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Case History-2

Application of Special Press-in Piling Method for ERSS in Singapore

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In view of the urbanisation and scarcity of land, basement construction at close proximity to existing buildings is common in Singapore for residential and commercial developments. To facilitate the construction of the basement and sub-structures, sheet pile wall is often considered as an economical and efficient form of temporary earth retaining system. Sheet pile wall is designed with wall penetration into firm stratum to prevent toe kick, base instability and to achieve the desire serviceability wall deflection requirement.

■ Noise and vibration

Conventional sheet pile installation using vibro-hammer generate significant amount of noise and vibration that exceed the tolerable limits. In some cases the vibration may cause damages to adjacent buildings and services. The maximum permissible noise levels for construction work allowed by the National Environment Agency (NEA) are shown in Table 1 and Table 2. The noise generated by sheet piling install using vibratory hammer ranges between 70dBA and 90dBA, which exceed the general requirement set by NEA.

Types of affected buildings	7am - 7pm	7pm - 10pm	10pm - 7am
(a) Hospital, schools, institutions of higher learning, homes for aged sick, etc	60 dBA (Leq 12 hr)	50 dBA (Leq 12 hr)	
	75 dBA (Leq 5 min)	55 dBA (Leq 5 min)	
(b) Residential buildings located less than 150m from the construction site	75 dBA (Leq 12 hr)	65 dBA (Leq 1 hr)	55 dBA (Leq 1 hr)
	90 dBA (Leq 5 min)	70 dBA (Leq 5 min)	55 dBA (Leq 5 min)
(c) Buildings other than those in (a) and (b) above	75 dBA (Leq 12 hr)	65 dBA (Leq 12 hr)	
	90 dBA (Leq 5 min)	70 dBA (Leq 5 min)	

Table 1 maximum permissible noise levels for construction work on Monday to Saturday

Types of affected buildings	7am - 7pm	7pm - 10pm	10pm - 7am
(a) Hospital, schools, institutions of higher learning, homes for aged sick, etc	60 dBA (Leq 12 hr)	50 dBA (Leq 12 hr)	
	75 dBA (Leq 5 min)	55 dBA (Leq 5 min)	
(b) Residential buildings located less than 150m from the construction site	75 dBA (Leq 12 hr)	65 dBA (Leq 1 hr)	55 dBA (Leq 1 hr)
	90 dBA (Leq 5 min)	70 dBA (Leq 5 min)	55 dBA (Leq 5 min)
(c) Buildings other than those in (a) and (b) above	75 dBA (Leq 12 hr)	65 dBA (Leq 12 hr)	
	90 dBA (Leq 5 min)	70 dBA (Leq 5 min)	

Table 2 maximum permissible noise levels for construction work on Sunday and Public Holidays

In accordance with Eurocode 3, the maximum acceptable vibrations to avoid structural damage for various types of structure ranges between 2 mm/s to 25 mm/s. However, the maximum acceptable vibrations to human is much lower, i.e. below 5 mm/s, as shown in Figure 1. White & Deeks (2007) has demonstrates that press-in technology using silent piler is able to keep the vibration during installation work to below the human acceptable limits as shown in Figure 2.

■ Hard driving

Based on local experience, sheet pile installation by silent piler or vibro hammer will hit refusal in soil stratum with SPT N ranges between 25 and 35 blows/30cm. The problem of noise and vibration will be amplified when the sheet pile is driven forcefully into hard soil stratum. Hard driving may cause de-clutching of sheet piles which could result in even bigger problem on site such as inflow of soil into the excavation through gaps between sheet piles and sink hole behind the wall. Common methods available to overcome the installation of sheet pile in hard soil stratum include: Pre-bore using contiguous flight auger, press-in method assisted by water jetting, press-in method assisted by augering and change of type retaining wall system from sheet pile wall to pre-bored soldier pile wall or contiguous bored pile wall system. Care should be taken when pre-boring using contiguous flight auger is adopted. The soil loosen by the pre-boring or pre-augering will cause excessive wall deflection during the excavation.

