Landmarks in Earth Reinforcement, Ochiai et al. (eds),
© 2001 Swets & Zeitlinger, ISBN 90 2651 863 3

The resistance of jacked-in pipe inclusions in soft soil

Tan Siew Ann, Cheang Wai Lum, Yong Kwet Yew & Ganeswara R. Dasari
Department of Civil Engineering, National University of Singapore

ABSTRACT: The technique of soil nailing, a method of earth reinforcement is a promising technique in slope stabilisation and as a support system in excavations. Due to its rapid top-down construction and cost-effectiveness, this method of earth reinforcement is going through tremendous growth in the geotechnical fraternity.

However much is still to be learned as the understanding of this technique is still very much in its infancy, specifically the use of nail inclusions in clayey soil conditions. Some of the current code of practices suggested that the technique of soil nailing is not well suited for soft clayey soils of low shear strength, of high liquidity index and soils where the SPT 'N' value is very low. Primarily, these restrictions are empirically based, as little data exist on the working mechanisms, deformations and stresses induced in the reinforced soil mass by the soil nail inclusions when this method is applied in soft clayey soil conditions. This paper attempts to highlight one of the possible modes of resistance of nail inclusions in clayey soils. Reported herein is a case history where jacked-in pipes which perform as soil nails were used in support of a deep excavation. The method of installation causes soil disturbances, compaction and increase in the interfacial shaft resistance of the inclusions. Nail set-up was primarily caused by re-equalisation of excess pore-water pressures, corresponding with a time-dependent increase in the effective radial stresses around the nail periphery. Coupled non-linear finite element analyses were conducted to investigate the phenomena of jack-in installation, which causes soil disturbance, the build-up of excess pore-water pressures and the subsequent increased in effective radial stress due to re-consolidation.

It was found that this technique of reinforcing the ground with jack-in pipes was effective in stabilising vertical cuts and arresting movements in soft clayey soil conditions.

1 INTRODUCTION

The geotechnical group at NUS has been involved in a sustained research effort to investigate the behaviour of soil nails in tropical residual soils. These efforts were motivated by the versatility and cost-effectiveness of soil nails in stabilising slopes and excavations. More recently, work has focused on developing sound methods for the prediction of nail pull-out capacity (Tan et.al.,1998, Tan et. al., 1999).

Reported herein is a case history on the utilisation of structural steel pipes as passive nail inclusions. These inclusions were used for the stabilisation of a deep excavation in soft tropical residual soil. The conventional technique of constructing a nail inclusion involves drilling a borehole to the required length and inclination, inserting an appropriate bar and filling the cavity with grout. This installation technique is a replacement method, whereby the volume of soil being removed is equal to the volume of the constructed nail and it involves predominantly the relief of soil stresses around the periphery of the inclusion. On the other end of spectrum, the construction of a nail which is carried either by driving or jacking involves the displacement of soil and hence generally an increase in the mean effective pressure around the nail.

This paper will highlight a novel method of nail installation by jacking steel pipes. It was used in conjunction with a contiguous bored pile wall for a deep vertical excavation in soft tropical residual soil in Malaysia. The aforementioned case history was reported by Cheang et.al. (1999). Another case history where this technique was used in conjunction with a flexible sheetpile wall was reported by Liew et.al. (2000).

2 A BRIEF DESCRIPTION ON THE USJ-19 NAILED EXCAVATION

The deep excavation project (Photo 1), which is located at Subang Jaya of Malaysia consists of three condominium towers of 33 storeys and a single 20-storey office tower. Due to the huge demand for parking space, an approximately three storey deep

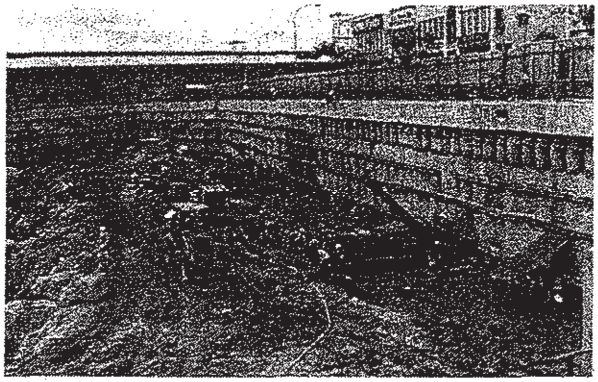

Photo 1: After second stage of construction

vehicular parking basement will be required. The deep excavation, through a filled layer of very loose silty sand and soft peaty clay varies from 11m to 13m. The presence of very soft soil condition and the fast track requirement of the project, contiguous bored pile (CBP) walls supported by jack-in pipe inclusions in six to seven rows were utilised to stabilise and control the lateral displacement and surface settlement. The supported face is approximately 6900 m^2.

