Case History: Press-in sheet pile on the collapsed riverbank

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ABSTRACT

An old canal surrounded by historical building is maintained even though the location is in the city center, and the canal acts as a retention pond during the rainy season. To facilitate and prevent the existing structure/building from flooding, canal dredging is conducted to increase the water retention capacity. Unfortunately, failure was caused at the riverbank and its retaining structure after dewatering and excavation, which is known to rapid drawdown instability. The canal was filled back with water to maintain the moved soil and also prevent further movement of existing/surrounding structures, which led to stability and serviceability problems of those structures. To reconstruct the canal protection structure after its failure, the steel sheet piles were designed to be used as the permanent structure because of their speedy construction time and the limited space required. The steel sheet piles were driven by a SILENT PILER^{TM}. The Press-in method is the key construction method which is concerned with being free of vibration to avoid affecting the disturbed soil at the riverbank and historical buildings. Moreover, low noise is generated during the construction. Finally, the old canal is rehabilitated with an improvement in water capacity. The monitoring record revealed no damage and further movement of the surroundings.

Key words: *Case History, Failure, Press-in, Sheet Pile, Riverbank*

1. Introduction

For over a hundred years, humans excavated canals in the Bangkok area, which were primarily used for transportation and economic purposes. There is a canal in Langsuan, Lumphini sub-district (city center of Bangkok) which locates adjacent to historical buildings as shown in **Fig.1** According to historical data, this building was constructed in 1920 and defined as architecture of King Rama VI. Due to urbanization and city development, most of the canals were backfilled for construction of the road. However, both the canal and historical building in the Langsuan area have endured to the present day, albeit serving different purposes over time.

The riverbank of the canal was protected by the old soldier piles and lagging walls for approximately 40 years. Presently, the canal is used as a retention pond to store excessive water before draining to the public drainage system (**Fig.2**) Moreover, this area including the historical building is protected from flooding especially during rainy days. As the canal has been used for a long time, a lot of sediment has accumulated on the canal bed, which has reduced the water storage capacity. Then, canal dredging was conducted in order to make the canal prepare for the upcoming rainy season.

Fig.1 The historical building and canal

Fig.2 The old canal used as retention pond

2. Canal Dredging

The team started with pumping out the water, which revealed that the canal bed was approximately 1 m below the level of the surrounding walkway before dredging (**Fig.3**). **Fig.4** shows the working platform which is made of timber piles and steel plates, which only a small excavator can be placed on.

Dredging took place at a depth of 1.5 m which is 2.50 m from the riverbank and ground level of surrounding structure as shown in **Fig.5**. Unfortunately, the riverbank of the canal and the wall collapsed and moved towards the canal (**Fig.6**). Water was filled back to maintain the stability of the riverbank as it was the fastest way to mitigate the effect of the incident.

Since the collapse occurred, surrounding properties were also damaged. Surveys of settlement and monitoring of cracks were conducted. The historical building beside the canal was in the area of greatest concern, but fortunately, the structure of the building was strengthened for a year before the carrying out of canal dredging. There was no any crack observed in wall and column of the historical building. However, the concrete slab next to the building the building was cracked and settled into the canal following the displaced riverbank.

3. Investigation and Analysis

An investigation of riverbank failure was started by collecting the data followed by sequencing activities with photos alongside the interviews of owner's representative and contractor. The canal dredging activities were summarized as mentioned in the previous topic (Canal Dredging).