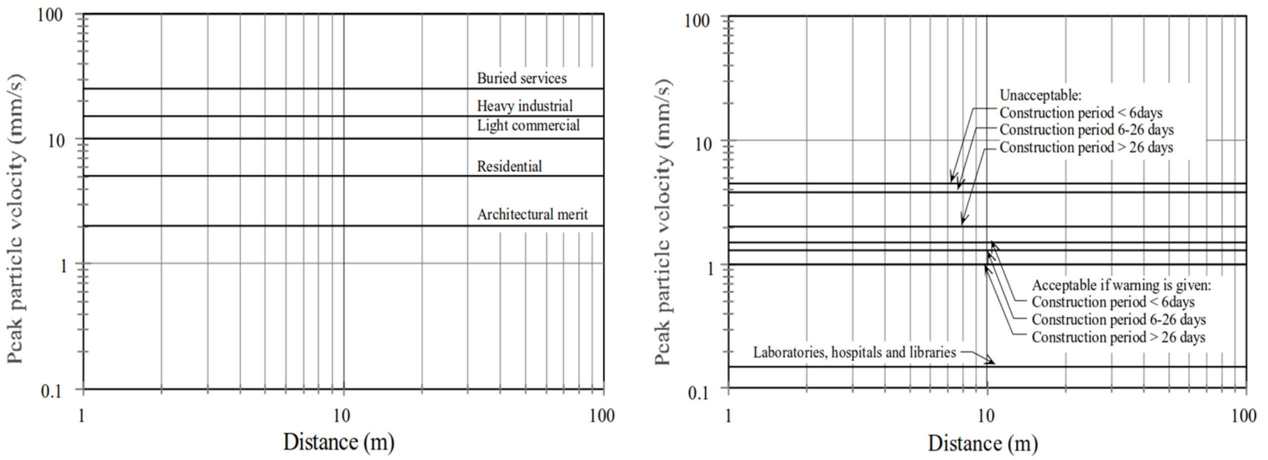

Figure 1 Maximum acceptable vibrations to avoid structural damage and to prevent human disturbance

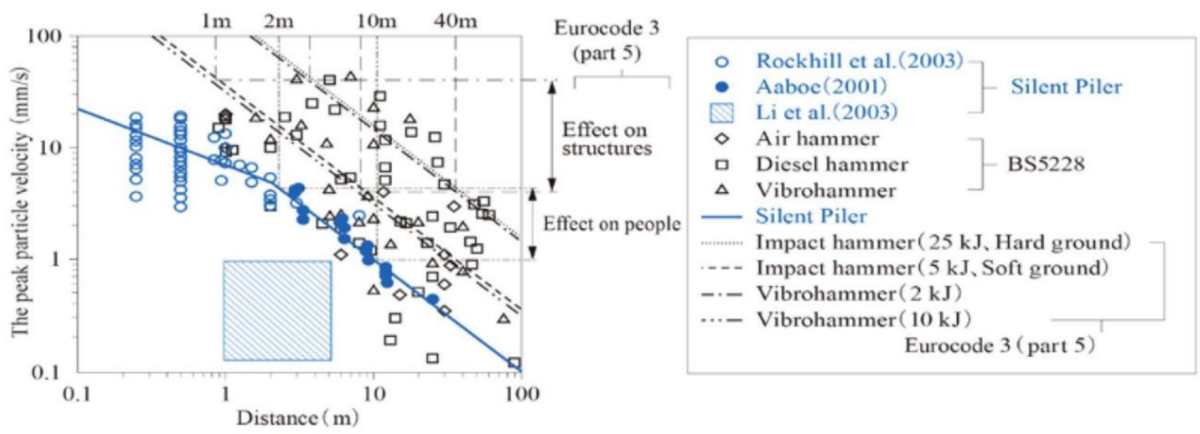

Figure 2 Comparison of vibration characteristics between driving and press-in (after White and Deeks, 2007)

