TUSTD Pre-AGM Talk "Advances in Bored Tunnel Design and Ground Investigations for KVMRT Project" Visit

by Ir. Khoo Chee Min

Ir. Khoo Chee Min is currently the Deputy Chairman of IEM Tunnelling and Underground Space Technical Division (TUSTD).

The IEM Tunnelling and Underground Space Technical Division (TUSTD) organised a talk prior to its 16th Annual General Meeting at the Prof. Chin Fung Kee Auditorium, Wisma IEM on 14 May 2016. The talk entitled "Advances in Bored Tunnel Design and Ground Investigations for KVMRT Project", was delivered by Er. Poh Seng Tiok and chaired by Ir. Andrew Yeow, the Chairman of TUSTD. Er. Poh is currently the Director, Planning & Design of Mass Rapid Transit Corporation (MRTC) leading the team in supporting the implementation of KVMRT Line 1 and Line 2 as well as providing the technical leadership on the Engineering Feasibility Study for KVMRT Line 3. The response to the talk was overwhelming which attracted 162 participants from various professional backgrounds. This was a record set for TUSTD since its inception.

In the introduction, Er. Poh explained the fundamental concepts of shield tunnelling by exemplifying the construction of Thames Tunnel. It was the first tunnel known to have been constructed successfully underneath the navigable Thames River in London, and was built between 1825 and 1843 using Marc Isambard Brunel's and Thomas Cochrane's newly invented tunnelling shield technology. The key innovation of the tunnelling shield was its support for the unlined ground in front and around it to reduce the risk of collapses. The tunnel was originally designed for, but never used by, horse-drawn carriages. It now forms part of the London Overground railway network under ownership of Transport for London.

Er. Poh continued with the overview of lining types, namely precast concrete segment (reinforced with steel bar), spheroidal graphitic cast iron (SGI) segment, steel fibre reinforced concrete (SFRC) segment and others: in-situ concrete, sprayed concrete (SCL). The terminology and basic principles of tunnel segment design were explained. Apart from designing the segment lining for overburden, groundwater loadings and surcharges under different load combinations and design checks such as tunnel flotation, heave and settlement, deflection, fire resistance, cracking; other checks on radial joint to resist tensile bursting stresses and circumferential joint to resist the ram force shall be carried out for safe handling and erection of segment linings. Er. Poh mentioned that the uniformity in segment design was achieved in this region as the experience learnt from early developments in precast tunnel lining design for Singapore MRT North-East Line.

He then proceeded to talk on the recent advances in bored tunnel design. As the owner of railway assets, the key considerations include safety, durability of the tunnels which in turn reduces long term maintenance costs. Thus the areas of focus on improvements are durability, fire resistance and waterproofing, to mention a few. On this matter, Er. Poh advocated that the use of Steel Fibre Reinforced Concrete (SFRC) has successfully addressed the durability concern in greater extent by explaining the advantages of SFRC over traditional steel reinforcement. He said SFRC enhances long-term durability by providing resistance against micro-cracking, which is achieved through fibre reinforcement distribution being multidirectional and evenly distributed throughout the segment section. In addition, SRFC provides increased resistance of segments against splitting, spalling and handling impacts, reducing damage to the segment during construction stages (i.e. handling/ erection). He also emphasised that the elimination of conventional reinforcement from the segments promoting productivity during manufacturing. This gives SRFC greater cost advantage by about 5-15% cheaper. The drawback is an economically thin SRFC segment may not be possible under certain circumstances of high bending moments and/ or high tensile bursting stresses resulting from the thrust forces, but this can easily be overcome by introducing special hybrid segments with conventional reinforcement added to the segments. Er. Poh highlighted that the use of SFRC becoming more popular in the international tunnelling industry perhaps the successful completion of KVMRT Line 1 tunnels marks an important step in the use of SFRC tunnel segmental lining in South East Asia.

