Design and Construction of PVD with Temporary Surcharge as Ground Treatment over Soft Clay in Batu Kawan, Penang, Malaysia

Conception et construction de PVD avec une surcharge temporaire comme traitement au sol sur l'argile molle à Batu Kawan, Penang, Malaysia

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ABSTRACT: An university college is proposed to be constructed over a 10 acres land situated at Batu Kawan, Seberang Perai, Penang, Malaysia. The proposed site is located at low lying terrain with water ponding. The original ground levels are around RL-0.30m. Based on the available geological map, the site is underlain by alluvium with Quaternary aged. The subsoil mainly consists of 15m to 20m thick soft CLAY. As the proposed site is located at low lying area, filling of 3.4m is required to form the building platform to prevent flooding. In view of the soft compressible CLAY and tight construction period, Prefabricated Vertical Drains (PVD) with temporary surcharge are utilised as ground treatment method to expedite the dissipation of excess pore water pressure generated from filling works of building platform level and to eliminate the long term settlement. This paper summarises the subsoil condition, design methodology and performance of the designed ground treatment method. Instrumentation results on settlement gauge are also presented in this paper to demonstrate effectiveness of the designed ground treatment to achieve the required performance. In addition, some good construction practices are also presented in this paper.

RÉSUMÉ: Un collège universitaire est proposé pour être construit sur un terrain de 10 acres situé à Batu Kawan, Seberang Perai, Penang, Malaysia. Le site proposé est situé sur un terrain peu étendu, avec des mares d'eau. Les niveaux de sol d'origine sont autour de RL-0.30m. Sur la base de la carte géologique disponible, le site est sous-jacent aux alluvions d'âge quaternaire. Le sous-sol se compose principalement d'argile souple de 15 m à 20 m d'épaisseur. Comme le site proposé est situé dans une zone de faible hauteur, un remplissage de 3,4 m est nécessaire pour former la plate-forme du bâtiment pour prévenir les inondations. Compte tenu de la CLAY souple compacte et de la période de construction serrée, les drains verticaux préfabriqués (PVD) avec surtaxe temporaire sont utilisés comme méthode de traitement au sol pour accélérer la dissipation de la pression d'eau de pore excédentaire générée par les travaux de remplissage du niveau de la plate- règlement. Cet article résume l'état du sous-sol, la méthodologie de conception et la performance de la méthode de traitement au sol conçue. Les résultats de l'instrumentation sur la jauge de localisation sont également présentés dans cet article pour démontrer l'efficacité du traitement au sol conçu pour atteindre les performances requises. En outre, certaines bonnes pratiques de construction ont également été présentées dans ce document.

KEYWORDS: PVD, surcharge, soft clay.

1 INTRODUCTION

An university college is proposed to be constructed over a 10 acres land situated at Batu Kawan, Seberang Perai, Penang Malaysia (Figure 1). The proposed site is located at low lying terrain with water ponding as shown in Figure 2. The subsoil mainly consists of 15m to 20m thick soft CLAY.

As the proposed site is located at low lying area, filling of 3.4m is required to form the designed building platform. In view of the soft compressible CLAY and tight construction period, Prefabricated Vertical Drains (PVD) with temporary surcharge are utilised as ground treatment method to expedite the dissipation of excess pore water pressure generated from filling works of building platform level and to eliminate the long term settlement.

This paper presents the subsoil condition of soft alluvium deposit and brief concept on ground treatment design of PVD. The performance of the adopted ground treatment method is also presented based on settlement gauge results to demonstrate the effectiveness of the adopted ground treatment in achieving the required performances

2 GENERAL GEOLOGY

The Geological Map of Peninsular Malaysia, 8th Edition published by Director-General of Geological Survey Malaysia in 1985, indicates that the site is underlained by Alluvium with Quaternary aged as shown in Figure 3.

3 SUBSOIL CONDITION

The subsoil generally consists of 15m to 20m thick very soft to soft CLAY/SILT overlying loose to medium dense silty SAND to SAND as shown in Figure 4. Whilst, the general subsoil properties of bulk density, compression ratio (CR), re-compression ratio (RR), over consolidation ratio (OCR), coefficient of consolidation in vertical and horizontal directions are plotted in Figure 5.