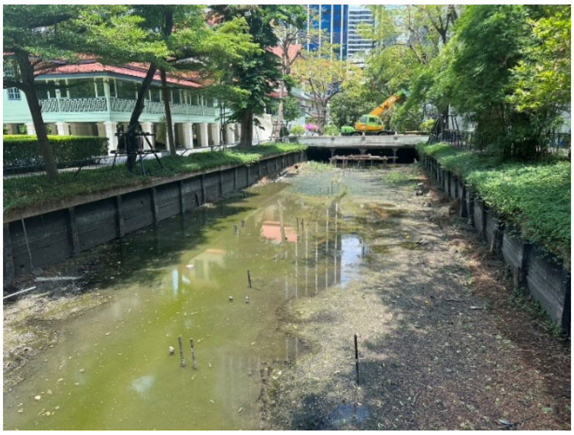


Fig. 3 Canal bed after water pumping

Fig. 4 Timber platform and small excavator

Fig. 5 Canal bed after dredging excavation

Fig. 6 Collapsed riverbank and wall

The finite element analysis (FEM) was conducted in Plaxis 2D software (Brinkgreve et al., 2002), for which the condition of plane-strain was applied. According to the soil report, from the ground surface to -0.75 m there was a fill crust layer overlaying a soft clay layer of 10.25 m thick. Medium stiff clay was found at depths ranging from-11.00 m to -15.00 m overlaying a layer of very stiff clay. The soil profile is illustrated in **Fig.7**. All soil layers were modeled using the Mohr-Coulomb soil model which has been widely used for Bangkok subsoils (Rukdeechuai, et al., 2009). Due to the short-term period of the activities, an undrained type C condition was applied in the analysis. A cohesion parameter as undrained shear strength (S_u) governed the material behavior in the undrained type C condition while frictional angle of material was zero (φ_u = 0 degree). Soil parameters used in the analysis are summarized in **Table 1**.

Fig.8 shows a schematic of the old riverbank protection. The riverbank of the canal was slightly sloped and covered with grass and bush for landscaping, then the topsoil (fill material) of the slope was also considered in the analysis. The modelling of the problem was performed, and the FEM mesh used in the analysis is shown in **Fig.9**. 4 m.-long concrete soldier pile and lagging wall were modelled as a plate structural element at the canal riverbank. Before dredging, the canal was filled with water, which led the surrounding soil to a fully saturated state at the beginning. The dredging activities were modeled as stage by stage based on the realism.

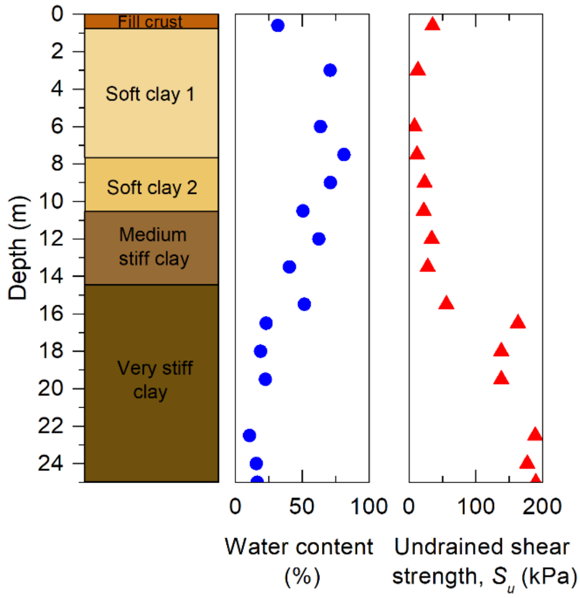


Fig. 7 Soil profile

Table 1. Soil Parameters

Soil layer	Elevation From	Elevation To	γ_t	S_u	E_u
	m	m	kN/m^3	kN/m^2	kN/m^2
Fill Crust	0.00	-0.75	18	35	17,500
Soft Clay 1	-0.75	-8.00	16	13	6,500
Soft Clay 2	-8.00	-11.00	16	25	12,500
Med. Stiff Clay	-11.00	-15.00	17.5	30	15,000
Very Stiff Clay	-15.00	-25.00	18	132	52,800

