Technical Talk on Some Experience on Application of Buttressed Diaphragm Wall in Limiting Excavation-Induced Ground Movements in Kenny Hill Formation

by Ir. Khoo Chee Min

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For urban underground construction, ground improvements and strengthening of lateral earth support systems are commonly adopted as measures to control movements induced by deep excavation. In accordance with the Railways (Railway Protection Zone) Regulation 1998, the maximum allowable movement of railway structures/tunnel caused by adjacent development works shall not exceed 15mm. Given this stringent requirement on railway structures/tunnel movements, the above measures may not be adequate to control excavation-induced movements in certain circumstances. Therefore, an additional auxiliary measure such as incorporation of buttress walls and cross walls to diaphragm wall may be required to control movements of the latter, induced by deep excavation to a tolerable limit.

Ir. Dr Law Kim Hing, Principal of KH Geotechnical Sdn Bhd, was recently invited by Tunnelling & Underground Space Technical Division (TUSTD), IEM to share his experience in this subject matter through an evening technical talk on 31 May 2019. The talk was held at Auditorium Tan Sri Prof. Chin Fung Kee, Wisma IEM and was well attended by 37 IEM members. The talk focused on 3 case histories in which buttressed diaphragm wall was adopted as a support system in deep basement excavation in Kenny Hill formation for movement control of underground tunnels and its surrounding ground. Both field performance and 3D numerical analysis results for the case histories were presented and discussed during the talk.

Buttress walls are basically concrete cast-in-situ walls perpendicular to diaphragm wall constructed before commencement of deep excavation (see Figure 1). Overall diaphragm wall movement is expected to be restrained to a certain extend with the restraining buttress walls. This is in light of the increased overall lateral resistance through frictional resistance developed on both sides of each buttress wall on top of the increased flexural stiffness provided by the buttressed diaphragm wall system. There are generally four types of buttress wall construction as illustrated in Figure 2.