2.1 *Subsurface geology*

The general subsurface soil profile of the site, shown in Figure 1 consists in the order of succession a firm clayey SILT, a loose to medium dense SAND followed by firm to hard clayey SILT. The soils are inter-layered by thick deposits of very soft dark peaty CLAY.

The plot of SPT'N' values, illustrated in Figure 2, shows significant scattering which is commonly found in tropical residual soils in the area. However the trend of the scatter plot shows that the SPT 'N' values increases with depth. For the underlain soft clayey material, the registered SPT 'N' values were zero and Vane Shear strength varies from 5 kPa to 20 kPa.

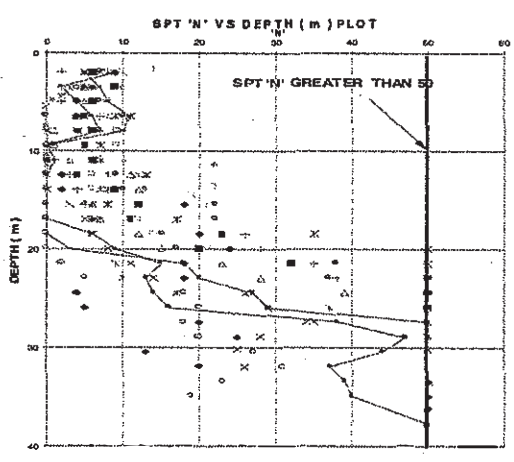

Figure 1. SPT 'N' values

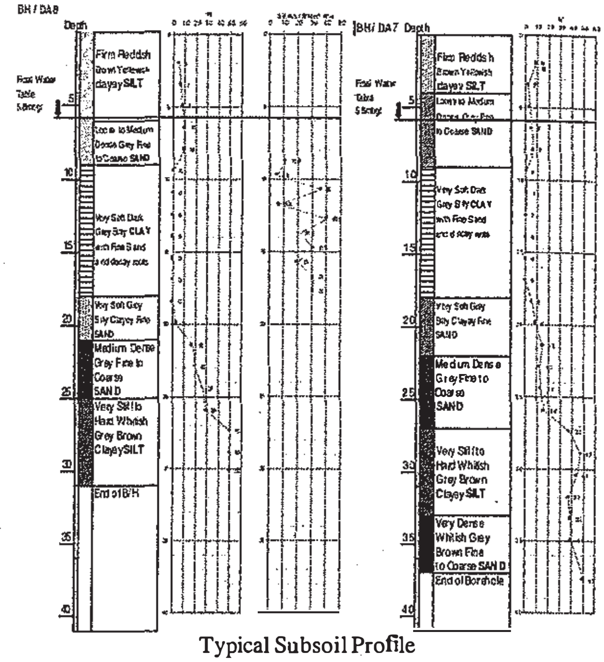

Figure 2. Sub-surface geology

2.2 *The hybrid system*

2.2.1 *Jacked-in pipe inclusions*

Mild steel pipes which functions as soil nails are installed by hydraulic jacking. This method has proven to be an efficient and effective technique for excavation support, where conventional soil nails and ground anchors have little success in such difficult soft soil conditions. Such conditions are sandy collapsible soil, high water table and in very soft clayey soils where there is a lack of short-term pullout resistance. In view of the close proximity of commercial buildings to the deep excavation, a very stiff retaining system was required to ensure minimal ground movements at the retained side of the excavation. Contiguous bored piles were installed along the perimeter of the excavation and supported by jack-in pipes.

In the initial design, conventional ground anchors were proposed, but the jacked-in pipes were accepted as an alternative as it was not feasible to locate the fixed lengths of the anchors at very deep depths. From experience gathered by the contractor from past application of this technique in similar ground condition, it was found that this technique would provide a cheaper alterative and site adaptability. Relatively, larger wall movements will occur for this support system when compared to ground anchors since soil movement is required to mobilised the tensile resistance of the passive inclusions. However it was anticipated that the ground settlement at the retained side and maximum lateral displacement of the wall using this system would still be within the required tolerance after engineering assessment.

2.2.2 *The construction sequence*

The retaining wall system consists of closely spaced 1000mm diameter bored piles near the commercial buildings and 800mm diameter for area away from the commercial buildings. To facilitate the Top-Down excavation of the deep basement, pipes of 150mm diameter were jacked in sub-horizontally after each excavation stage. The phases of the basement construction are described in Figure 3.