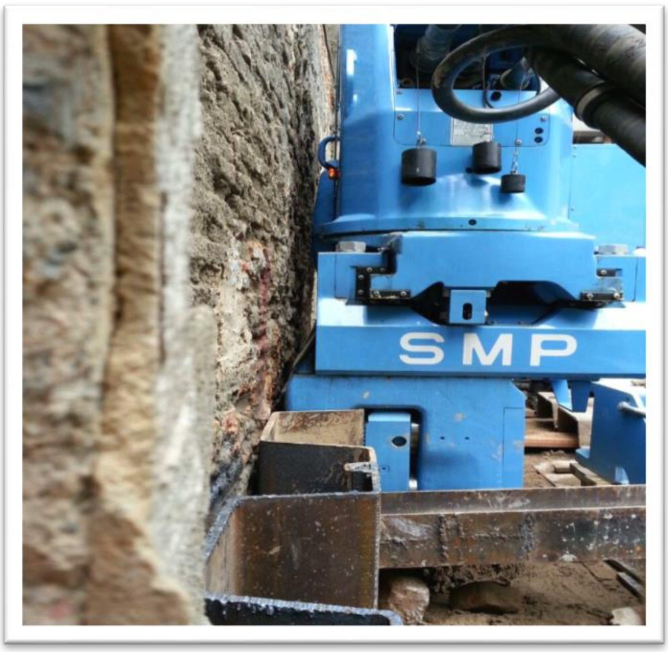

Figure 3 Zero clearance press-in method

■ Sheet pile construction next to existing structure

In land scarce Singapore, architect and developer has inclination to construct the building and substructure all the way to the land boundary. In development where the proposed sub-structure is to be built next to existing structures, conventional sheet piling method is sometime not feasible due to the lack of working space required for the machinery to install the sheet piles.

To overcome such site constraint, zero clearance press-in method or zero piler as shown in Figure 3 could be used.

Case Study #1: Press-in method assisted by augering

The proposed landed property is bounded by public road on the front and back of the development and two existing buildings on the other two sides. The ground level of the site is sloping from the back to the front of the house as shown in Figure 4. The maximum retained height for the basement is 3.3m from the existing ground level.