4 GROUND TREATMENT

As the site is located at low lying area, filling of 3.4m is required to form the designed building platform. In view of the soft compressible CLAY and tight construction period, Prefabricated Vertical Drains (PVD) with temporary surcharge are utilised as ground treatment method to expedite the dissipation of excess pore water pressure generated from filling works of building platform level and to eliminate the long term settlement. The ground treatment details adopted for the filled embankment are summarised in Table 1.

In PVD design, the effect of installation disturbance is a vital parameter. Generally, a zone of smear with reduced permeability (Barron 1948) is assumed in PVD design to

determine the degree of consolidation. Numerous solutions have been proposed by Barron (1948), Aboshi & Yoshikuni (1967), Hansbo (1979) etc. However, there is no satisfactory solution available today. As such, the design of PVD with temporary surcharge was carried out based on local experience as described by Tan & Lee (2012). In general, the PVD was designed with smear zone ratio, ds/dw = 4 and permeability ratio, kh/ks = 2 as per recommendation by Tan et. al (2015).

Figure 1 Site location

Figure 2. Existing ground condition before site clearing.

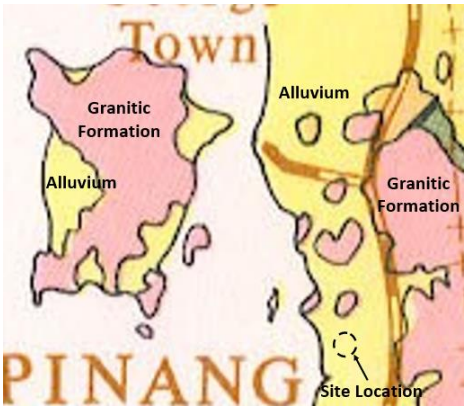

Figure 3 General geology of the site

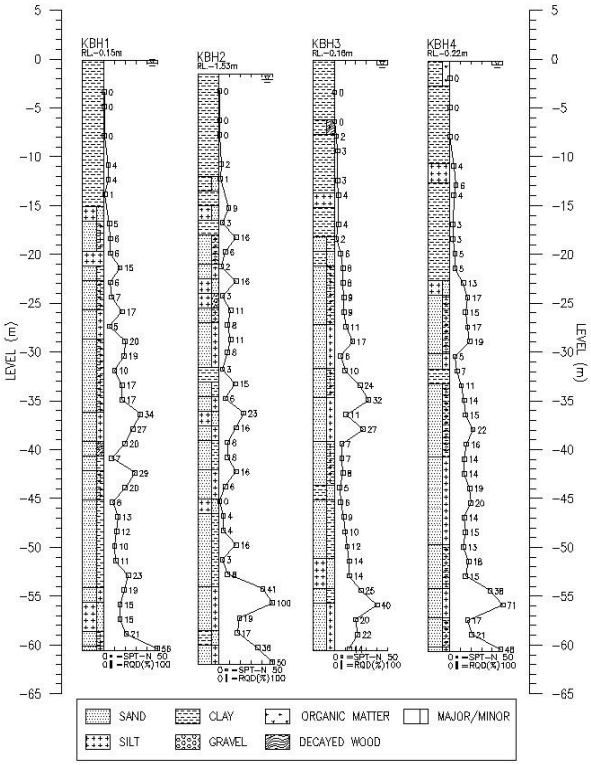

Figure 4. Borehole profiles.

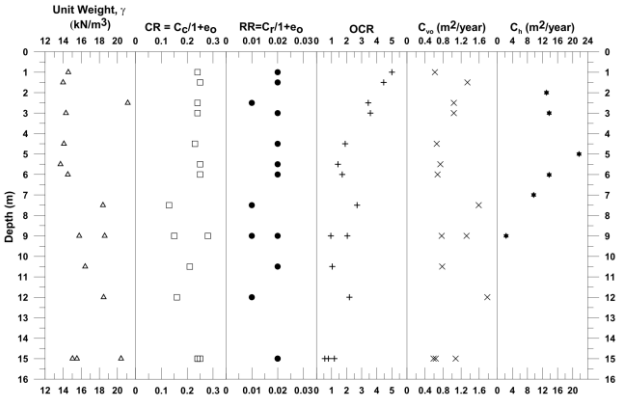

Figure 5. Subsoil properties.