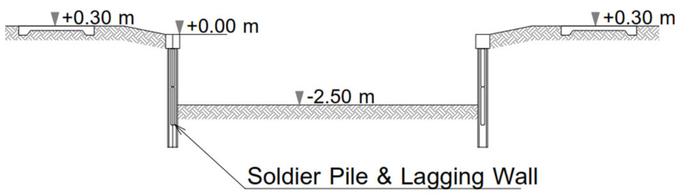


Fig. 8 Schematic of old riverbank protection

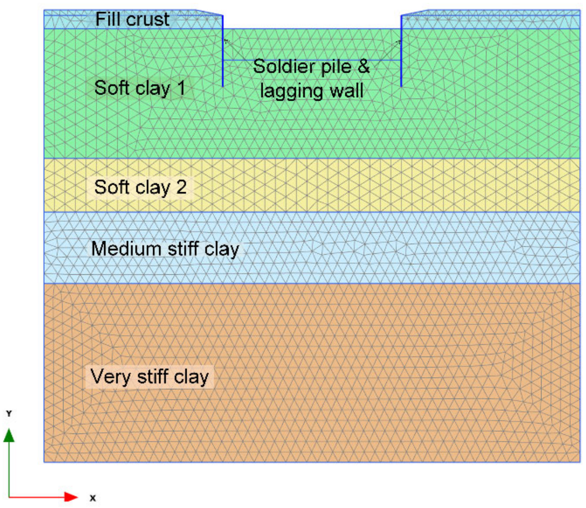


Fig. 9 FEM mesh of the analysis

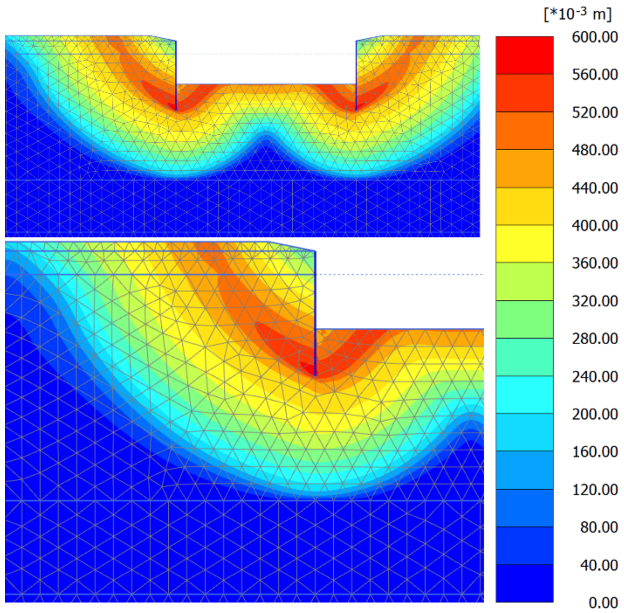


Fig. 10 Resultant displacement shading at final excavation

Fig.10 shows the shading of resultant displacement occurred at the final stage (dewatering and excavation of 2.50 m deep from the riverbank). It is seen that the maximum resultant displacement is approximately 600 mm. The results at the final stage are further discussed to clarify the cause of failure. **Fig.11** shows schematic of typical retaining wall and symbols list.

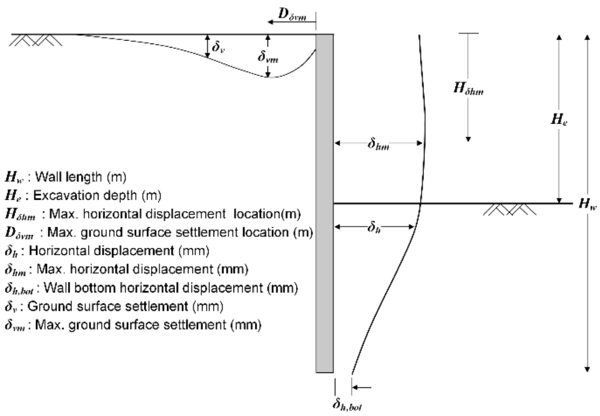
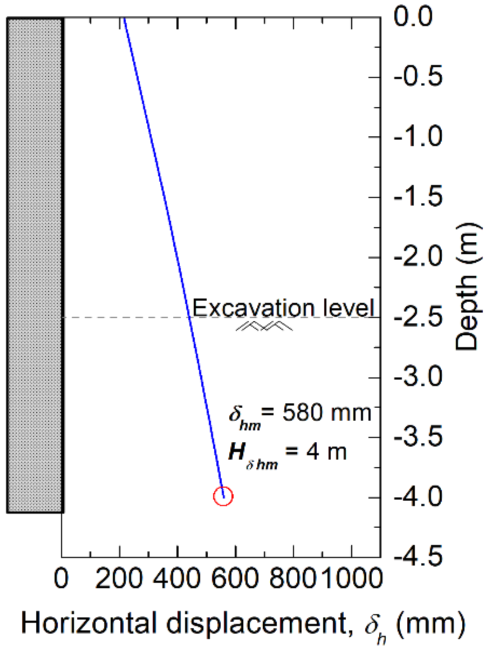