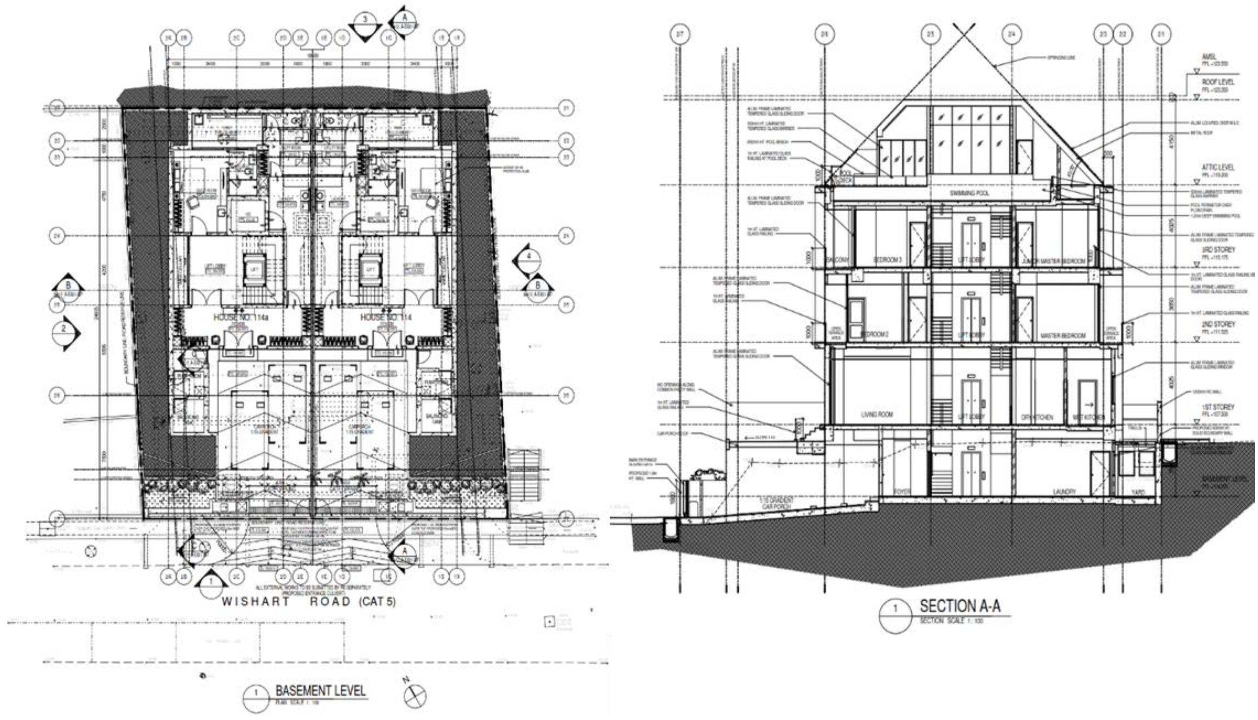

Figure 4 Basement plan and cross section for Case Study #1

DIA. OF BORING: 100mm
BORE HOLE NO: BH 1
WATER TABLE: 4.04m bgl on 20/04/13
JOB REF. NO.: GSS/7573/13

DEPTH (m)	SYMBOL	SAMPLE NO.	THICKNESS (m)	SOIL DESCRIPTION Surf.El: 106.6mRL(Approx) Coordinates: E:,N:	BLOWS/30cm N	DEPTH (m)	Undrained Shear Strength c_u (kN/m^2)	$\phi°$	M/C %	Bulk den. Mg/m^3	LL %	PL %
0.30		D1	0.30	Loose dark yellowish brown and dark brown fine and medium SAND with some fine gravel. (Fill)								
1.10		D2	0.80	Firm brownish yellow and reddish orange very Sandy SILT. (Fill)								
2.00		D3 UD1	0.90	Very loose to loose reddish orange and brown Clayey fine to coarse SAND. (Fill)		UD1 : 1.50-2.00			17	2.04	31	17
2.70		D4 SPT1	0.70	Soft to firm reddish orange and brown Sandy SILT. (Fill)	4	SPT1 : 2.00-2.45						
3.50		D5 UD2	0.80	Firm brownish yellow and reddish orange Sandy CLAY. (RS; Class E-JF)		UD2 : 3.00-3.50	41	0	21	2.05	36	15
4.10		D6 SPT2	0.60	Hard brownish yellow and yellowish grey Sandy SILT. (RS; Class E-JF)	42	SPT2 : 3.50-3.95						
5.50		D7 SPT3	1.40	Hard brownish yellow very Sandy SILT. (RS; Class E-JF)	100/12cm	SPT3 : 4.50-4.69						
		D8 SPT4			100/14cm	SPT4 : 6.00-6.22						

Figure 5 Borehole log for Case Study #1

Figure 5 shows the borehole log from the soil investigation. The typical ground condition comprises of 3.0m thick Fill layer comprises of clayey sand/sandy silt with SPT N < 10 overlying 1.0m thick residual soil with SPT N > 40. Beneath the residual soil is completely weathered Jurong Formation with SPT N > 100.

In view of the relatively shallow retained height and tight construction space, temporary sheet pile wall is considered to be the most economical solution. The close proximity of the proposed construction to surrounding buildings call for more environment friendly press-in method. To overcome the hard soil stratum from the depth of 4m below the existing ground level, press-in method assisted by augering was adopted.

The proposed sheet pile wall and strutting layout is shown in Figure 6. The sheet pile is supported by diagonal strut and raker struts. Figure 7 shows the typical finite element model used to analyze and design the temporary earth retaining system. During the progress of the excavation, the performance of the sheet pile wall was monitored by inclinometers. It was noted that the maximum sheet pile wall deflection exceeded the predicted value before the installation of the struts.