2.3 *Geotechnical instrumentation and field data*

The geotechnical instrumentation program consists of 18 vertical inclinometer tubes located strategically along the perimeter of the contiguous bore pile wall and 30 optical survey markers for settlement monitoring.

Figure 6 shows the trend of measured horizontal displacement of the hybrid system at successive excavation stages. The deflection profile exhibits predominantly restrained cantilever effect due to the reinforcement effect of nail inclusions.

Stage 0	Installation of Contiguous Bored Pile Wall
Stage 1	Excavation 1: Excavation to 2.7m below ground level
Stage 2	Jacked-in pipe: Level 1 at 1.7m below ground level.
Stage 3	Excavation 2. Excavation to 4.5m below ground level.
Stage 4	Jacked-in pipe: Level 2 at 3.5m below ground level.
Stage 5	Excavation 3: Excavation to 6m below ground level.
Stage 6	Jacked-in pipe: Level 3 at 5m below ground level.
Stage 7	Excavation 4: Excavation to 7.5m below ground level
Stage 8	Jacked-in pipe: Level 4 at 6.5m below ground level

Figure 3. Construction stages

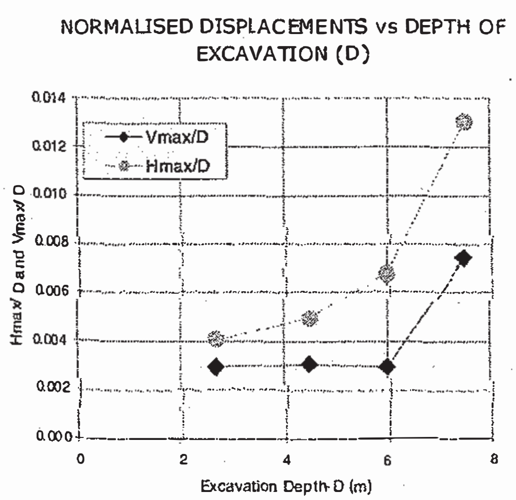

Figure 4. Normalised horizontal and vertical displacements

2.4 *Performance of the hybrid system*

The maximum displacement of a soil nailed system generally ranges from H/1000 to 4H/1000 (Clouterre, 1998). It is of interest to find out how this hybrid system compares with conventional soil nailed systems. For this system, the maximum ever recorded horizontal displacement after an excavation depth of 7.5m (stage 8) was 98mm and its corresponding normalised value is 0.013.or 13H/1000. This value is not within the range of H/1000 (7.5mm) to 4H/1000 (30mm). This is expected as the normalised values that ranges from H/1000 to 4H/1000 were obtained from field studies conducted in stiff competent soils.

2.4.1 *Horizontal deflection*

Figures 4 and 5 shows the normalised maximum horizontal displacement for various excavation depths for a critical section of the excavation. The trend of increment seems to indicate that when the excavation reaches a depth of 6m, there is a sharp drastic increased in the horizontal deflection for the whole hybrid support system. In may be speculated that as the excavation reaches the 6m depth, the soil mass at the retained side has reached full plasticity. It is further speculated that due to the presence of the long nail inclusions it changes the strain profile of the soil (Basset & Last, 1978), large wall movements were required to attain full plasticity of the soil mass at the retained side. This global mode of resistance exhibited by the presence of the nail inclusions is known as strain arrestment (Basset et.al., 1999).

2.4.2 *Vertical settlement*

The normalised vertical displacement for the whole support system is shown in Figures 4 and 5. The normalised vertical displacement for an excavation depth of 2.7m to 6m reaches a constant value. How-