Table 1. Ground treatment details.

PVD details	15m length at 1.25m c/c spacing triangular pattern
Surcharge period	Stage 1 (fill to 4m thick) – 3 months Stage 2 (fill to designed surcharge level) – 4 months
Sand thickness	500mm

5 MONITORING RESULTS

A total of 30 of settlement gauges were installed within the project site to verify the performance of subsoil. Based on the available settlement gauges, the measured settlements contour ranges from 800mm to 1150mm as shown in Figure 6.

Figure 7 shows the measured and calculated settlement profiles of selected settlement gauges. The calculated settlement profiles were determined based on Terzaghi consolidation theory and Barron radial consolidation theory using in house developed spread sheet. The graph shows there is insignificant settlement after surcharge removal at the end of designed surcharge period (7 months). In addition, the graph also verifies the adopted designed parameters such as smear zone ratio, ds/dw = 4 and permeability ratio, kh/ks = 2 as both measured and calculated settlements showed in closed match.

Backfilling of 1.3m of suitable earth and 300mm of sand were carried out in order to provide a stable working platform for PVD installation. The settlement gauges were only be installed after completion of PVD installation. The total period from the 1.6m fill to the settlement gauge installation is about 2 months. Therefore, the settlement induced by the 1.6m thick of fill were not captured by the settlement gauges. In view of this, additional of about 110mm settlement was added to the measured settlements in Figure 7 to capture the settlements induced by the 1.6m thick of fill. The 110mm settlement is estimated based on Terzaghi consolidation theory and Barron radial consolidation theory with rest period of 2 months.

The total settlement in terms of percentages to the total constructed embankment height are presented in Figure 8. It is shown that the total settlement is about 15% to 20% of the constructed fill thickness.

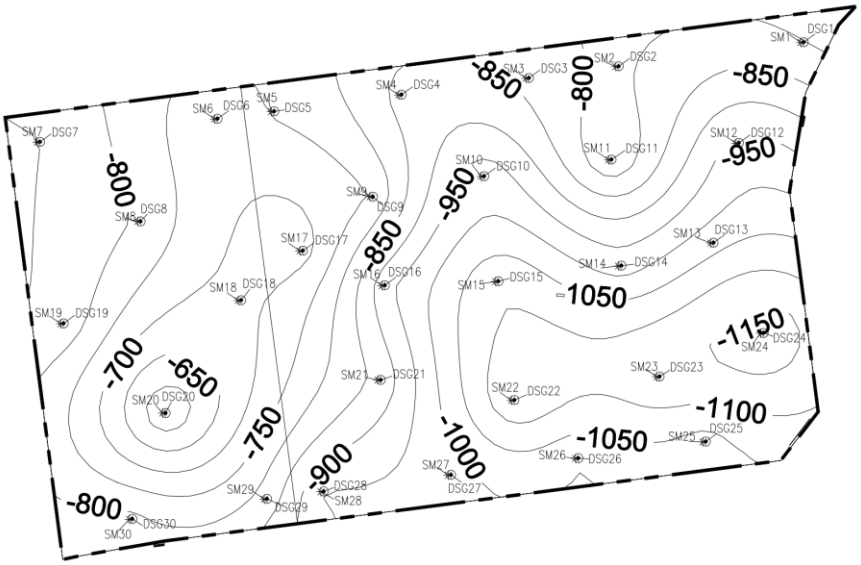

Figure 6 Contour of measured settlement.