Fig. 11 Schematic of typical retaining wall and symbols list

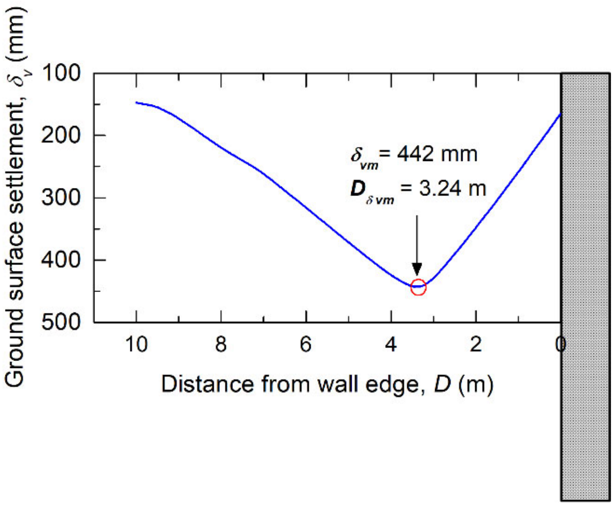
Horizontal displacement of the soldier pile and lagging wall along its depth is plotted in **Fig.12a**. The maximum horizontal displacement of 580 mm is highlighted and found at a depth of 4 m (the toe of solider pile and lagging wall) Vertical displacement in terms of ground surface settlement behind the riverbank at final excavation is also observed and shown in **Fig.12b**. The maximum ground surface settlement is 442 mm, which locates at 3.24 m behind the soldier pile and lagging wall, related to the crack and settlement found on the walkway along the canal.

The characteristic of wall's horizontal displacement, where the maximum magnitude is at the toe of retaining wall, is similar to those field data observed in Wang et. al (2010). This horizontal displacement characteristic can be classified as mode C deformation pattern (**Fig.13**) according to Waichita et al. (2019); even though the retaining wall systems are difference.

This phenomenon is called "wall bottom kick-out" as shown in **Fig.14**. The ground surface is settled and dragged by the movement of soil and wall at the failure surface. The movement is governed by soil failure mechanism similar to those observed in previous studies (Ou, 2006). This is caused by an insufficient embedment length of soldier pile and lagging wall system compared to the excavation at the final stage.



(a) Horizontal displacement of soldier pile and lagging wall



(b) Ground surface settlement behind soldier pile and lagging wall

Fig. 12 Displacement at final excavation

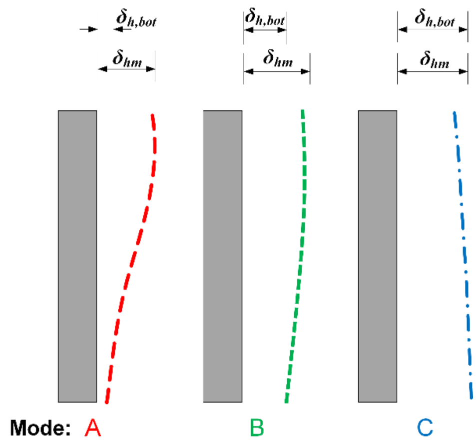


Fig. 13 Deformation modes of retaining wall (Waichita et al., 2019)

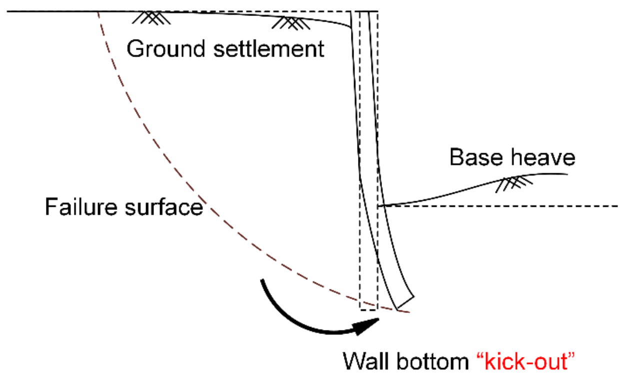
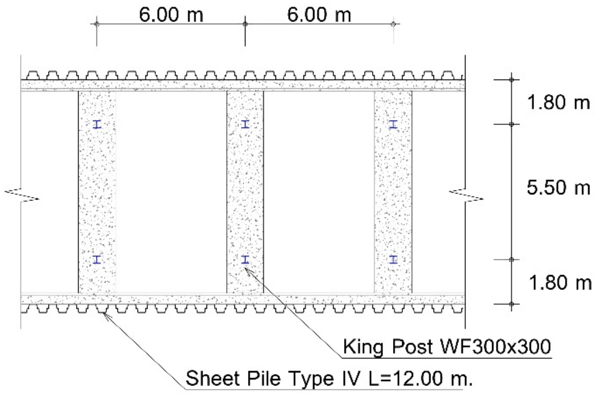