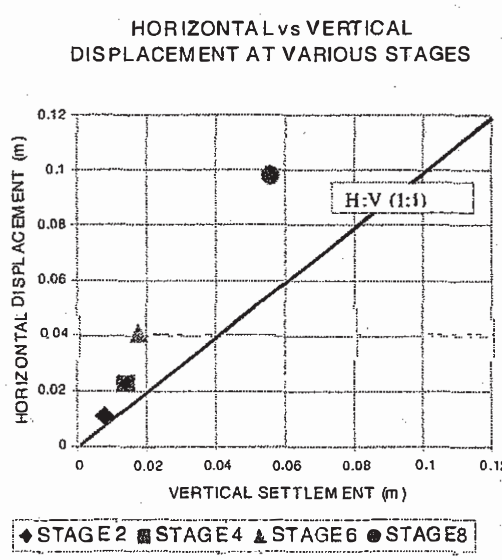

Figure 5. Horizontal and vertical displacements

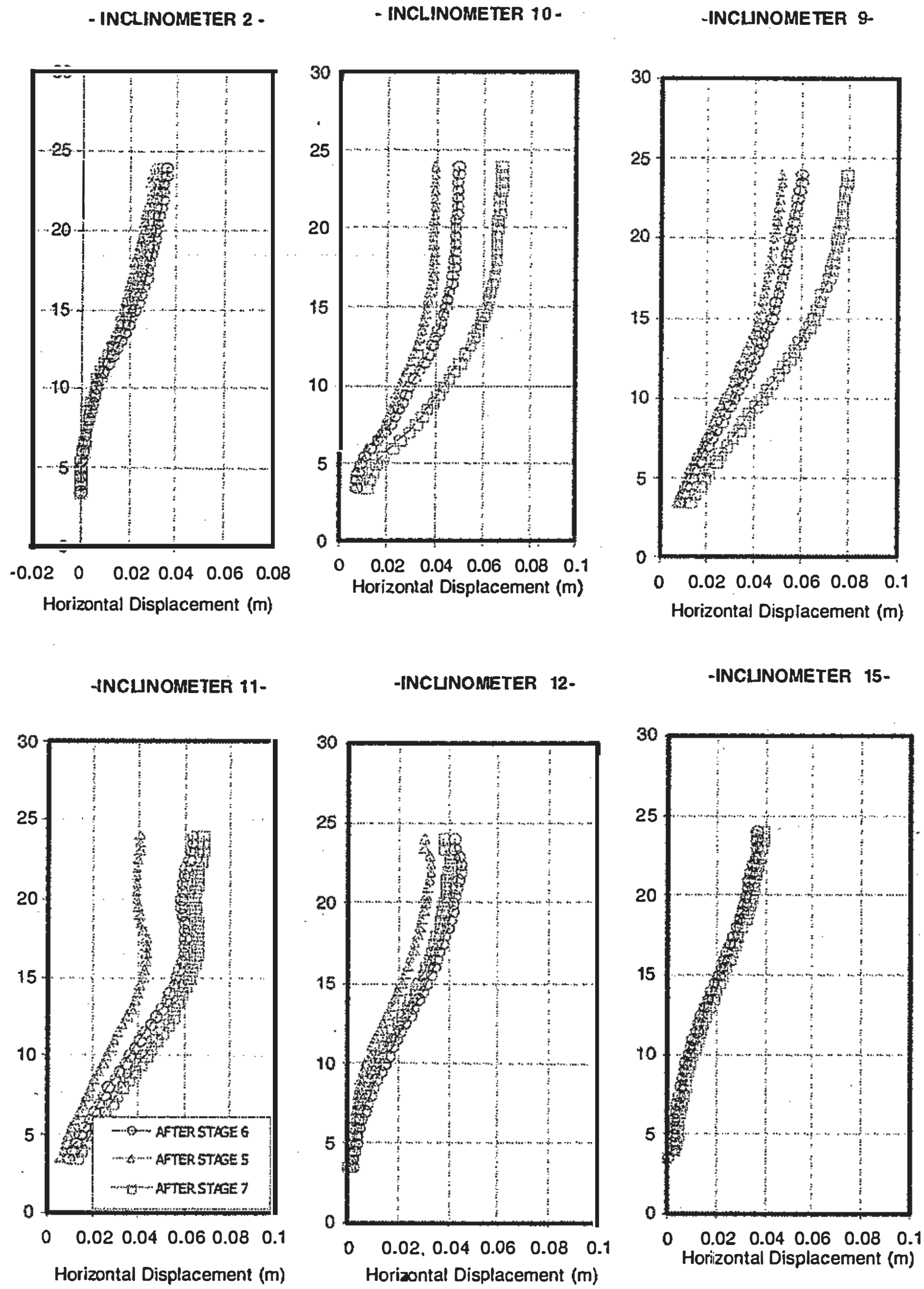

Figure 6a. Summary of geotechnical field data on measured deflection profiles.