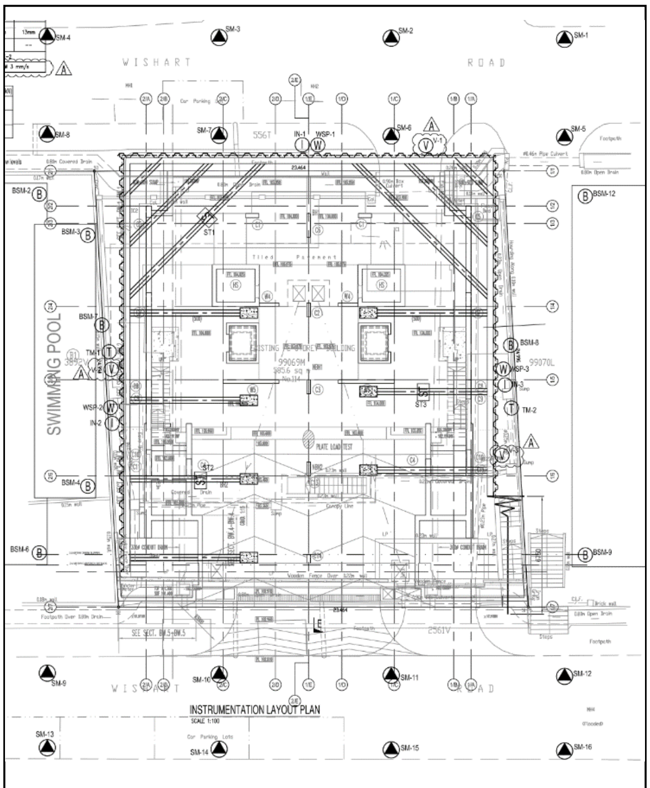

Figure 6 Sheet pile wall and strutting layout plan

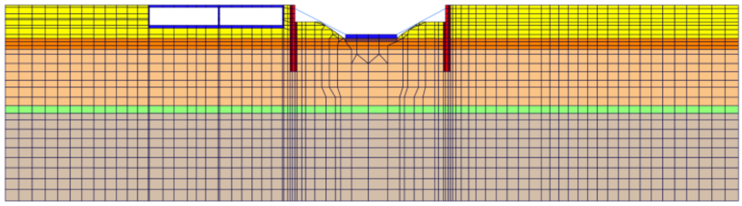

Figure 7 Finite element model

Results of inclinometer is presented in Figure 8. Soil loosening around the sheet pile, due to the pre-augering, was identified on site. Back-analysis was then carried out by simulating a localized zone of loose soil around the sheet pile wall. The revised numerical prediction was able to reproduce the measured wall deflection quite well. This shows that the soil loosening effect by pre-augering is likely to be the cause for the additional 'unexpected' lateral deflection measured by the inclinometer.

Hence, in the design of press-in assisted by augering, the loosening effect around the sheet pile wall shall be taken into consideration. The adverse effect is most critical when the sheet pile wall is acting in cantilever mode.

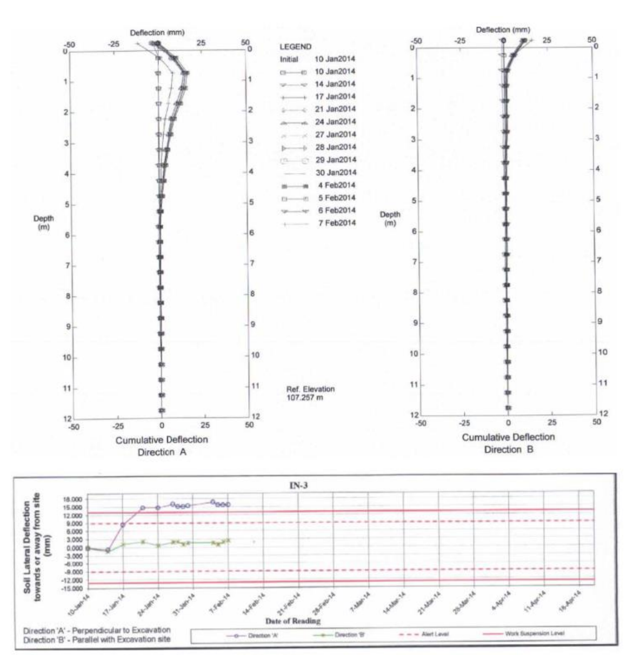

Figure 8 Sheet pile wall deflection due to excavation

Case Study #2: zero clearance press-in method

The Case Study #2 is a hotel development sandwiched between two existing buildings. One of the existing building is supported on raft foundation while the other is supported on piles. The architect and developer has decided to construct the new hotel fully to the legal boundary, abutting the existing building. The plan and typical section of the proposed excavation is shown in Figure 9.