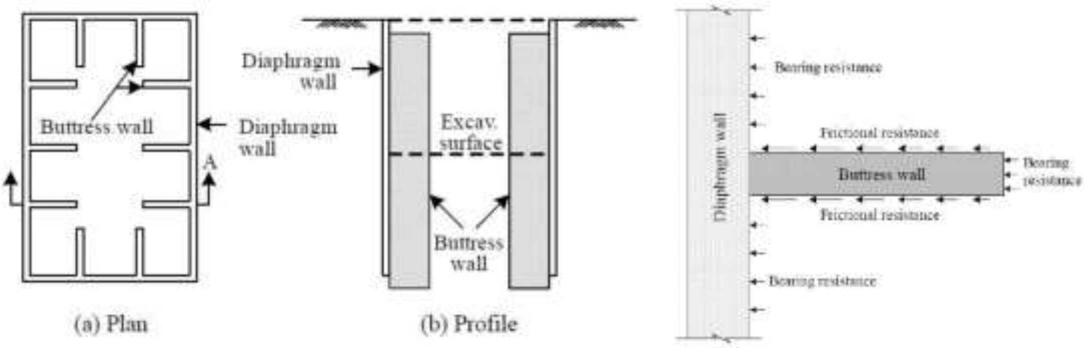

Figure 1: Schematic representation of buttress wall

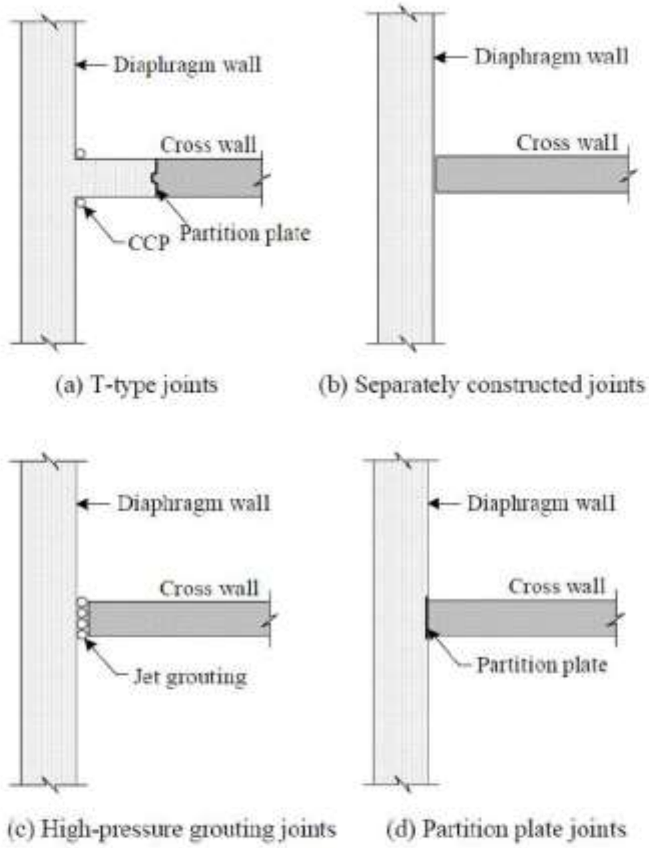

Figure 2: Types of buttress wall

Case 1 involved the application of cantilever buttressed diaphragm wall for a 11m deep strut-free wide excavation. The project site having a rectangular-shaped boundary of 165m x 100m is supported by 600mm thick diaphragm wall with 600mm thick unreinforced buttress walls spaced at 6.5m centres (4m long each). Dr Law rationalised the application of buttress walls was made possible for an open excavation with reasonably good ground control at this large excavation site against the conventionally adopted lateral support system either using internal steel strut bracings/ tie-back anchors or even propping of basement floor slabs via top-down construction method. The introduction of buttress walls had effectively reduced the diaphragm wall deflection as well as the induced wall bending moment. Needless to say, substantial time and cost savings have been realised with the strut-free buttressed diaphragm wall excavation system at this project site.

Case 2 involved the application of buttress walls in combination with top-down construction method for a 22.5m deep basement excavation to limit the excavation-induced tunnel movement. The operating railway tunnels which run parallel to one side of the excavation, is located at 15.5m below the ground at the nearest distance to the proposed diaphragm wall measuring 6.3m from tunnel centre-line. A series of parametric analyses were carried out to explore the effects of buttress walls spacing, thickness and length on existing tunnel as well as diaphragm wall movements. In addition, the relative effectiveness of the sequentially removing-off and not removing-off buttress walls on the displacement of the tunnel and diaphragm wall is also compared.

Some of the insightful analysis findings shared by Dr Law are as below:

(i) Influence of buttress walls spacing – as expected the wall deflection decreases with reducing buttress walls spacing. The rate of reduction in wall deflection is consistent and seems to correlate linearly to buttress walls spacing.

(ii) Influence of buttress walls length – the wall deflection decreases with the increase of the buttress walls length. The decrease does not seem to be significant when buttress length reaches 9m and above. Separately, a comparison study of 3m, 6m, 9m and 12m long buttress walls revealed that 3m long buttress wall has a poor effect in reducing the wall and tunnel displacement.

(iii) Influence of buttress walls thickness – the thickness of buttress wall plays a relatively minor role in reducing the tunnel displacement.

(iv) Influence of progressive removal of buttress walls – to achieve optimum performance in minimising tunnel displacement, buttress walls should not be sequentially removed-off during the excavation.

Case 3 involved the application of buttress wall in combination with ground anchor tie-back method for a 20m deep basement excavation to limit the on-grade railway track movement. This is a challenging urban redevelopment site concerning the use of underground space in large-scale for commercial complex, car parking lots and underground road connectivity. The development site was opened up for basement excavation in multiple phases. At one location, the deep excavation was being carried out in close proximity to two existing interchange railway stations, one at grade and the other elevated. Anchored diaphragm wall was adopted in combination with buttress walls as earth retaining system to control the ground and track movements in facilitating both the deep excavation and underground construction works. It was demonstrated that adopting full height buttress walls could successfully reduce both wall and ground movements.

Dr Law ended his talk with a summary of take-away points and lessons learned. After which, the floor was opened for questions and answers session, which was actively conducted. This was followed by a presentation of mementos and certificate of appreciation to the speaker by Ir. Khoo Chee Min, Chairman of TUSTD, IEM.

Dr Law gladly fielding questions from attendees during the Q&A session