Fig. 14 Wall bottom kick-out phenomenon

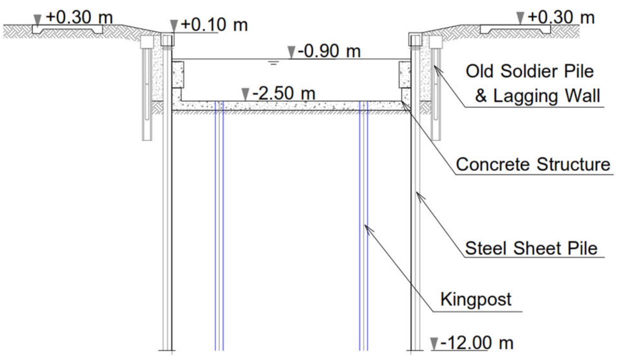
4. Rehabilitation and Reconstruction of Riverbank Protection Concept

Once the failure occurred, then the soil mass at the riverbank moved toward the canal. The void between the foundation of the building and existing soil was exposed. Soil backfilling with timber pile row installation was carried out for the surrounded buildings. Monitoring of further effect on the surrounding was conducted, with settlement points and tilt meters installed for measurement.

As the condition of the riverbank is currently in a collapsed or disturbed state, the construction of any structure should be carefully considered. Many options of the canal walls were proposed i.e., steel sheet piles, corrugated concrete piles, and deep mixing walls.



(a) Plan view



(b) Section

Fig. 15 Conceptual design for riverbank protection

Finally, a 12 m-long U-sheet pile type IV was selected due to its quick installation time and adequate flexural modulus which can retain soil pressure in an unbalanced state. In addition, the owner team requested a design to have the same characteristics of canal and wall which should be capable for the canal dredging in the future, then concrete facing in the front of steel sheet pile and concrete bracing beam were designed. The conceptual design for the canal riverbank protection is shown in **Fig.15**

5. Construction and Press-in Sheet Pile

Firstly, a temporary platform was installed for working due to limited space and to minimize the impact on the collapsed riverbank. Sheet piles were manufactured and coated in order to be used as the permanent structure which could prevent the corrosion.

To construct on the disturbed soil after failure, the Press-in method is the key method for construction. Sheet piles can be installed without vibration and noise caused during working hours. The SILENT PILER applies its self-weight and the reaction force from previously installed sheet piles to press the current sheet pile, thus it can install sheet piles and drive itself to limited space and also be aligned with the canal as shown in **Fig.16**. The self-driving forward SILENT PILER (**Fig.17**) does not require a full working platform area.

The advantages of the SILENT PILER method enabled our team to complete sheet piling work with total length (perimeter) of 220 m within 45 days, ahead of the expected schedule. Concrete facing and cross beams were casted following the progress of sheet piling. King posts (steel columns of the platform) were used for supporting the concrete cross beam as shown in **Fig. 18** (after removal of the temporary platform)

Moreover, a settlement of neighboring structures was monitored throughout the construction period. There was no additional settlement observed since the rehabilitation and reconstruction of riverbank protection.

6. Conclusion

An old riverbank wall of the canal collapsed after dewatering and excavation of the canal bed, which caused rapid drawdown instability and the phenomenon of wall bottom kick-out. Moreover, the analysis also showed that the embedment length of the soldier pile and lagging wall was not sufficient to resist the unbalanced force.

Fig. 16 Alignment of sheet pile pressing-in

Fig. 17 SILENT PILER driving forward

Fig. 18 New riverbank protection (after platform removal)

Rehabilitation and reconstruction efforts were undertaken, taking into account the impact on surrounding structures and landscape. The environmental impacts such as vibration and noise during construction were also concerned since the location was in the city center where restrictions applied during office hours. Since there was a historical building beside the collapsed riverbank, the Press-in method was employed and implemented in this project and helped facilitating the construction successfully.

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