The maximum depth of excavation required to construct the pile caps and deep perimeter ground beams is 3.75m. The boundary wall of the existing building is literally abutting the new structure and there is little space left for installation of any form of temporary earth retaining system. Hence, zero clearance press-in method was adopted. 9m length cantilever sheet pile wall was proposed for retained height more than 3m while 6m length cantilever sheet pile wall was proposed for retained height less than 3m.

Zero clearance press-in method uses a special type of sheet pile, named zero sheet pile NS-SP-J. The zero sheet pile is 600mm wide each and has interlock joint on the outer elements of the section. This is different from conventional U-shaped sheet pile where the interlocks are located on the neutral axis. Because of its unique design, the flexural stiffness (EI) of individual zero sheet pile is equivalent to Type SP-V_L U-shaped sheet pile even though the thickness of zero sheet pile is relatively much thinner as compared to the latter.

However, for plane strain finite element analysis, the EI per metre length of wall is more relevant, and not the EI for a single sheet pile. In term of EI per metre of wall, the EI of zero sheet pile is 12,090 cm^4/m as oppose to 16,800 cm^4/m for Type SP-III and 38,600 cm^4/m for Type SP-IV sheet pile, respectively. The designer adopting zero clearance press-in method should beware that the stiffness of zero sheet pile is merely 72% of sheet pile SP-III and 31% of sheet pile type SP-IV, even though a single zero sheet pile can be as strong as sheet pile type SP-V_L.

