between Sungai Buloh and Kajang (SBK) which passes through the centre of Kuala Lumpur. The line starts from Sugai Buloh and passes through Kota Damansara, the Curve, Bandar Utama, Taman Tun Dr Ismail, Jalan Semantan, Cheras, Bandar Tun Hussein Onn and Balakong before ending in Kajang. The length of the SBK line is an estimated 51 km, of which 9.5 km are underground and 41.5km are elevated. There will be 31 stations, with 7 underground and 24 elevated stations, and 16 Park and Ride facilities.



	DESCRIPTION	Total	Elev.	U/G
	Length (km)	51.0	41.5	9.5
	Station (nos)	31	24	7
	Provisional Station (nos)	3	3	0
P	Park & Ride	16		

Interchange Sations with Existing Rail Line at:

1. Sg. Buloh
2. KL Sentral
3. Pasar Seni
4. Merdeka
5. Bukit Bintang Central
6. Maluri
7. Kajang

Figure 1: Proposed Klang Valley MRT Line

1.3 The boring of the underground tunnels will be made with several Tunnel Boring Machine (TBMs), one at each end of the sections. As of date of this writing, a Malaysian company has been awarded with the project to conduct the construction underground tunnelling portion of the SBK Line. This paper seek to describe the survey work which covered 9.5 km underground portion of the SBK Line, beginning from KL Sentral Station to Maluri Station, its philosophy and design, methodology of the surface geodetic control network and underground geodetic networks, field and office procedures for the precise transfer operations and extensive horizontal and vertical control into the underground facilities, and the control traverse scheme employed in the tunnels.

2. PRIMARY CONTROL SURVEY NETWORK

2.1 Based on geographical extent of the project site, a Primary Control Network, shall be designed with the following criteria:

a. Optimal distribution of the stations on both sides of the alignment of the tunnel;

b. Inclusion of national geodetic stations in the design network;
c. Inclusion of control stations which have been established by the Project Delivery Partner (PDP);
d. Connection to the local geodetic reference frame, which in this case GDM2000.

2.2 The following network shall be designed:
  a. A network comprising of Department of Survey and Mapping Malaysia (JUPEM) MyRTKnet Continuous Operating Reference Stations, the Malaysia Primary Geodetic Network Stations I(MPGN) and control stations along the alignment of the 9.5 km tunnel;
  b. These stations shall be measured using static GNSS technique; and
  c. The GNSS measurement duration and software shall be selected so as to ensure relative baseline accuracy of one part per million (1 ppm).

2.3 **Figure 2** shows the proposed Primary Control Network.

Figure 2: Primary Control Survey Network

2.4 In order to maintain standardization and quality, the following tests shall be carried out on the GNSS receivers:

a. A zero baseline testing shall be performed before the start of a survey to test and validate the GPS equipment and the software;
b. A short baseline testing shall be performed before the start of a survey to test and validate the GPS equipment and the software;
c. The tribrach shall be checked to ensure that the optical plummet and the plumb line are correct.

2.5 Carrier phase observations of static mode shall be carried out with duration of a minimum of 2 hours over 3 epochs for the purpose of optimization of the reliability and redundancy of the network.

2.6 The data processing and adjustment shall be carried out using appropriate GNSS processing software to compute formal a-priori standard errors from the baseline variance/co-variance statistics and subsequently to produce a posteriori errors computed at the 95 percent (2 sigma) confidence level for the adjusted station coordinates.

3. SECONDARY CONTROL SURVEY NETWORK

As the tunnels will be approached from multiple sections or portals, primarily from seven (7) MRT stations, a densified secondary control survey network shall be established to support the underground network. This secondary control survey networks (surface network) shall consist of stations from the Primary Control Network and new survey stations at the TBM launching sites. Field measurements of angle and distance shall be carried out with the following criteria:
a. The difference between repeated angle measurements shall not be more than 3”.
b. The difference between repeated distance measurements shall not be more than the precision of the total station (2mm + 2ppm).
c. The adjusted coordinates of the stations shall be within 1:100,000.
d. Distances between adjacent stations established to be between 500 and 1000m.

4. UNDERGROUD NETWORK

4.1 The underground network shall be established to control the TBM. There are two horizontal observations on the tunnels namely the distances and angles. The distance measurements shall be applied with meteorological corrections, scale projection and scale factor with varying heights or refraction and the angle measurements shall be conducted with six (6) series of zero directions for each observation set. The rejection criterion for the angle shall be 2”. The computation and adjustment of all these observations shall be carried out by least square adjustment.

