Removal of underground obstructions – A review of pile extraction methods

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ABSTRACT

With increased urbanization and scarcity of land, the underground space utilization for development of infrastructure projects has become a necessity. In Singapore, more and more infrastructure projects need the extensive use of underground space. Singapore's Thomson East Cost Line (TEL) is the latest underground rail line of more than 43km long passes through several dense urban areas and terminates at multilevel underground depot at eastern end of the island. The depot site is located at a former sewerage treatment plant site where more than 5400 piles were left in the ground after demolition of the sewerage plant. The proposed depot is a 3 level structure for different railway lines with large column spacing. The structure will be supported by more than 2500 foundation piles. Old foundation piles of sewerage plant are obstructing the new foundation piles thatare need to be removed.

There are several pile extraction methods are available for different types of piles and each has its advantages and disadvantages. Site constraints also play an important role in choosing the pile extraction methods. Bored piles of different sizes have to be removed along with RC piles, steel H piles and sheet piles. Several challenges were encountered during pile extraction requiring modification of the method to suit the site condition and pile type.

There is limited amount of published data available on pile extraction methods to identify a suitable method to address various challenges that weree encountered. This paper attempts to fill the gap with experience gained from several cases of extraction methods studied in this project. Various challenges encountered due to issues like bent and broken H piles, large diameter bored piles and slanted piles etc are discussed in this paper. Improvised or modified pile extraction methods that address these challenges are presented and this will be a useful guide for cases where future developmental needs requires the removal of foundation obstructions.

Keywords: Obstructions; bored piles, H piles, Sheet piles, bent pile, pile extraction

1 INTRODUCTION

The Thomson East Coast Line (TEL) is 43km long passes through several dense urban areas and terminates at depot on east. To optimize the land use the depot houses three different Mass Rapid Transit (MRT) lines are located at same site by stacking one over the other at different levels, Down Town Line (DTL) depot at underground, TEL depot at grade and East West Line (EWL) depot at elevated level, The proposed depot structure is 3-storeys which has large column spacing and will be supported on about 1700 numbers of large diameter bored piles and about 975 barrette piles to transfer the heavy loads. The depot site is located at site belongs to demolished sewerage treatment plant, all plant structures were demolished leaving behind 5400 numbers of old foundation piles consists of steel piles, driven piles and cast in-situ bored piles. New foundations piles will be obstructed by these exiting foundation piles, in addition the new diaphragm wall used as a retaining structure along the perimeter of depot is also obstructed by the existing piles. In order to build the new structures, all the existing piles that are obstructing have to be removed in advance. Since there are no established methods that can address all types of piles, several methods have to be tried to extract the piles. In this paper, various pile extraction methods were discussed. Improvised pile extraction methods that address site challenges like broken and slanted piles, large diameter piles etc. are presented. This experiences will be a useful guide for cases where future developmental needs require the removal of foundation obstructions.

2 PROJECT BCAKGROUND

2.1 Site location and proposed construction

The construction of a multilevel rail depot spanning over 1050m long and 145m to 360m wide, with an area of approximately 23 hectares requires a 15m deep

excavation with diaphragm wall system to house multi-level depot structure. The project site is located at the East side of Singapore adjacent to the existing Depot as shown in Figure 1.

Fig. 1. Site layout.

The proposed foundation consists of large diameter bored piles (diameter from 1.2m to 2.5m) and barrette piles (1.2mx3.0m to 1.5mx5.0m) to be installed before excavation to base slab for basement. The depth of these foundation piles varies and most of them are estimated to be 60m deep.

2.2 Left in foundation piles

The site was previously occupied by the demolished Bedok Water Reclamation Plant, which consisted of several tanks and other structures. All the structures of the plant have been demolished and removed from the site leaving behind the foundation piles. Nearly 5400 numbers of piles are left behind as shown on Figure 2. The piles are expected to be as deep as 35m below the ground level and consists of steel H piles, RC driven piles and cast in-situ bored piles. Re-using of these existing piles to found the proposed development is not a feasible option considering the much higher loads that are required due to multi-level depot. To install the new foundation piles, retaining walls for deep excavation, the left-in piles will form an obstruction and are required to be removed.

Based on the layout of new structures, about 1617 exiting piles out of the 5400 have to be removed in advance to facilitate the installation of new piles and retaining walls. All other remaining piles can be cut and extracted as excavation proceeds to the base slab level. The various types of piles to be extracted are shown in the Table 1.

3 PILE EXTRACTION METHODS

There is no single universal method available to extract the various types of piles, different methods have to be tried in order to identify the suitable method for the site conditions. There are several challenges that are encountered during the pile extraction works, pile heads were located around 5m-7m below the ground level. Some pile heads were already damaged in some cases making it difficult to extract the piles. Some of the steel piles were bent or broken or slanted, while weak joints for some of the piles also made it difficult to extract. With such difficulties pile extraction process is tedious and slow. The following sections describe the various methods used for extraction of different pile types.