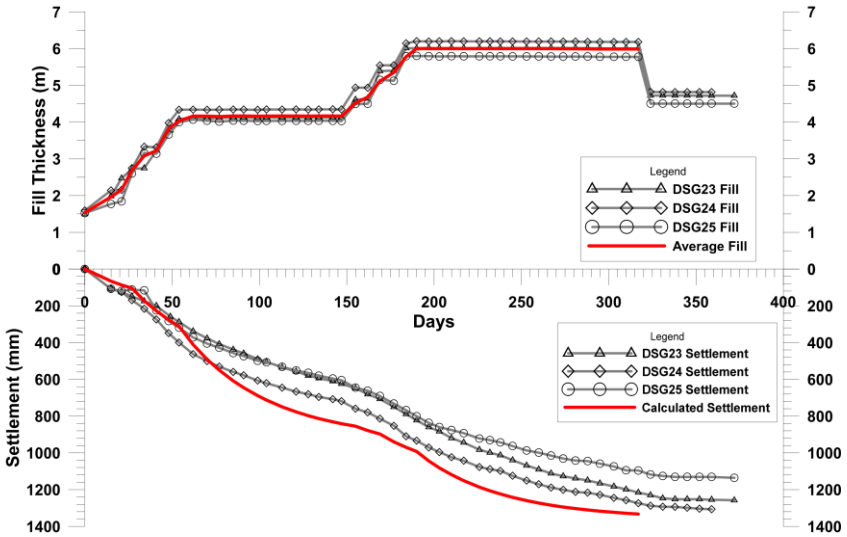

Figure 7 Settlement profiles (measured and calculated).

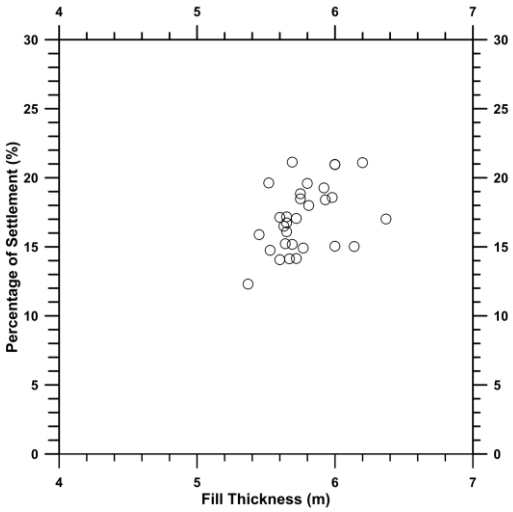

Figure 8 Percentage of settlement over constructed fill thickness

As mentioned in the earlier section, the settlement gauges were installed after backfilling of 1.6m thick of fill and after PVD installation. Therefore, additional of about 110mm settlement was added to the measured settlements in the calculation of settlement percentage over constructed fill thickness.

6 GOOD CONSTRUCTION PRACTICE

Water discharge outlet is paramount important in PVD construction. Without proper discharge, the generated excess pore water pressure will not be discharged effectively and will lead to prolong of surcharge period. This effect will be obvious for development project compared to linear project such as highway, railway etc. This is because development projects generally involve filling over a large area.

The excess pore water (especially at the center of development) need to travel a longer distance to be discharged. In addition, the induced settlement profile would be larger at the center of filled area. This may further reduce the hydraulic gradient for the discharge of pore water pressure at the center of the filled embankment. Therefore, subsoil drains connected to several pumping well were installed during the construction work as shown in Figure 9.

Figure 9 A total of 3 pumping wells were installed at site

The subsoil drains will collect the generated excess pore water to the pumping well. Each pumping well is equipped with submersible pump that with automated system. The pump will be activated automatically to discharge the water once the water level reaches a pre-determined level. This will increase the efficiency of water discharge and thus to prevent prolong of surcharge period.

7 CONCLUSIONS

Based on the settlement gauge monitoring results, the following conclusions can be drawn:

a) PVD with temporary surcharge have performed satisfactory as ground treatment for embankment constructed at Batu Kawan. This verifies the adopted parameters of smear zone ratio, ds/dw = 4 and permeability ratio, kh/ks = 2 in PVD design.

b) The total settlement is about 15% to 20% of the constructed fill thickness

c) Pumping wells is effective to improve PVD efficiency and thus to prevent prolong of surcharge period.

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