All KVMRT Line 1 SFRC tunnels completed on 11 April 2015

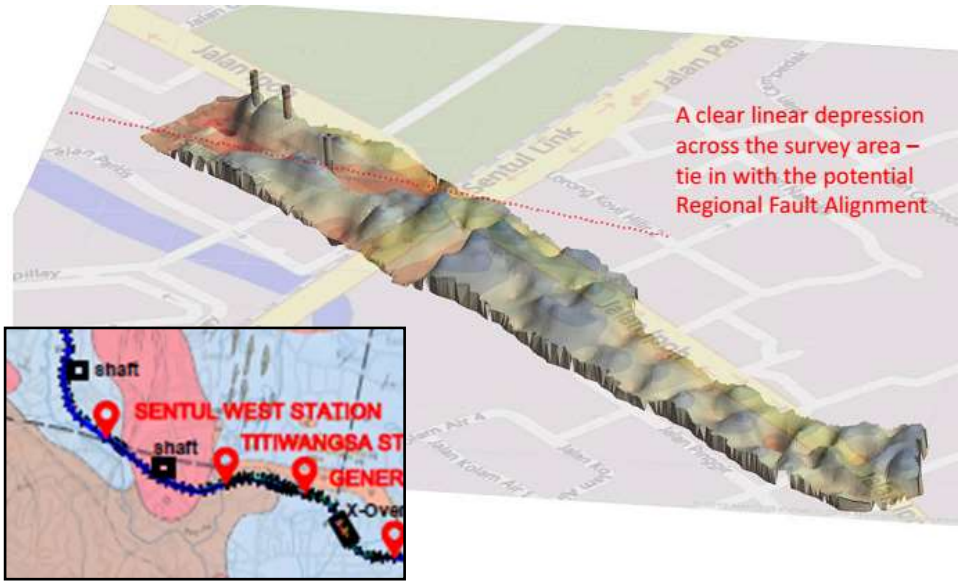
In term of fire damage concern, Er. Poh mentioned that polypropylene fibres are added during the segment casting with the aim to form interconnecting passages for vapour pressure to escape when it is melt and thus preventing concrete spalling. Polypropylene fibres shall be manufactured to ISO 9001:2000 and comply with the requirements of BS EN14889-2 with proper CE conformity marking

and labelling. As for the challenges of water leakage, a high standard waterproofing of the tunnel linings has been adopted in KVMRT project, of which the groundwater leakage rates shall not exceed 5 ml/m^2/h, for any 10m length of tunnel the water ingress rate shall not exceed 10 ml/m^2/h. He said a co-extruded single composite gasket consisting an elastomeric carrier and hydrophilic facing material throughout the segmental tunnel linings is specified. The elastomeric gasket shall be an Ethylene Propylene Diene Monomer (EPDM) formulated to provide good retention of elasticity and low stress relaxation properties. The samples of the proposed EPDM material shall be subjected to accelerated aging test, accelerated stress relaxation test at elevated temperatures. Er. Poh shared the project photographs illustrating the SRFC handling and transportation starting from segment production at the precast yard up to segment erection inside the TBM.

The presentation continued with second part on ground investigation. Er. Poh highlighted the complexity and geological challenges of KVMRT Line 2 disheartened with various fault lines, quartz dike/ reefs, deep slump zone, multifarious geological interfaces along the underground alignment, not to mention the infamous Kuala Lumpur Limestone for its extreme karst formations. Ground investigations make use of the advances made in geophysics and in-situ testing (i.e. borehole televiewer, downhole seismic, p-s logging) were employed in this project, thus increasing substantially the value of geotechnical design that later be based on their findings.

On the geophysical investigation, Er. Poh provided the overview of various geophysics methods and briefly discussed those being utilised in KVMRT Line 1. Then he went on to discuss in detail the application and experiences in using Gravity Survey, as a reconnaissance ground investigation method to identify areas of enhanced ground risks, in the complex variable and unpredictable KL karstic limestone formation during the underground reference design stage of KVMRT Line 2.

He explained the principle of gravity method and the reasons this method was chosen. As the gravity geophysical method is totally passive, it relies on no controlled energy sources but measures naturally occurring variations of the earth's gravity field. Measurement of the variation of the gravity field provides information about the local variations of the rock densities. While the strength of the local variations of the gravitational field is directly proportional to the rock mass excess or deficiency, and therefore also to the density of the subsurface materials. Operationally the gravity method is a non-intrusive passive technique requiring only a small footprint for setting up, fast in data collection with minimum logistics preparation and usually demands no special provisions for execution in the urban environment. It may also be conducted within buildings at ground or basement level if necessary and not being confined to profile operations, enables lateral definition.



He also briefly covered the procedures of data acquisition, data processes and geological modelling/ interpretation as well as the QA/QC checks in carrying out gravity survey. Examples of the advantages that could accrue is illustrated by the use of gravity survey as one of the key approaches to identify the potential fault line in locality of the proposed Sentul West Station and deep limestone depression/ karstic solution detected in the proposed Chan Sow Lin Station, which would not have been apparent from the pre-existing borehole exploration. A vertical borehole was repositioned close to the centre of the survey area to investigate the contrasting conditions of locally deep depression indicated by the interpretation model. On hindsight, without proper geophysical survey as the guiding tool for repositioning the borehole location, karstic features within the limestone may be frequently unrecognized by adding boreholes in random or conveniently available locations.

Throughout the talk, Er. Poh shared a lot of photographs/ sketches and pulled out some anecdotes from this previous design experiences. The two-hour talk was very informative and followed by an interactive question-and-answer session. An obviously appreciative audience fielded many questions as they eagerly wanted to learn more. As a token of appreciation, the Chairman of TUSTD presented a certificate and the book, Engineering Heritage of Malaysia, to Er. Poh Seng Tiok.