Fig. 2. Left in foundation piles

Table 1. Type of pile obstructions.

Type of piles	Total Numbers	No of Piles to be extracted
Steel H pile/Sheet piles	3994	1151
RC piles	1089	304
Bored piles	318	142

3.1 Steel H piles and Sheet piles

As described on Table 1, most of the piles to be extracted are steel H piles or sheet piles. These piles are generally installed by driving to set. The following five methods describe the extraction process.

3.1.1 Steel pile extraction using Jacking method

Pile head of H pile is exposed and extended and the surrounding soil is loosened by wash boring. Once the friction is loosened the pile is extracted using a hydraulic jack as shown in Fig.3. This method was slow in extracting the pile, and some piles could not be extracted successfully because of several pile joints and higher friction.

3.1.2 Steel pile extraction using Augering and Wash boring

This method is an improvement from the previous method.After exposing the pile head, the surrounding soil is loosened using augering and wash boring before pile is extracted using a vibro-hammer as shown in Fig.4. On average it took 4-5 days to extract a single pile using this method.

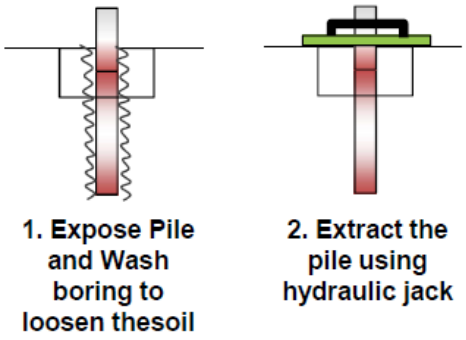

Fig. 3. Steel pile extraction using Jacking method

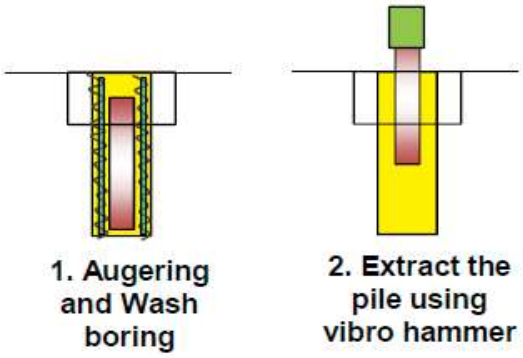

Fig. 4. Steel pile extraction with augering and wash boring

3.1.3 Steel pile extraction using wire rope

A casing with wire rope was installed by using water jet. After casing installation, the pile is then extracted by lifting the wire rope (Fig 5). This method was quite successful with and an average 1.6 piles per day removed with this method. This method was very effective in dealing with bent, twisted and slanted piles.

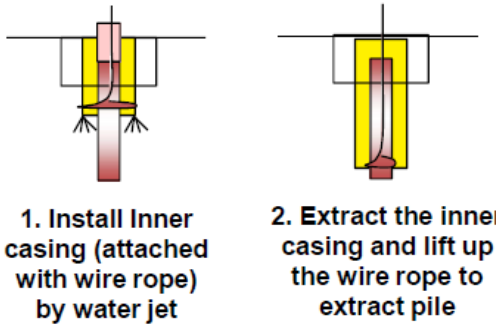

Fig. 5. Steel pile extraction with augering and wash boring

3.1.4 Steel pile extraction using mechanical grab

In some of the instances, piles are located much deeper from the ground level and this made it more challenging to use the other methods to extract the piles. It would have required a temporary excavation with a retaining wall to expose the pile. Instead of using any temporary excavation to expose the pile, a mechanical grab has been used to excavate the side of the pile (Fig.6). This creates a stable trench and pile can be pulled out . An average of 1.5 piles per day could be extracted using this method. This method is suitablewhere the pile heads are located deeper depth below existing ground level

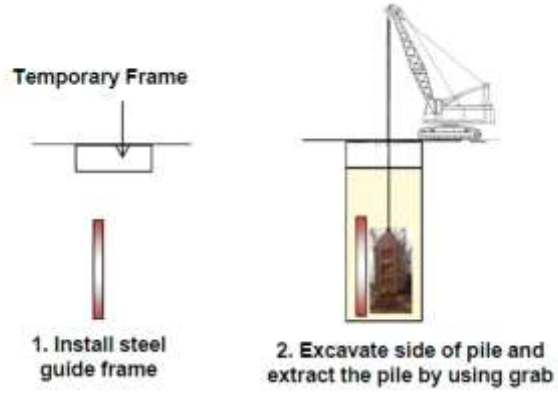

Fig. 6. Extraction of pile using mechanical grab.