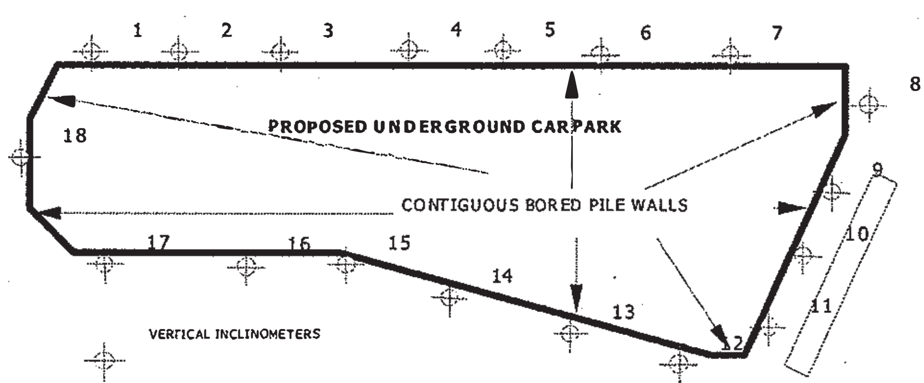

Figure 6b. Location of field monitoring positions

ever there is a trend of sharp increase in soil settlement at the retained side when the excavation reaches a depth of 6m and it corresponds to the instance when there was a sharp increased in horizontal displacement.

2.4.3 *Overall effect of the inclusions*

The presence of the long inclusions changes the strain field of the retained mass. The reinforced soil mass acted very much in a homogenized manner and this can be seen from the restrained cantilever deflection profile of the CBP wall as shown in Figure 7.

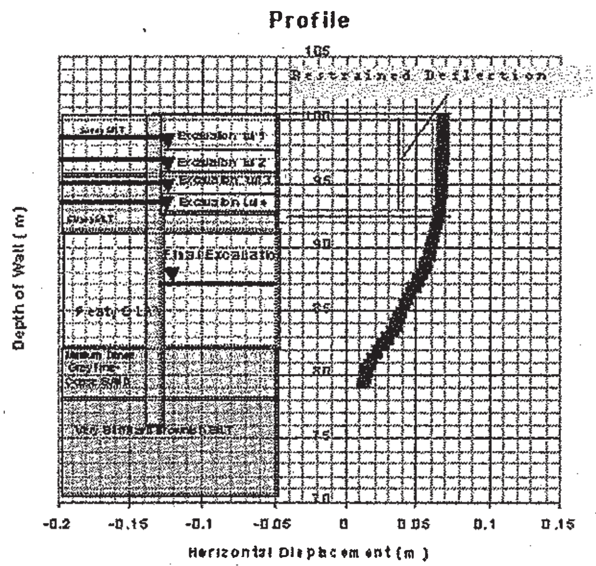

Figure 7. Restrained cantilever deflection profile

3 CONCLUSION

Reported herein is a case study where passive nail inclusions were used in conjunction with stiff cast in-situ wall for the stabilisation of a deep excavation located in soft soils.

This technique of soil nailing is a departure from the conventional method of nailing as it was used in conjunction with a stiff cast in-situ for the stabilisation of a deep excavation in soft soil. The measured deflection profile of the system indicated that movements were restrained and as the excavation progresses to a depth of 6m, there was a sharp increased in wall lateral movement.

Overall, this new hybrid support system located in soft soil has performed well.

4 ACKNOWLEDGEMENTS

The authors would like to thank SGE Sdn. Bhd for the provision of field data and support. Many thanks to Ir. Dr. Gue See Sew for his kind assistance.

REFERENCES

Basset, R.H, Tan, S.A & Cheang, W.L., 1999, Private Communication.

Basset, R.H & Last, H.C, 1978, Reinforced Earth below footings and embankments. Proceedings of ASCE Symposium, on Earth Reinforcement, Pittsburgh, 212-221.

CLOUTERRE French National Research Project, 1993, Recommendations Clouterre 1991-Soil Nailing Recommendations, Presses de l'Ecole Nationale des Ponts et Claussees.

Cheang, W.L., Tan, S.A., Yong, K.Y., Gue, S.S., AW, H.C., Yu, H.T. & Liew, Y.L. ,2000, Jacked-in pipe reinforcement of a deep excavation in soft soil, Field measurements in geomechanics, 311-318, Balkema.

Liew, S.S, Tan, Y.C. & Chen, C.S. 2000, Design, Installation and Performance of Jack-in Pipe Anchorage System for Temporary Retaining Structures, International Conference on Geotechnical and Geological Engineering. GeoEng 2000, Balkema.

Tan, S.A., Cheang, W.L., Yong, K.Y. & Dasari, G.R., 2001, Resistance of Jacked-in Pipe Inclusions in Soft Soil, International Symposium on Earth Reinforcement, Kyushu.