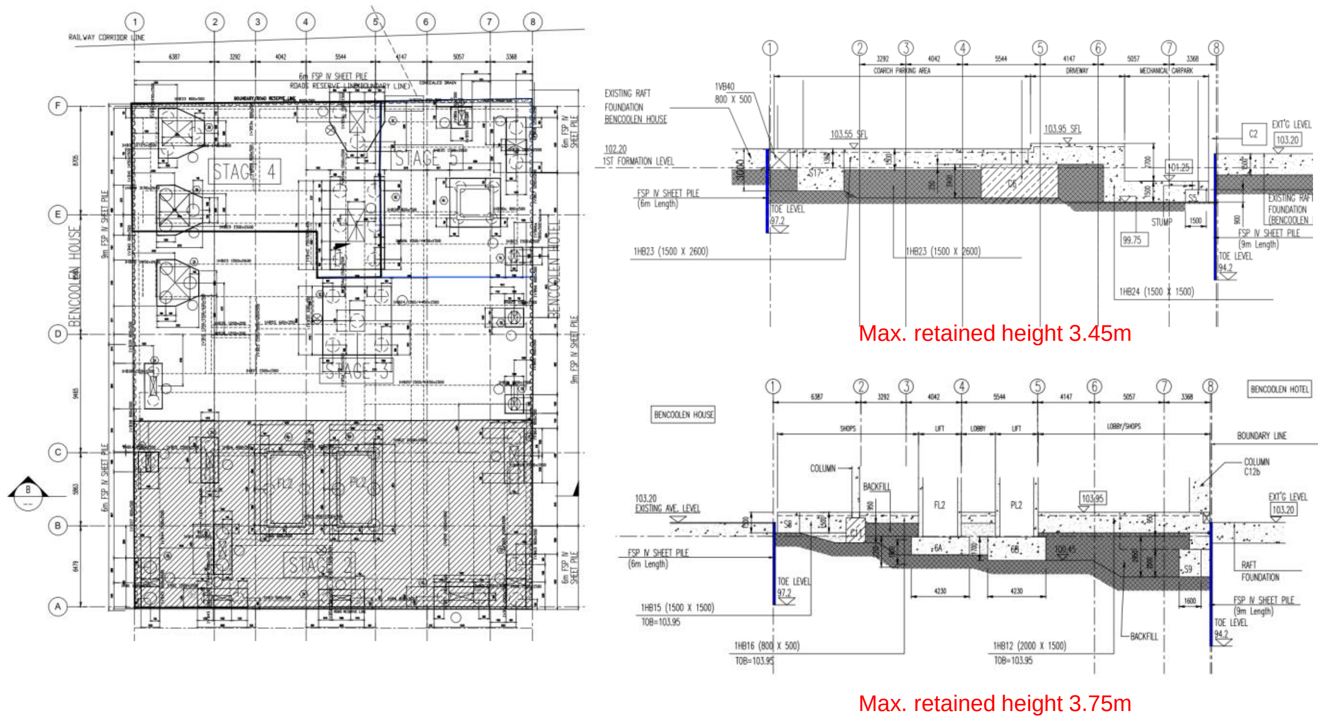

Figure 9 Plan and section of substructure for Case Study #2

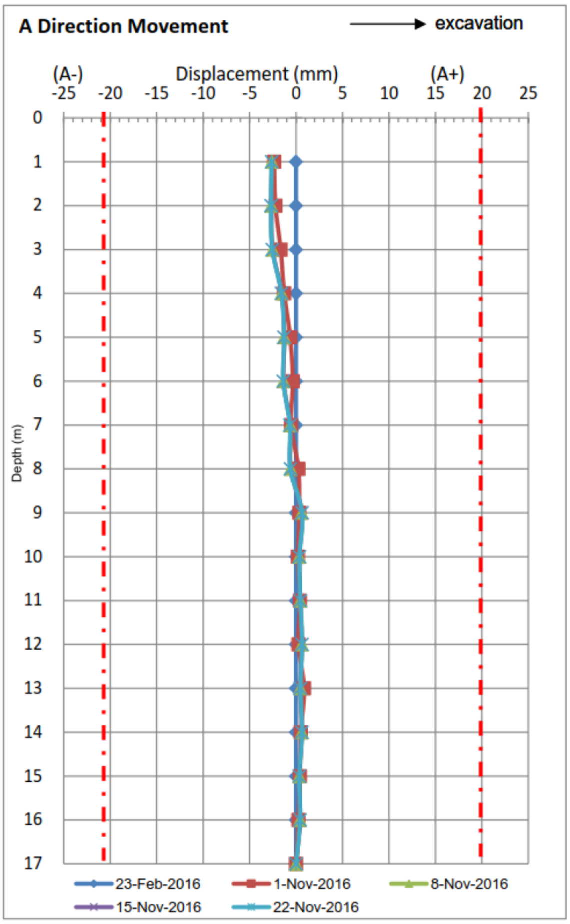

Figure 10 Sheet pile wall deflection due to excavation

A comprehensive instrumentation and monitoring scheme has been devised to ensure that the temporary earth retaining system is performing as per the design prediction and does not induce excessive lateral ground movement or settlement beyond the acceptable limits.

Figure 10 shows the results of inclinometer measured during the excavation. The measured sheet pile deflection is fairly small and well within the prediction. This shows that even though the stiffness of zero sheet pile may be relatively low, if use appropriately, its performance is satisfactorily.

Conclusions

- Conventional sheet pile installation using vibro hammer generates excessive noise and ground vibration that exceed the limit tolerable by human
- Stringent control has been imposed by NEA for construction near to residential and sensitive structures
- Press-in piling method could be used to mitigate the problem of noise and vibration
- Press-in method with simultaneous augering system could be adopted to overcome pile penetration in hard soil / weak rock
- Design should take into consideration the soil loosening effect around the sheet pile due to the pre-augering
- Zero clearance press-in method could be adopted in site with very tight space constraint.
- Proper sheet pile properties shall be adopted in the analysis and design if zero sheet pile is used