4.2 The error analysis and reliability of the adjustment shall be carried out with the following criteria:

a. Errors in the instruments

b. Pre-analysis a priori error
c. Quality control information
d. Check on the normal distribution
e. Coordinates closure to other control stations

4.3 As the axis of the tunnel is not readily available for observation, the underground networks must be designed in zigzag manner for the purpose of reducing the lateral refraction error.

4.4 Main Survey Control Points shall be established for each tunnel bore on each track inside the Stations. The Survey Control Points shall be located on the tunnel roof or walls clear of the track and walkway concrete. Additional points shall be installed at each level within the station to suit the other Works Contractor's requirements.

4.5 If two TBMs were to be at work on the project, each shall be able to excavate up to 20 m per day. The networks shall be extended by about 200 m each time to keep the machines moving forward. In this way, the surveyors maintain and expand the tunnel's network of control points towards each other. For each new control point, the survey crews shall install threaded bolts into the tunnel walls or floor. Three instrument setups shall be required to extend the control network which the total station makes multiple measurements to approximately 18 targets

5. TRAVERSES IN TUNNEL

5.1 The most difficult part of the tunnel works is that sight lines are narrow in the tunnels. Therefore multiple prisms shall be used for a total station's field of view. To solve the problem, 1" robotic instrument combines with precise measurement and target technology shall allow the automatic pointing and fast, high-accuracy measurements to be carried out within the limited spaces.

5.2 One of the most demanding setting-out projects is the alignment of the TBMs. Each TBM is more than 150 m long, and the concrete blocks that support it must be placed accurately. Working beneath the machine, surveyors shall install profile points on the tunnel walls at intervals of 10 m. Each TBM advances approximately 20 m per day, and survey crews need to set out six points at a time. The robotic total station automatically turns and target at the set direction and makes repetitive measurements until the appropriate point is found on the tunnel wall. It then produces a red laser dot on the point and the surveyor marks the spot with a rock anchor.

5.3 When the whole cross-section of the tunnel head is advanced simultaneously through the TBM, 3D coordinates and offsets at chainage intervals shall be provided by the surveyor to the TBM operator who steers the machine by observing laser beam targets mounted on the machine. These TBM have sensors to detect and display the position of the laser while driving the TBM on the correct alignment. The total station which measures angles and distance to the reflectors on the TBM gives guidance to the TBM. From the coordinates of the reflectors, positioning parameters are determined in real-time and transmitted continuously to the TBM operator in steering the machine.

6. AS BUIT SURVEY

As built survey shall be carried out to check tolerances of completed structures by the following techniques:

a. The use of laser scanner which emits laser beams at angular intervals on a rotating plane either vertically or orthogonal to the tunnel centre-line.
b. The use of reflectorless total station by which points outcropped from tunnel surface are automatically obtained.

7. CONCLUSION

7.1 In this Underground Tunnel MRT Line of Klang Vally, an estimated 9,5 km of tunnel shall be laid by the TBM and this has brought about the accuracy demands for the establishment of control networks for the proper and construction of the tunnel.

7.2 The Primary Control Survey Network and Secondary Control Survey Network are important in bringing the reference and control to the construction sites.

7.3 The surface control networks must be carried out by GNSS techniques in static mode.

7.4 This design and method used for the transfer of control shall be able to detect errors and prevent it from being propagate down the constructed tunnel.

7.5 The errors due to refraction though extensive, it could be reduce by the employing the double zigzag method of traverse within the tunnel.

REFERENCES

Bickel J O 1996 Tunnel Engineering Handbook

JUPEM CBDRF 2004, Department of Survey and Mapping Malaysia

Radcliffe E 1989 Control Surveys and Setting Out for the Channel Tunnel

BIOGRAPHICAL NOTES

Education: B Land Surveying University of Technology, Malaysia 1991, Mphil in Engineering Surveying and Space Geodesy, University of Nottingham, UK

Work Experience: Licensed Land Surveyors since 2011
Land Surveyors with Department of Survey and Mapping Malaysia – 1982 - 2011

CONTACTS

David Leng Hua CHANG
DC Survey Consultant
33-2A, Jalan USJ Sentral 3
Persiaran Subang 1
Subang Jaya, Selangor
MALAYSIA
Tel. +60123205962
Fax + 60380242611
Email: davidchang@ljt.org.my
Web site: www.ljt.org.my