3.1.5 Steel pile extraction using drilling rig

In this method, the pile is extracted using the casing rotator. After installing the double wall casing rotator, the surrounding soil around the H pile is excavated using a drilling rig (Fig.7) and pile has been extracted using hammer grab

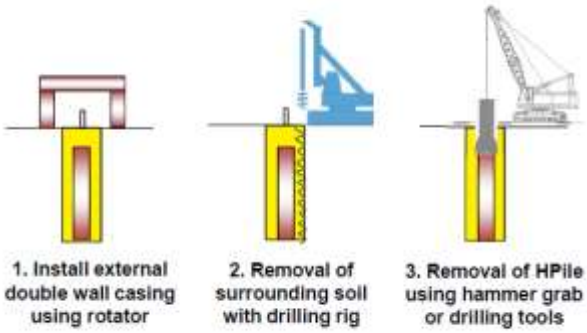

Fig. 7. Extraction of pile using drilling rig.

3.2 RC Driven piles

Similar to steel H piles, pre-cast RC driven piles are installed by driving to set. Some of the methods used for H pile removal can also be adopted for RC pile removal.

3.2.1 RC pile extraction using augering and wash boring

This method is similar to H pile removal method described in Section 3.1.2 and Fig 4, where surrounding soil is loosened by augering or wash boring before the pile can be extracted. This method is relatively slow requiring 5 – 6 days to extract each pile.

3.2.2 RC pile extraction by crushing

A double wall casing rotator is installed which is similar to steel pile extraction method described in section 3.1.5, instead of pulling out the pile it has been crushed using the boring rig (Fig 8) and crushed debris was removed before backfilling the hole. This method was extremely productive and one pile could be extracted completely within a singale day.

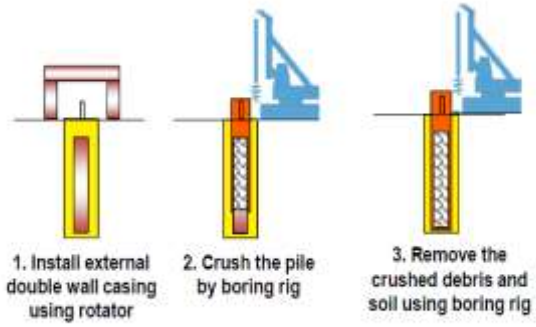

Fig. 8. Extraction of RC driven piles by crushing

3.3 Bored piles

The number of bored piles to be extracted from the site were fewer, compared to driven piles. But extraction of these piles was extremely challenging, because these piles are installed deeper into hard stratum unlike driven pile which are unable to penetrate into hard layers making this challenging to extract. Hence, methods used for steel pile and RC piles are not suitable for removal of bored piles.

3.3.1 Bored pile removal by jacking up the pile.

In this method, a Dywidag bar is installed through the pile to the pile toe and casing is installed before pile is pulled up by a hydraulic jack and cut at 1.5m intervals. This method was extremely slow and required 3 weeks to remove a 25m deep pile.

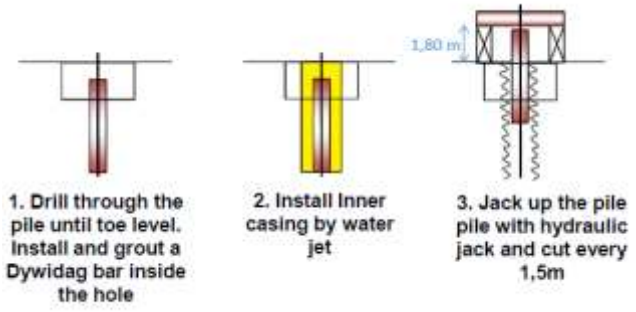

Fig. 9. Extraction of bored pile by jacking up

3.3.2 Bored pile removal by clamp casing.

A powerful casing rotator was used to install a casing with a clamp (Fig.10) or blade to grip the pile before it is crushed. This method was highly productive requiring 7-14 days to extract each pile

Fig. 10. Casing with clamp and blade

4 CHALLENGES OF PILE EXTRACTIONS

Main challenges encountered including left-in piles which are either slanted twisted or bent (Fig.11) especially driven H piles. Several methods were unsuccessful to remove such piles, wire rope method (described in section 3.1.3) was successfully used to extract such piles. Some of the installed pile heads were 5m-7m below ground level, where mechanical grab was successfully used without any need for a temporary strutted excavation.

Fig. 11. Bent and twisted piles

5 CONCLUSION

The proposed 3-level depot structure located at a site where old foundation piles of a sewerage plant are obstructing the new foundation piles needed to be removed. Different types of pile extraction methods were used to extract the existing piles and several site challenges are presented in this paper. This will be a useful guide for cases where future development or tunneling requires the extraction of underground pile foundation.